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FEED THE FUTURE KENYA CROPS AND DAIRY MARKET SYSTEMS ACTIVITY

DAIRY ANIMAL NUTRITION STUDY REPORT

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Feed the Future Kenya Crops and Dairy Market Systems Activity

TECHNICAL REPORT: DAIRY ANIMAL NUTRITION STUDY IN PRIORITY COUNTIES

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Photo Caption

Front Cover: Photo 1- Margaret Ngao Malika processes hay for her dairy cows at her farm and training center in Makueni County. Photo 2- Cows at Peter Mang'eng'e's farm in Makueni County

Back Cover: A cow feeds at Makueni County Fruit Processors Factory in Makueni County

LIST OF ABBREVIATIONS AND ACRONYMS

AKEFEMA	Association of Kenya Feed Manufacturers
BSE	Bovine spongiform encephalopathy
Ca	Calcium
CBO	Community-Based Organization
CP	Crude Protein
DE	Digestible Energy
DM	Dry Matter
DP	Digestible Protein
FAO	The Food and Agriculture Organization of the United Nations
FCM	Fat Corrected Milk (4%)
FtF	Feed-the-Future
GDP	Gross Domestic Product
ICI	Inter-calving Interval
ILRI	International Livestock Research Institute
KCDMS	Kenya Crops and Dairy Market Systems
KEBS	Kenya Board of Standards
LCR	Lactating Cow Ration
NaCl	Sodium Chloride (Salt)
MBM	Meat and Bone Meal
ME	Metabolizable Energy
MUPs	Molasses Urea Products
NEl	Net Energy for Lactation
NIR	Near Infrared Spectrophotometry
P	Phosphorus
RMA	Ruminant Methane Assessment
TDN	Total Digestible Nutrients
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WCA	Wet Chem Analysis

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EXECUTIVE SUMMARY

Introduction

The dairy industry is one of the most dynamic agricultural subsectors in Kenya, growing at an estimated rate of 3-4% annually[1]. The Kenyan dairy value chain is currently valued at over US$1.9 billion and contributes 6-8% of GDP, of which an estimated 80% is contributed by smallholder farmers. National milk production grew from an estimated 2.22 billion liters in 2000 to 5.2 billion liters in 2016.[2] Dairy sector growth in Kenya is largely a result of increasing herd size rather than increased animal productivity. Kenya's estimated average annual milk production of 1,017 liters/milking cow (1,187 liters/milking cow for improved breeds) is poor by any standard, and less than half of what should be expected from a reasonably nourished crossbred dairy animal.

Nutritional factors are the greatest constraint to increasing ruminant livestock production and productivity in East Africa. Dairy production and productivity are the outcome of a complex combination and interaction of nutritional factors related to animal management and diet. Nutritional issues include macro nutrient imbalances (energy, protein), macro mineral imbalances (calcium, phosphorus), and overall macro nutrient and mineral availability. Sustained increases in dairy production and productivity require feeding both the **quantity** and the **quality** of feed needed to provide a balance of essential macro nutrients and minerals beyond what is needed to maintain normal body functions. Cows fed a balanced diet will be well-nourished, healthy and fertile. Additionally, balanced rations give livestock the ability to manage the nutritional stresses associated with high milk production.

This study assesses the critical dietary and nutritional constraints to smallholder dairy productivity in the KCDMS focus areas. It provides an indicative look at current feeding practices, nutritional status, available feeds and supplements, and production levels. It considers the potential for reducing ruminant methane emissions intensity and their contribution to Kenya's greenhouse gas emissions (GHGs). Finally, the study includes a snapshot of the potential economic impact of improving smallholder feeding practices and overall dairy nutrition.

Objective of the Study

The study objective was to accurately assess the critical dietary constraints to optimal dairy productivity for smallholder farmers in the KCDMS focus areas. The two key study questions are: ***(1) what are the principal nutritional constraints limiting smallholder dairy production in the KCDMS areas?*** and ***(2) What can the local feed industry do to mitigate those constraints?***

The study used the Ruminant Methane Assessment (RMA) methodology for this analysis. The RMA is a tool for assessing the efficiency of developing country livestock production systems and development projects and is based on the United Nations Framework Convention on Climate Change (UNFCCC) methodology known as ***AMS-III.BK***[3]. The methodology is specifically designed to assess nutritional efficiency and methane emissions from large ruminant production systems in the developing countries of Africa, Asia and Latin America.

The study team collected detailed farm-level data from a sample of 120 smallholder dairy producers in the three USAID Feed-the-Future geographic focus areas of Kenya: Eastern, Nyanza, and Western. (See map on page 1 of the full report.)

[1] Kenya Ministry of Livestock Development, 2010.
[2] Generous estimate. FAOSTAT 2018 estimated Kenya's 2016 milk production at 4.1 billion liters.
[3] https://cdm.unfccc.int/methodologies/documentation/meth_booklet.pdf#AMS_III_BK

Data was collected on production parameters (genetics, weight, milk production, calving interval) and feeding practices (rations, concentrates, supplements) combined with the nutrient profiles of the rations being fed. This data was used to analyze the nutritional status and productive efficiency of smallholder dairy cattle in the focus areas and identify the principal nutritional constraints. The team also interviewed feed value chain participants in the focus areas to obtain information on feed formulation and nutrient profiles, raw material supply, testing and quality control, and regulatory issues. In addition to information on the use and effectiveness of commonly used dairy meals and supplements, the team collected samples of 15 dairy meals and 5 supplements and tested them using Wet Chem Analysis to confirm their nutrient profiles.

Background

Ruminant nutrition*,** the science of feeding cattle, is a complex and detailed topic. Good animal nutrition is the cornerstone of dairying, as well as a necessary and sufficient condition for increasing dairy production and productivity. A dairy cow needs enough feed to maintain her body, grow a fetus, and produce milk. Specific nutrient levels are needed for each of these functions. Proper feeding requires balancing the different nutrient requirements and supplying the required amount and type of nutrients in a ration. The productive potential of any given ration is determined by the ***quantity, ***nutrient content*** and ***nutrient quality*** of the feed consumed.

The ***quantity*** of feed a dairy cow can consume is based on the digestibility of the feed and the size of the cow. A large cow can consume more feed than a small one, and all cows can consume more highly digestible feed than low digestibility feed. The amount of feed that is consumed by the cow, digested in the rumen, and then cleared for more input is called "throughput". ***Nutrient content*** means that some feeds contain more nutrients than others. It is generally better to feed high nutrient content, highly digestible feed to maximize consumption and production. ***Nutrient quality*** means that different feeds may contain similar levels of macro nutrients, but that some plant species provide greater nutrient availability than others due to their genetic makeup.

Digestibility, nutrient content and nutrient quality help determine the productive potential of a ration. Potential increases in dairy production and productivity from improved nutrition are a combination of increased daily milk production, increased length of lactation, and decreased calving intervals. The challenge is to increase nutrient uptake, while substituting feeds with better nutrient profiles to maximize productivity from available resources.

In summary, increasing productivity by applying good ruminant nutrition relies upon the interaction of a complex set of biological factors. There are no shortcuts, and no single solutions for problems that disrupt this interaction. Nutrient requirements of the targeted animals must be identified, nutrient profiles of the available feed developed, and then any shortages in required nutrients must be addressed by applying proper ration formulation.

Results Overview

Level of Confinement: Total and semi-confinement are the predominant feed management systems being used by dairy producers in the focus areas. Zero grazing is prevalent in Eastern, while partly grazing dominates in Western and Nyanza. Even animals classified as partly grazed are confined most of the time. The main issue is that confined and semi-confined dairy cows are underfed (not being fed enough total feed) and chronically undernourished (not receiving enough nutrients from the feed they do receive).

Genetics: The common perception that poor genetics is an issue in the Kenyan dairy herd is not borne out by our survey results. All operations were milking at least cross-bred cattle (25%-75% exotic blood), and one-third of the operations were milking cows with at least 75% exotic blood.

All the milking cows measured exhibited exotic blood - usually Friesian or Jersey – with strong genetic potential for milk production and productivity.

Cow Size: The common assumption that Kenya dairy cows weigh an average of 300kg is consistent with what we found in Western and Nyanza. However, average cow weights in Eastern were 25% larger at 393kg. More importantly, the range in weights encountered (147-724kg) is so great that any generalized statements of average cow size are practically meaningless.

Feeding Practices: Smallholder dairy producers are using a combination of feeding practices where the potential benefits of feeding dairy meal and/or salt/mineral supplements are canceled out by the inclusion of low-quality feeds in the basal ration.

Productivity: Annualized milk production in Nyanza ranges from a high of 1,606 liters to a low of 795 liters. In Western, it ranges from a high of 1,290 liters to a low of 611 liters. Annualized milk production in Eastern is higher than the Kenyan average for all systems and genetics, ranging from a high of 1,587 liters to a low of 1,183 liters. The low levels of daily milk production, short lactation periods, and long inter-calving intervals we encountered are a direct result of poor nutrition and feeding practices prevalent in the focus areas. Although dairy productivity for the best producers is above the Kenyan average of 1,017 liters of milk per year, that average is poor by any standard and demonstrates the great potential for improving dairy production and productivity.

Major Production/Productivity Indicators

Feeding System & Genetics	Age at 1st Calving (months)	FCM/Day (liters)	Real Lactation[4] (Days)	Calving Interval (days)	FCM/Year (liters)	# Producers
Nyanza						
Aa	26	10.6	226	547	1,606	7
Ab	28	7.4	203	596	923	4
Bb	31	6.0	206	572	795	26
Western						
Aa	29	8.8	249	620	1,290	8
Ab	43	7.1	228	777	757	6
Ba	27	7.9	213	642	952	4
Bb	34	5.8	180	620	611	21
Eastern						
Aa	32	10.4	254	609	1,587	24
Ab	29	9.0	214	596	1,183	8
Bb	29	8.6	231	579	1,245	8

Aa = Zero Grazing, >75% Exotic blood Ba = Part grazing, >75% Exotic blood
Ab = Zero Grazing, 25%-75% Exotic blood Bb = Part grazing, 25%-75% Exotic blood

[4] The number of days the cow should be milked based on her nutritional status.

General Findings

1. ***Smallholder dairy producers in the focus areas are not feeding enough feed.*** Most producers are not feeding their animals enough feed, resulting in chronic undernutrition which leaves animals permanently stunted and unable to demonstrate their genetic production potential.

2. ***Most basal rations contain overly mature forages.*** Ration quality issues arise from the use of overly mature and poorly digestible grasses and legumes. Napier grass, a component in 84% of the basal rations, has many good qualities. But producers are feeding it as an overly mature grass, little better than maize stover.

3. ***Most basal rations contain low digestible, nutrient poor feedstuffs.*** The inclusion of low-quality crop residues (maize stover, millet straw, maize cobs, etc.) in the basal rations greatly reduces the nutrient content and balance consumed by the animal. This is a common problem in all three geographic areas, found in 75% of the respondent farms. Low quality crop residues may keep cows alive during extreme forage shortages but cannot provide adequate nutrition to a lactating herd. They are best used as a ration component only for animals that are not kept for milk production.

4. ***Lactating rations are rarely balanced.*** In nearly all farms visited (96%), the basal rations being fed are not balanced properly for macro-nutrients (protein and energy). In a majority of the farms (54%), this imbalance equals a loss of at least two liters of milk per day. In some extreme cases (23%), simple ration balancing using existing feedstuffs and adjusting the amounts fed, would increase milk production by 4 liters/day.

5. ***Dry cows and replacement heifers are fed very poor rations.*** Common feeding practices for dry cows and heifers do not include supplemental forage, concentrates or minerals. As a result, dry cows are not prepared for the re-initiation of lactation. For heifers, substandard feeding results in long term physical issues such as stunted growth, inadequate udder development, low nutrient absorption capacity and reduced body fat deposition. In short, farmers are not doing a good job of feeding replacement stock to prepare them for breeding and lactation.

6. ***Kenyan dairy meals are not formulated to mitigate macro nutrient issues.*** Dairy farmers in the focus areas have access to a broad range of commercial dairy meal formulated to comply with Kenya Bureau of Standards (KEBS) Dairy Cattle Feed Supplement Specifications[5]. However, the KEBS Standard requires a fresh updating in terms of nutrient profiling and applicability to Kenyan conditions and needs to reflect the nutrient requirements of dairy cows fed tropical forages rather than the current temperate forages. As a result, dairy meals formulated to the KEBS standard are only marginally effective as a supplement for the observed basal rations, and meals that do not meet the standard are rated even lower. Furthermore, laboratory testing of the 15 dairy meal samples gathered found only three that met the published KEBS standards.

7. ***Kenyan salt/mineral supplements are not formulated to mitigate macro mineral issues.*** The macro mineral content and balance of the Kenyan basal rations is poor, which severely constrains milk production and reproductive efficiency. At the same time, most salt and mineral supplements available in the market are formulated for temperate climate forage

[5] Kenya Standard (KS) 62:2009, ICS 65.120: Dairy Cattle Feed Supplements – Specification. 2009 (confirmed 2014)

conditions and therefore inadequate to balance the macro mineral needs (especially the calcium/phosphorus ratio) for Kenyan dairy cattle.

8. ***Kenyan producers do not have access to information needed to improve dairy nutrition.*** Dairy meals are not labeled as to content (ingredients) and nutrient profile; and information about the correct use and selection of dairy meal is not available to producers. As a result, producers often use them in a manner which is only marginally effective in supporting increased dairy production and productivity.

9. ***Smallholder dairy producers in the focus areas do not understand dairy production.*** Producers are using feeding practices that demonstrate a poor basic understanding of dairy animal production and management for replacement heifers, dry cows or lactating cows. Unfortunately, the common practice of prolonged milking, leading to delays in pregnancy, further complicates nutritional management.

10. ***The present regulatory system needs to be reviewed and updated to increased dairy production and productivity.*** KEBS standard dairy meal and salt/mineral formulations are not based on current nutritional information or animal nutrient requirements. Furthermore, the regulatory system needs to be structured to encourage or support new product development. Updating the standards with current information offers a significant opportunity for impact for a dairy industry that has seen little increase in sector production and productivity over the past 50 years.

11. ***Increased forage production is essential to sustain and increase overall dairy production and productivity.*** Increasing dairy productivity requires basal rations with both the **quantity** and **quality** of forage needed to provide animals with a balance of essential macro nutrients and minerals.

12. ***Documented evidence on the benefits of using feed products is lacking.*** Dairy producers rely on word of mouth and on-farm experience to judge the effectiveness of incorporating new feedstuffs into their operations. Producers are generally of the opinion that new feedstuffs are expensive because their effectiveness is so questionable. These conclusions tend to be right because any amount paid for a substandard, ineffective product is – by definition – too much.

13. ***The two major nutritional issues encountered are:***
    a. ***Crude protein (CP) or net energy for lactation (Nel) are the limiting macro-nutrient factors.*** Operators with a shortage of protein can reduce the use of overly mature forage, and/or add protein (cottonseed meal, soybean meal, etc.) to the ration. Operators with a shortage of Nel can address forage issues, and feed more high-energy feeds (ground maize, molasses, etc.).

    b. ***Calcium (Ca) shortage is limiting reproductive performance.*** The calcium/phosphorus (Ca:P) ratios we encountered are generally low, with nearly half of farms below minimum requirements. An imbalance or shortage of Ca can be addressed by adding limestone to the diet or feeding improved dairy meal formulations or salt/mineral supplements with a higher ca/phosphorus ratio of at least 2.5:1.

14. ***Overall nutrition management is a multi-faceted issue.*** We categorized producers into three groups based on a combination of their macro-nutrient quality (TDN) and macro-mineral ration (Ca:P) scores. The results summarize the challenges of reaching out to farmers to improve their dairy productivity.

Those groups are:

a. ***Good Producers*** for whom simple changes in their use of concentrates and some adjustments to forage feeding and management will significantly improve productivity.

b. ***Fair Producers*** for whom it will take moderate efforts to address issues (adjust rations, improve forage management, incorporate revised dairy meal and mineral mix formulations) with potential for dramatic improvements in productivity.

c. ***Poor Producers*** for whom concerted attention is needed to address multiple issues. With well-planned and focused activities, most of these producers will be able to eventually make the transition from subsistence to commercial dairy production. But those efforts are unlikely to have significant impact in the near term.

The Potential Impact of Improved Nutrition

We have developed a set of ***Lactating Cow Rations*** based on the survey data to illustrate the impact of changing feeding practices on milk production, and the potential for improving existing rations to increase productivity. We start with a common basal ration in the survey areas to provide a practical example of how a cow's diet can be improved to increase production and productivity.

The potential impact of improved feeding practices on dairy production and productivity is summarized in the table below to illustrate the potential gains from modest changes in feeding practices for the same cow. Calculations assume a 300kg crossbred dairy cow. These changes are a direct result of increased DM intake and rumen throughput from improved digestibility and balanced macro-nutrients and minerals.

Potential Productivity Gains from Improved Nutrition

Lactating Cow Ration	Dry Matter (DM) Intake (kgs)	Daily Milk Production (liters)	Length of Lactation (days)	Inter-calving Interval (days)
Mature Napier / Maize Stover	6.77	1.5 – 3	160	785
Young Napier	7.87	5.3 – 6.6	190	785
Young Napier / Best Meal	8.35	6.7 – 7.7	200	550
More "Best Meal" plus Limestone (Ca)	8.91	8.5 – 9.8	270	390
KCDMS Dairy Meal plus Maize Bran	10.73	16+	300	380

The potential impact of improved feeding practices on Greenhouse Gas (GHG) emissions is also significant, as illustrated in the table below. The Mature Napier/Maize Stover ration shows 292 grams emitted for each liter of milk produced. Simply changing to the Young Napier ration reduces methane emission intensity by over 50% to 135 grams per liter. Further improvements show the potential to reduce emissions to as little as 20 grams per liter.

Potential Reductions in Methane Emissions Intensity

Lactating Cow Ration	Annual Methane (kgs)	Annualized FCM Production (liters)	CH4 Emissions/liter (kgs)
Mature Napier/ Maize Stover	54.26	186	0.292
Young Napier	65.83	486	0.135
Young Napier/Best Meal	68.24	889	0.077
Best Meal + Limestone	74.63	2,148	0.035
KCDMS Meal	90.11	4,611	0.020

As reflected in the tables above, there is significant potential for increasing dairy production and productivity and reducing methane emissions intensity by adopting improved feeding practices.

The economics of improved nutrition on dairy production and productivity, in terms of ***cost*** and ***income*** is summarized in the table below. We calculated the estimated daily cost of feeding a lactating cow (forage, dairy meal, salt/mineral) during her effective lactation period for each ration. This was done using consolidated information from the feed and fodder value chain assessment[6] to estimate the costs of producing 1 kg of forage (DM). Dairy meal salt/mineral and limestone costs are based on information gathered during the survey.

Note that dairy meal, salt/mineral supplements and limestone must be purchased by the producer and are therefore cash costs. Forage produced on the farm to feed cows has value, but not an immediate cash cost. We represent that value as a cost/kg for this analysis, understanding that its use is not generally recognized as a real cost by producers.

Daily feed costs for a lactating cow varies from KSh 128/day to KSh 331/day depending upon ration. However, the daily cost of feeding a cow during lactation is only part of the picture. The full picture requires including the cost of feeding dry cows. For this, we developed three illustrative Dry Cow Rations to complement the five Lactating Cow Rations using survey data as the base. The daily feed cost for a lactating cow was then multiplied by the annualized number of days milked in a year, and the daily feed cost for a dry cow by the annualized number of days not in lactation during the year, deriving total annual feed costs/cow as reflected in the table below.

Total annualized feed costs ranged from KSh 41,744 for LCR1 to KSh 105,640 for LCR 5. The total annualized feed costs were divided by the annualized milk production for each ration to derive the ***break-even price*** needed to cover the costs of feeding the cow. Break-even prices ranged from KSh 226/liter for LCR1 to KSh 23/liter for LCR5.

[6] USAID-Kenya Crops and Dairy Market Systems (KCDMS) Feed and Fodder Value Chain Assessment Report, September 2018

Economics of Improved Dairy Nutrition

Estimated Break-Even Milk Price								
Ration	Annualized Feed Costs				Total	Annualized		Breakeven
	Lactating Cow		Dry Cow		Feed Cost	Milk Production		Milk Price
	KSh/day	# Days	KSh/day	# Days	per Year	ltrs/day	ltrs/year	(KSh/liter)
1	128	74	111	291	41,744	2.5	185	**226**
2	186	88	133	277	53,081	5.5	484	**110**
3	192	133	133	232	56,317	6.7	891	**63**
4	221	253	132	112	70,767	8.5	2,151	**33**
5	331	288	132	77	105,640	16	4,608	**23**

In summary, a smallholder farmer with cows producing an average of less than 8 liters/day/of milk is operating at a subsistence level and is not being compensated for growing and collecting the fodder needed to feed his/her cows. The scale of the loss is masked by the steady stream of income from milk sales, and the "hidden costs" of feeding dry cows during extended inter-calving intervals. Producers at lower levels of production feel the economic squeeze without understanding what is happening.

At these levels, a producer would be better off selling his/her cows and producing fodder for sale. ***An economically viable operation is one where the producer makes the nutritional changes needed for his/her cows to produce an average of 8.5 liters of milk, extend lactation to 270 days, and decrease the inter-calving interval to 390 days.***

Potential Mitigating Actions

There are a variety of issues facing the Kenyan feed industry. Most are inter-related and will need to be addressed to improve dairy production and productivity. There is also a key structural issue with the forage and fodder value chain which requires attention. The major issues that need to be addressed are:

1. ***The Kenyan dairy industry does not have access to the tools and information needed to improve dairy nutrition, production and productivity.*** A standard component of producing concentrate feedstuffs for dairy production is ascertaining the nutrient profile of the raw materials used, as well as check testing of the finished product. Access to reliable testing as a quality control measure would ensure that concentrate feeds are better formulated, more balanced, and contain appropriate ratios of significant nutrients. Kenyan feed mills that produce dairy meal are required to meet the KEBS standard in order to market their product. We collected samples of dairy meal and had them analyzed at an ISO certified facility, finding that only three out of 15 met the KEBS minimum dairy meal standards for protein and energy content. The lack of testing facilities is the number one issue facing the feed industry in Kenya.

   Until feed manufacturers can regularly test raw material and analyze finished products, it will be extremely difficult for the industry, and the dairy farmers they serve, to increase productivity.

2. ***The overall purpose of dairy meal standards is regulatory and could be designed to be more supportive.*** The KEBS standards are too prescriptive to be practical and need to be enforced in a way that encourages the feed industry to adapt to changing needs or innovate and develop new products for Kenyan conditions. Shifting to a minimum standard that

encourages the industry to produce customized products that exceed that standard would be more conducive to development.

3. ***Kenya Bureau of Standards (KEBS) standards for dairy meal need to be updated.*** The KEBS standard nutrient profiling is mostly based on out of date information from the US and UK, and applicability to Kenyan conditions is questionable. Basal rations based on tropical climate forages are far different from those found in temperate climates, with generally lower levels of macro-nutrients and digestibility in tropical forages. As a result, dairy meals formulated to the KEBS standard appear only marginally effective as a supplement for the observed basal rations, and those that do not meet the standard yield even poorer results. *An alarming factor in the standard is that it allows meat and bone meal to be used in formulating dairy meal.* This practice is illegal in nearly every country in the world. The KEBS standard should be reviewed and updated based on modern nutrition management and the basal rations fed in the country and expanded to include standards for both seasonal and productive differences.

4. ***Feed industry needs to provide producers with access to the information needed to improve dairy nutrition, production and productivity.*** Although quite common in other countries, dairy meal is not labeled as to contents (ingredients) and nutrient profile, or with relevant instructions for usage. There is no documented evidence to back up the recommendations, and no advice on calibrating usage based on the weight of the animal being fed. Therefore, the contents, nutrition profile and correct application of Kenyan dairy meals and supplements is unknown by producers. As a result, feeding recommendations are often ignored, and commonly used recommendations are almost uniformly ineffective in supporting increased dairy production and productivity.

5. ***Forage value chain participants focus on the agronomic aspects of improved forages but completely ignore the nutritive aspects***. There are a variety of private and public forage improvement efforts underway in Kenya. However, nearly all the efforts related to forage improvement focus on the agronomic aspects of forage production. There is very little information available regarding the nutrient profiles or optimal harvest stage for these new forage varieties, and how they can best be used to improve dairy production.

   For producers to incorporate new forage varieties into their operations, they need to fully understand the nutrient profile of the crop and how to insure optimal nutrient supply through timely harvesting.

6. ***Salt/mineral supplements in the Kenya market are formulated for temperate climates.*** There is a broad array of salt and mineral formulations available in the Kenyan market, with a wide variety of formulations. The use of supplements is common, but most of the products available are formulated for temperate climate dairy production. As a result, they are largely inadequate to balance the macro mineral needs of tropical dairy cattle – especially with regard to the balance of calcium and phosphorus in the diet. There are even some products being used by a substantial number of producers (34%) that are detrimental (due to high phosphorus content) to the macro mineral situation and exacerbate the already poor balance. Nevertheless, there are several available products which would work well in the observed basal rations.

Recommendations

We conclude that there is tremendous potential to significantly increase dairy production and productivity in the KCDMS focus areas. In our opinion, it is possible to increase annual milk production of producers in these areas by two to four times the amount that we observed at present in the study. The nutritional obstacles to exploiting this potential are significant but can be overcome.

The main obstacles on the producer side are a lack of knowledge of proper dairy management practices, poor forage crop management, imbalanced basal rations in both macro nutrients and macro minerals, and an overall lack of proper dairy nutrition knowledge and practices. Industry issues are the inability to properly determine the nutrient content of raw materials and finished products, poor understanding of the nutrient requirements of animals being fed, and a general lack of practical information and instructions for product use. Revisions to GOK feed policies are also needed to overcome producer and industry obstacles and modernize the sector, especially regarding feed standards and regulatory systems. The approach to overcoming these obstacles must focus on nutrition as the foundation of all efforts to improve dairy production and productivity.

Our recommendations for overcoming the present barriers to increased productivity and for enabling dairy producers in the KCDMS focus areas to transition from subsistence dairy activities into full commercial dairy production are as follows:

Dairy Value Chain Producer Needs

1. **Extensive training in basic dairy/nutrition management:** To overcome the fundamental lack of practical dairy nutrition and management skills in the KCDMS areas, it is essential that extension personnel and producers be trained in basic feeding and nutrition principles and applications. ***We recommend an extensive ruminant nutrition training program focused on developing private sector nutrition advisors***.

2. **Encourage better forage utilization and basal rations:** Several programs are underway in Kenya to increase forage availability and introduce improved forage varieties. However, these efforts are unlikely to succeed if producers do not learn to use their forage resources properly.

   To apply their training, producers need better information and advice on the nutrient profile of different forages, on harvesting practices to ensure quality and nutritional value, on feeding forage mixes (grass/legumes), and on supplying the total quantity of feed their animals need.

   We recommend a comprehensive forage and basal ration information program to compile and disseminate available information on the nutrient content of forages, yields and optimal nutritional value, as well as the costs and benefits for common forages encountered during this study.

3. **Access to improved dairy meal formulations:** Producers who are feeding better quality basal rations can make the best use of supplements specifically formulated to mitigate nutrient shortfalls and increase productivity. ***We recommend providing producers with nutritional information on available dairy meals, and recommendations on the amounts to feed based on the size of their animals.***

4. **Use of appropriate mineral supplements:** Most salt and mineral supplements available in Kenya are not formulated based on tropical feeding requirements and are inadequate to balance Kenyan macro-mineral requirements. There are a few products available in Kenya that can be usefully fed, but lack of producer knowledge and general availability are obstacles to their widespread adoption. ***We recommend fully defining and mapping macro mineral deficiencies in the basal rations in the various areas to inform recommendations.***

5. **Access to nutrition advice:** Dairy farmers need access to professional advice and counsel on animal nutrition and feeding to make the best possible use of the resources at their disposal to increase production and productivity. ***We recommend developing a corps of field nutritionists trained in proper dairy nutrition management to advise farmers.***

Feed and Forage Value Chain Supplier Needs

1. **Access to information on nutrient content:** Formulation of more effective dairy meals and supplements starts with the quality of the raw materials. Feed mills need access to better information on the nutrient profile of their raw materials and the ability to randomly test their finished product. As noted in Section 2.3, the lack of feedstuff testing facilities is the number one issue facing the feed industry in Kenya. Until feed manufacturers can regularly test raw materials and analyze finished products, it will be extremely difficult for the industry, and the dairy farmers they serve, to increase productivity. The equipment and skills needed to perform WCA of feedstuffs is common, and there may be several commercial laboratories in Kenya that could conduct feedstuff analysis. ***We recommend an assessment of commercial laboratory capacity in Kenya to identify what is needed to make available the needed analytical services required by the industry.***

2. **Access to nutrition advice:** The present system in Kenya which produces only two general types of dairy meal is seriously hampering the development of better on-farm animal nutrition. Feed mills need access to professional advice on the nutritional needs of different classes of animals to know how best to meet those needs. Advice is needed on the proper use of nutrient profiles in formulating appropriate feeds for local conditions. Feed processors also need advice on adjusting their formulations depending upon material availability and cost, while maintaining quality, and the use of appropriate manufacturing techniques. ***We recommend expanding the recommendation of developing a corps of field nutritionists trained in proper dairy nutrition management to include professionals that can advise feed mills as well.***

3. **Increase access to information on the nutritional status of client dairy animals:** The effectiveness of dairy meals, supplements and improved forages is founded on an understanding of the nutrient needs of the animals at the farm level, and physical factors impacting recommended use.

   Suppliers in the feed and forage value chain need to be made aware of the nutritional deficiencies faced by producers, and the farm level need for dairy meals, supplements and forages designed to meet those needs. ***We recommend developing a program to compile and disseminate information on dairy cattle nutritional needs to suppliers to help them develop products to meet the needs.***

4. **Publicize nutritional guidelines for improved forages:** A range of forage improvement activities in Kenya are either underway or in the planning stages. The effectiveness of those efforts is largely dependent upon the effective use of the forage produced, based on their nutritional profiles.

   We recommend a comprehensive industry program to compile information on nutrient content, dry matter production and digestibility, and the costs and benefits of new forage varieties.

5. **Support a program of demonstrative feeding trials:** Even with the best supplement formulation and forage use data, dairy producers must be convinced of the benefits of using a product for them to make the effort to incorporate it into their operations. Traditional

marketing approaches are not enough to convince producers to try new products. Feed and forage demonstrations at the farm level do more to convince producers of the benefits of new products and practices than any advertising could ever accomplish. ***We recommend working with producer cooperatives and locally based feed/forage suppliers to establish short term feeding trials that demonstrate the effectiveness of the new inputs over the current basal rations***.

Regulatory Issues

Review, revise and update industry regulation. The KEBS standard for Dairy cattle feed supplements could better reflect the realities of dairy nutrition in Kenya. Limited to only two feeds, it does not encourage improved nutrition or new product innovation, or support increased dairy production and productivity. No single ration formulation can mitigate nutritional issues for the entire industry. (There is no such thing as one size fits all). ***We strongly recommend a comprehensive review and reconsideration of the standard seeking a new regulatory framework for the industry.***

Specifically, this framework would:

a. **Set minimum nutrient profile requirements** for products to be marketed as dairy meal and/or supplements with a focus on meeting the basic nutrient requirements of the animal class in question, allowing and encouraging manufacturers to exceed those standards.
b. **Specify unallowable ingredients which** cannot be included in dairy feeds (for example, blood and bone meal) with reference to international regulations.
c. **Set upper limits** for the presence of certain elements (aflatoxin, non-protein nitrogen, etc.)
d. **Require a labeling system for feeds** and specify the information to be included on labels to inform producers and help them balance their on-farm rations. These feed tags, attached to every package of dairy meal and feed supplements, would contain a list of ingredients, nutrient profile, and instructions for use calibrated by animal size.
e. **Approve and support third party certification system for the industry** as an alternative means of certifying dairy meals and supplements. Experience in many other countries has shown that this approach provides proper oversight, leads to innovation, and makes the feed industry more responsive to their customer base.

For this task, ***we recommend a participatory process using a broadly-based committee of industry stakeholders, supported by experts in nutrition and feeding to produce an initial draft.*** That draft should be widely consulted as it is developed, before being formalized. Once formalized, the set of standards should be made readily available for public use.

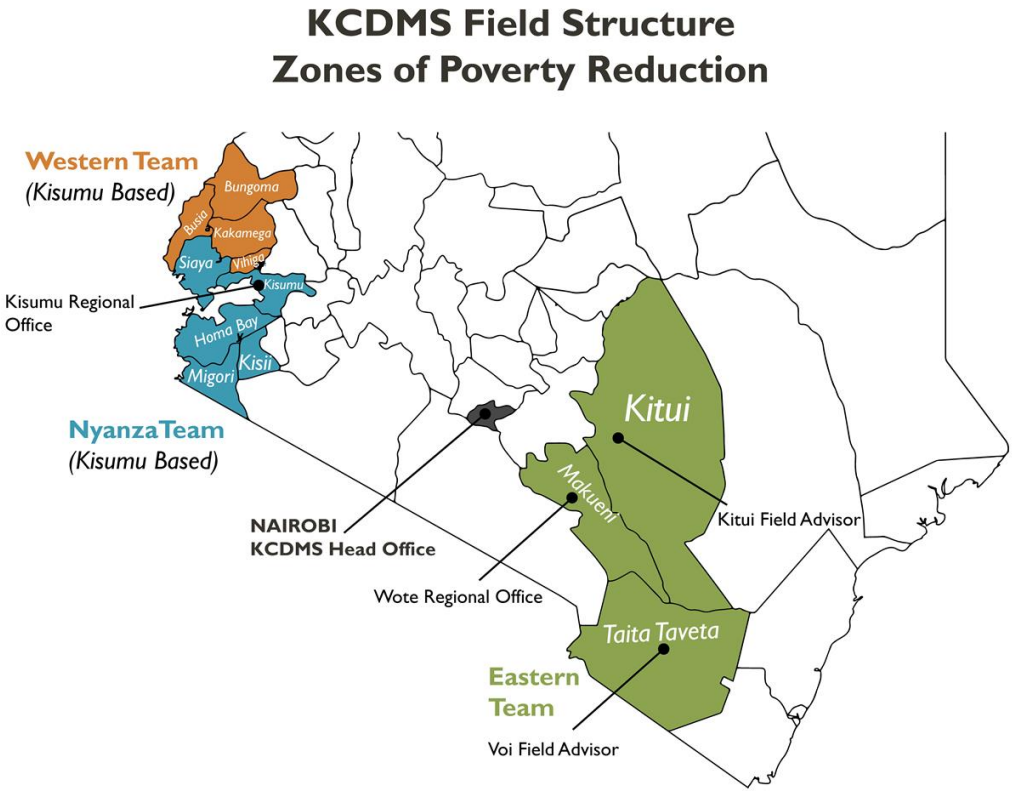
Conclusion

There is significant potential for increasing smallholder dairy production and productivity in the focus areas, and increasing producer income, while simultaneously achieving a significant reduction in methane emissions intensity by adopting improved feeding practices. Actions in support of improved practices will only be successful if they encourage producers to make the nutritional changes needed for their cows to produce an average of 8.5 liters of milk, to extend lactation to 270 days, and to decrease the inter-calving interval to 390 days. Achieving that goal will require an integrated approach to improving basal nutrition at the producer level by making available more appropriate forages and feed/supplement formulations to mitigate nutritional issues, as well as modernizing the regulatory framework for the feed industry.

1. INTRODUCTION

1.1 Background to the Study

The goal of the Kenya Crops and Dairy Market Systems (KCDMS) Activity is to transform agricultural market systems to enable intensification and diversification into higher value commodities and non-farm activities. KCDMS is being implemented in the 12 focus counties of the Eastern, Western and Nyanza areas of Kenya by RTI International and its KCDMS partners.



The dairy industry is one of the fastest growing agricultural subsectors in Kenya, growing at an estimated rate of 3-4% annually[7]. The Kenyan dairy value chain is currently valued at over US$1.9 billion and contributes 6-8% of GDP, of which an estimated 80% is contributed by smallholder farmers. National milk production grew from an estimated 2.22 billion liters in 2000 to 5.2 billion liters in 2016.[8]

Dairy sector growth in Kenya is largely a result of increasing herd size rather than increased animal productivity. Kenya's estimated average annual milk production of 1,017 liters/milking cow (1,187 liters/milking cow for improved breeds) is poor by any standard, and less than half of what should be expected from a reasonably nourished crossbred dairy animal.

Nutritional factors are the greatest constraint to increasing ruminant livestock production and productivity in East Africa. Dairy production and productivity are the outcome of a complex combination and interaction of nutritional factors related to animal management and diet. Nutritional issues include macro nutrient imbalances (energy, protein), macro mineral imbalances

[7] Kenya Ministry of Livestock Development, 2010.

[8] Generous estimate. FAOSTAT 2018 estimated Kenya's 2016 milk production at 4.1 billion liters.

(calcium, phosphorus), and overall macro nutrient and mineral availability. Sustained increases in dairy production and productivity require feeding both the **quantity** and the **quality** of feed needed to provide a balance of essential macro nutrients and minerals beyond what is needed to maintain normal body functions. Cows fed a balanced diet will be well-nourished, healthy and fertile. Additionally, balanced rations give livestock the ability to manage the nutritional stresses associated with high milk production.

Smallholder dairy farmer feeding practices and rations determine the nutritional status of their cows, which directly determines dairy production and productivity. Therefore, KCDMS specifically seeks to develop interventions that will improve smallholder dairy farmer access to information on feeding practices, especially on the use of feed concentrates and supplements, to improve livestock nutrition and increase dairy productivity. Ideally such information and products can be made sustainably available through a network of informed private sector agro-dealers, cooperatives and other producer organizations.

This study assesses the critical dietary and nutritional constraints to smallholder dairy productivity in the KCDMS focus areas. It provides an indicative look at current feeding practices, nutritional status, available feeds and supplements, and production levels. It considers the potential for reducing ruminant methane emissions intensity and their contribution to Kenya's greenhouse gas emissions (GHGs). Finally, the study includes a snapshot of the potential economic impact of improving smallholder feeding practices and overall dairy nutrition.

1.2 Study Objective and Key Questions

The study objective was to accurately assess the critical dietary constraints to optimal dairy productivity for smallholder farmers in the KCDMS focus areas. The two key study questions are: ***(1) what are the principal nutritional constraints limiting smallholder dairy production in the KCDMS areas?*** and ***(2) What can the local feed industry do to mitigate those constraints?***

This study responds to these questions by first gathering and analyzing accurate farm-level measurements of production data and information on what smallholder dairy farmers are feeding their animals. This analysis is combined with information obtained during interviews with feed value chain participants regarding formulation practices, the feed concentrates and supplements commonly in use in the areas, and their nutrient profiles. All this information was collated and analyzed to:

1. identify the nutritional constraints in the smallholder dairy production system in the three KDCMS focus areas;
2. recommend alternative rations, feed formulations and feeding practices to address the identified constraints;
3. calculate the potential impact of alternative technical interventions on production, and productivity as well as methane emissions;
4. identify potential alternative institutional mechanisms for producing and delivering improved feeds and supplements; and
5. estimate the potential impact of applying these alternatives with regards to milk production, household income and food security, and methane emissions.

1.3 Study Design and Methodology

The study used the Ruminant Methane Assessment (RMA) methodology for this analysis. The RMA is a tool for assessing the efficiency of developing country livestock production systems and development projects and is based on the United Nations Framework Convention on Climate

Change (UNFCCC) methodology known as ***AMS-III.BK***[9] developed by RuMeth International Ltd. (RuMeth). The methodology is specifically designed to assess nutritional efficiency and methane emissions from large ruminant production systems in the developing countries of Africa, Asia and Latin America.

The RMA enables practitioners to assess the efficiency of large ruminant production systems; identify nutritional issues and constraints; and estimate the impact of technical interventions to address those constraints. It uses farm-level data on seasonal feeding practices and production parameters (genetics, weight, milk production, calving interval) to calculate nutritional status and productive efficiency. It is specifically designed to provide a clear indication of nutritional status and limiting factors based on information from a small sample of producers.

The study adapted previously utilized data collection and interview guides to ensure the information obtained is that which is needed to achieve the study objective. Specifically, the study team collected detailed farm-level data on production parameters (genetics, weight, milk production, calving interval) and feeding practices (rations, concentrates, supplements), and combined it with data on the nutrient profiles of the rations being fed. This data was used to analyze the nutritional status of and productive efficiency of smallholder dairy cattle in the focus areas and to identify the principal nutritional constraints to increased productivity.

The team also interviewed feed value chain participants (manufacturers, formulators, wholesalers and retailers) in the focus areas to obtain detailed information on how they formulate their feeds, the nutrient profile of their feeds, raw material constraints, testing and quality control practices and regulatory issues. This included information on the various feed concentrates and supplements in use by smallholder dairy farmers, and anecdotal information on their effectiveness. Finally, we compiled published data on the nutrient profiles of the forages used in the areas, collected samples of the most common feed concentrates and supplements, and had them tested to confirm their nutrient profiles.

The information collected, the source, and the collection method utilized are summarized as follows:

Information	Source	Collection Method
Production data: dairy cow genetics, age and weight; daily milk production and, length of lactation; breeding information and calving interval.	Smallholder dairy producers	Producer survey
Feeding practices: rations (combination and amount of forage, concentrates and supplements) fed to lactating cows, dry cows, and heifers in both dry and wet seasons.	Smallholder dairy producers	Producer survey
Feed concentrates and supplements: concentrates and supplements being used, formulations, and recommended usage.	Feed mills, manufacturers, distributors, and retailers.	Key informant interviews
Nutrient profiles: nutrient profiles of forages, concentrate feeds, and mineral supplements being used by producers.	Laboratory analysis of samples, published data	Tests of feed samples, desk review

[9] https://cdm.unfccc.int/methodologies/documentation/meth_booklet.pdf#AMS_III_BK

Data Collection Methodology

The study team collected ***farm-level data*** from a sample of 120 smallholder dairy producers in the three USAID Feed-the-Future focal areas of Kenya (40 producers in each area). Data was collected between April 2 and April 12, 2019 in Eastern Kenya (Makueni, and Taita-Taveta counties); Nyanza (Homa Bay, Kisii, Kisumu, Migori and Siaya counties); and Western (Bungoma, Kakamega and Vihiga counties). See **Annex 1** for the raw dataset.

KCDMS provided RuMeth with an initial list of producer organizations (cooperatives and community-based organizations) in the focus areas from their Producer Organization Sustainability Assessment. The team reviewed that information, and selected an initial group of producer organizations to sample based on the following criteria:

1. Membership (more than 20 registered members)
2. Availability of records
3. Project management and governance
4. Holding a cooperative/CBO license
5. Amount of milk produced/day (more than 500 liters), or any other livestock related produce e.g. feed and fodder production
6. Available project information (written material that describes organization activities, management and membership)

This initial list was reviewed and adjusted in collaboration with KCDMS to develop a final list of 19 smallholder dairy organizations from which to sample producers. Each organization was contacted and asked to identify a sample list of 20 members. From those lists we randomly selected a total of 40 dairy farmers in each of the three areas and compiled the list for interviews. The interview list included the name of each organization, contact person and phone number, and each farmers name and mobile telephone number. The data collection schedule listing organizations, names, contact information, and the number of producers sampled is shown in **Annex 2**.

For ***feed value chain participant interviews*** (manufacturers, distributors, wholesalers, and retailers/agro-vet stores) KCDMS provided us with contact information on suggested enterprises to be interviewed. We interviewed as many of those enterprises as time allowed, as well as additional firms identified during field work. The list of firms interviewed, their location (county) and contact names and telephone numbers are shown in **Annex 3**.

We also collected samples of 22 dairy meals and 8 supplements used by farmers in the focus areas for laboratory analysis. We obtained some samples directly from the manufacturer and purchased others at distributors and retail outlets (agri-vets). 21 samples were taken to the U.S. for Wet Chem Feed Analysis at Soiltest Farm Consultants, Inc. in Moses Lake, Washington.

An additional 9 samples underwent Wet Chem Feed Analysis at the University of Nairobi Animal Nutrition Laboratory. We used the nutrient profiles obtained from Soiltest for ration analysis. We also compiled a list of the forages fed by dairy farmers sampled in the focus areas and we gathered information on their nutrient profiles from published sources.

1.4 Report Limitations

Farm-level production and productivity data collected during this study is specific to smallholder dairy producers in the USAID Feed-the-Future focus areas of Kenya. The data is not representative of the Kenya's dairy value chain as a whole, even though some of the results (such as average animal weights) are consistent with those contained in other reports. We used a very specific sampling methodology to gather the information needed to calculate nutritional profiles for dairy cows in the smallholder operations surveyed. Those profiles are **indicative** of nutritional conditions in emergent smallholder dairy operations in the KCDMS focus areas. They should not

be misinterpreted as being representative of all such operations in those areas. Nonetheless, our experience is that the indicative nature of the profiles generated will be consistent with what would be found in a larger survey.

1.5 Primer on Ruminant Nutrition and Dairy Improvement

Ruminant nutrition, the science of feeding cattle, is a complex and detailed topic. Good animal nutrition is the cornerstone of dairying, as well as a necessary and sufficient condition for increasing dairy production and productivity. Therefore, we are including this brief primer on ruminant feeding and nutrition to help readers better understand the science behind our work.

A dairy cow needs enough feed to maintain her body, grow a fetus, and produce milk. Specific nutrient levels are needed for each of these functions. These nutrient requirements are well documented and understood and form the basis for our understanding of how to optimize productivity in a cow. Proper feeding requires balancing the different nutrient requirements and supplying the required amount and type of nutrients in a ration. The productive potential of any given ration is determined by the ***quantity***, ***nutrient content*** and ***nutrient quality*** of the feed consumed.

The ***quantity*** of feed a dairy cow can consume is based on the digestibility of the feed and the size of the cow. A large cow can consume more feed than a small one, and all cows can consume more highly digestible feed than low digestibility feed. The amount of feed that is consumed by the cow, digested in the rumen, and then cleared for more input is called "throughput". ***Nutrient content*** means that some feeds contain more nutrients than others. It is generally better to feed high nutrient content, highly digestible feed to maximize consumption and production. ***Nutrient quality*** means that different feeds may contain similar levels of macro nutrients, but that some plant species provide greater nutrient availability than others due to their genetic makeup.

Digestibility, nutrient content and nutrient quality help determine the productive potential of a ration. Potential increases in dairy production and productivity from improved nutrition are a combination of increased daily milk production, increased length of lactation, and decreased calving intervals. The challenge is to increase nutrient uptake, while substituting feeds with better nutrient profiles to maximize productivity from available resources.

As previously mentioned, potential increases in dairy production and productivity as a result of improved nutritional practice comes from three distinct sources. These are: ***daily production, the length of the lactation period, and the inter-calving interval***.

Daily milk production increases as more nutrients are made available to the animal. This phenomenon is usually apparent within a few weeks of initiating improved feeding and continues to increase for the next few weeks. The greatest improvement in daily milk production will be seen in animals that are just starting lactation when nutrition is improved. Cows in late lactation will see minimal productivity gains from improved nutrition in the short run, but daily milk yield will increase in their next lactation.

The ***length of the lactation period*** is the second area of productivity increase. After a cow gives birth, she begins producing milk. Eight to ten weeks post-partum the animal reaches her "lactation peak" which is when the highest daily amount of milk is produced. Daily milk production will gradually decrease from this point on. The animal's level of nutrition is the primary factor contributing to the length of lactation. Cattle on relatively poor diets tend to have shorter lactations while animals consuming a more balanced ration tend to have longer ones. One important aspect of maintaining a long lactation is that the higher the lactation peak, the more days the animal will produce milk. High peak lactations can be achieved by proper feeding during that critical period at the beginning of the lactation. In developed countries, the average length of

lactation is 305 days; whereas in the KCDMS survey areas the average is slightly more than 200 days.

The third source of increased milk production from improved nutrition comes from the decrease in time between calvings (giving birth). At a point during the lactation period, the cow is re-bred. As the calf she is carrying develops and requires more nutrients, her production of milk decreases. When milk production has diminished to an almost negligible amount, milking ceases and the cow enters a "dry" phase. During this phase, the animal uses its nutrients for maintenance and development of the unborn calf. When she finally calves, she enters a new lactation period and the cycle starts again. The time that elapses between the initiation of the two lactation periods is referred to as the ***"inter-calving interval".***

The "dry" period, or length of time the animal is unproductive, is determined by subtracting the lactation period from the calving interval. In order to optimize this interval, the cow must be re-bred on a regular basis. While there are management practices involved with re-breeding an animal (availability of males or AI), there are nutritional constraints as well. The most important of these nutritional factors is the mineral and vitamin balance in the animal's diet. Without an adequate balance of vitamins and minerals, re-breeding can take longer due to irregular estrus cycling and poor uterine conditioning. An animal receiving enough of these important nutrients will be more likely to ovulate, become pregnant, and carry the embryo to full term.

In summary, increasing productivity by applying good ruminant nutrition relies upon the interaction of a complex set of biological factors. There are no shortcuts, and no single solutions for problems that disrupt this interaction. Nutrient requirements of the targeted animals must be identified, nutrient profiles of the available feed developed, and then any shortages in required nutrients addressed by applying proper ration formulation.

2. FINDINGS AND CONCLUSIONS

To respond to the study objective and key questions, we surveyed 120 smallholder dairy farmers in the USAID Feed-the-Future focal areas of Kenya: Eastern (Makueni, and Taita-Taveta counties); Nyanza (Homa Bay, Kisii, Kisumu, Migori and Siaya counties); and Western (Bungoma, Kakamega and Vihiga counties) from April 2nd to 12th. The work emphasized gathering and analyzing farm-level measurements of production data and detailed information on what smallholder dairy farmers feed their animals throughout the year, including difference between the rainy and the dry season. See **Annex 5** for a list of the feedstuffs encountered during the study. The data collected was complemented by information gathered in interviews with key informants in the feed value chain regarding the formulation and manufacture of dairy meals and salt/mineral supplements. The study findings are based on the combination of this information.

2.1 Survey results overview

Level of Confinement: Total and semi-confinement, as shown in the Table 1 below, are the predominant feed management systems being used in the focus areas. Zero grazing is prevalent in Eastern, while partial grazing dominates in Western and Nyanza. Even animals classified as partially grazed are confined most of the time. The main issue is that confined and semi-confined dairy cows are being given insufficient quantities of feed. Good feeding practices would make certain that animals have continual access to feed. Nutrient intake is always limited without continual access to feed, resulting in chronic undernourishment.

Table 1: Level of Confinement (120 operations)

	Zero Grazing	Part Grazing	Only Grazing
Nyanza	11	29	0
Western	14	26	0
Eastern	31	9	0
Total	**56**	**64**	**0**

Genetics: The common perception that poor genetics is a problem in the Kenyan dairy herd is not borne out by our survey results. All operations were milking at least cross-bred cattle (25%-75% exotic blood), and one-third of the operations were milking cows with at least 75% exotic blood. All milking cows measured exhibited exotic blood – usually Friesian or Jersey – with strong genetic potential for milk production and productivity.

Table 2: Herd Genetics (120 operations)

	75-100% Exotic	Cross (25-75% Exotic)	Local (less than 25% Exotic)
Nyanza	9	31	0
Western	12	28	0
Eastern	24	16	0
Combined	**45**	**75**	**0**

Cow Size: The common assumption that Kenya dairy cows weigh an average of 300kg is consistent with what we found in Western and Nyanza. However, at 393kg/animal, the average cow weights in Eastern were 25% larger than the reported national average. More importantly,

the range in weights encountered (147-724kg) is so great that any generalized statements of average cow size are practically meaningless.

Table 3: Cow weight in kilograms (296 cows)

	Average Size	Median Size	Range
Nyanza	303	298	161 – 481
Western	300	271	147 – 724
Eastern	393	378	213 – 702
Combined	**335**	**309**	**147 – 724**

Feeding Practices: Smallholder dairy producers in the focus areas are using a combination of feeding practices that largely cancel out the potential benefits of feeding dairy meal and/or mineral mix. The inclusion of overly mature Napier grass and low-quality maize stover in the basal ration is counterproductive. This often contradictory and ineffective mix of practices is illustrated in Table 4 below:

Table 4: % of Farmers incorporating various components in the dairy rations

	Dairy Meal	Mineral mix	Napier	Low Digestibility
Nyanza	85%	78%	85%	65%
Western	53%	75%	88%	88%
Eastern	83%	100%	80%	73%

Productivity: Annualized milk production in Nyanza ranges from a high of 1,606 liters to a low of 795 liters. In Western, it ranges from a high of 1,290 liters to a low of 611 liters. Annualized milk production in Eastern is higher than the Kenyan average for all systems and genetics, ranging from a high of 1,587 liters to a low of 1,183 liters. Dairy productivity for the best producers in the focus areas (Table 5 below) is above the Kenyan average of 1,017 liters of milk per year. However, that average is poor by any standard and demonstrates the great potential for improving dairy production and productivity.

Table 5: Major Production/Productivity Indicators

Feeding System and Genetics	Age at 1st Calving (months)	FCM/Day (liters)	Real Lactation[10] (Days)	Calving Interval (days)	FCM/Year (liters)	# Producers
Nyanza						
Aa	26	10.6	226	547	1,606	7
Ab	28	7.4	203	596	923	4
Bb	31	6.0	206	572	795	26
Western						
Aa	29	8.8	249	620	1,290	8
Ab	43	7.1	228	777	757	6
Ba	27	7.9	213	642	952	4
Bb	34	5.8	180	620	611	21
Eastern						
Aa	32	10.4	254	609	1,587	24
Ab	29	9.0	214	596	1,183	8
Bb	29	8.6	231	579	1,245	8

Aa = Zero Grazing, >75% Exotic blood Ba = Part grazing, >75% Exotic blood

Ab = Zero Grazing, 25%-75% Exotic blood Bb = Part grazing, 25%-75% Exotic blood

Productivity indicators, like cow weights, have a very wide range (Table 6 below). The low levels of daily milk production, short lactation periods, and long inter-calving intervals in the majority of Western and Nyanza producers are a direct result of poor nutrition and feeding practices.

Table 6: Major Production/Productivity Indicator Ranges

Area	Age at 1st Calving (months)	FCM/Day (liters)	Real Lactation (Days)	Calving Interval (days)	FCM/Year (liters)
Nyanza	20 - 48	2.5 - 12.5	105 - 300	395 - 1,065	398 - 3,206
Western	24 - 48	2.0 - 14.5	150 - 270	437 - 1,204	353 - 4,020
Eastern	25 - 51	3.8 - 16.1	165 - 300	397 - 1,023	541 - 3,007

The average productivity in Eastern is higher than in Western and Nyanza, but there are still many issues with ration balancing, proper nutrient allocation and the use of sub-standard feedstuffs. These are evidenced in the wide range of productivity indicator values, which demonstrate the complex and multiple issues facing the dairy sector in the areas. There is no single solution to these issues, but rather multiple options depending on specific situations and constraints.

2.2 General Findings

The general findings below articulate the principal issues encountered during the survey. Corrective actions will be described in Section 3: Conclusions and Recommendations.

[10] The number of days the cow should be milked based on her nutritional status.

2.2.1. ***Smallholder dairy producers are not giving their cows enough feed.*** A large proportion of producers in the KCDMS focus areas (50%) are not be feeding the quantity of feed (mostly forages) their animals need. When an animal is in a confined living situation, it must always have forage and water available. Unfortunately, many of the confined animals in the study area do not have forage and water continually available. The resultant shortfall in total dry matter intake is a serious concern, especially for the zero-grazers, and results in chronic undernutrition which leaves animals permanently stunted and unable to demonstrate their genetic production potential. When feed and water are not continually available, the animals are denied the opportunity to consume what they need and will not produce efficiently.

2.2.2. ***Most basal rations contain overly mature forages.*** Ration quality issues arise from the use of overly mature and poorly digestible grasses and legumes. A good example of this phenomenon is Napier grass. This widely known grass is a component in 84% of the basal rations, and the majority component in 58% of the rations surveyed. Napier has many good qualities, but unfortunately, the producers we surveyed are generally feeding it as an overly mature grass. Napier grass has a good nutrient profile up to about 60 days of growth. Beyond that point available nutrients decrease as the plant matures, with a 40% decrease in protein and a 24% decrease in energy seen in 90-day mature Napier.

2.2.3. ***Most basal rations contain low digestible, nutrient poor feedstuffs.*** The inclusion of low- quality crop residues in the basal rations greatly reduces the nutrient content and balance consumed by the animal. By using sub-standard feedstuffs (maize stover, millet straw, maize cobs, etc.) producers are negatively impacting the cow's consumption, absorption and utilization of nutrients from the higher quality components. This is a common problem in all three geographic areas, with 75% of the respondent farms. Low quality crop residues may keep cows alive during extreme forage shortages but cannot provide adequate nutrition to a lactating herd. They are best used as a ration component only for animals that are not kept for milk production.

2.2.4. ***Lactating rations are rarely balanced.*** In nearly all farms visited (96%), the basal rations being fed are not balanced properly for macro-nutrients (protein and energy). In a majority of the farms (54%), this imbalance equals a loss of at least two liters of milk per day. Because of limited producer knowledge about the nutritional needs of their animals and the nutrient content of their feeds, there are wide variations in nutrient balance. In some extreme cases (23%), simple ration balancing using the existing feedstuffs and adjusting the amounts fed, would increase milk production by 4 liters/day.

2.2.5. ***Dry cows and replacement heifers are fed very poor rations.*** Common feeding practices for dry cows and heifers do not include any supplemental forage, concentrates or minerals. As a result, dry cows are insufficiently prepared for the re-initiation of lactation, with lower than desirable body conditioning, low levels of stored nutrients, and shortened predicted lactation periods. For heifers, substandard feeding results in long term physical issues such as stunted growth, inadequate udder development, low nutrient absorption capacity and reduced body fat deposition. In short, farmers are not doing a good job of feeding replacement stock to prepare them for breeding and lactation.

2.2.6. ***Kenyan dairy meals are not formulated to mitigate macro nutrient issues.*** Dairy farmers in the focus areas have access to a broad range of commercial dairy meal formulated to comply with Kenya Bureau of Standards (KEBS) Dairy Cattle Feed

Supplement Specifications[11]. However, the KEBS Standard does not reflect the nutrient requirements of dairy cows fed tropical forages. It was developed based on references from livestock nutrition knowledge and practices in North America and Europe dating from the 1960's and 1970's and is outdated in terms of nutrient profiling and applicability to Kenyan conditions. The problem is that basal rations based on tropical forages are far different from those found in temperate climates, with generally lower levels of macro-nutrients and digestibility found in the tropics. In addition, the quality of the tropical nutrients, primarily the energy fraction, is very different from those in common temperate basal rations. As a result, dairy meals formulated to the KEBS standard appear only marginally effective as a supplement for the observed basal rations, and those meals that do not meet the standard produce even poorer results. Furthermore, laboratory testing of the 15 dairy meal samples gathered found only three that met the published KEBS standards.

2.2.7. Kenyan salt/mineral supplements are not formulated to mitigate macro mineral issues. The macro mineral content and balance of Kenyan basal rations is poor, which severely constrains milk production and reproductive efficiency. At the same time, most salt and mineral supplements available in the market are formulated for temperate climate forage conditions and therefore inadequate to balance the macro mineral needs (especially the calcium/phosphorus ratio) for Kenyan dairy cattle. 85% of surveyed producers use some type of mineral supplement to mitigate this issue, but 34% are using products that are detrimental (high phosphorus content) to the macro mineral situation and exacerbate the already poor Ca:P balance.

2.2.8. Kenyan producers do not have access to the information needed to improve dairy nutrition. The study found that 74% of the surveyed farms feed dairy meal. Dairy meals are assumed to conform to the KEBS standard, which is not always the case (***see 6 above***). Furthermore, they are not labeled as to content (ingredients) and nutrient profile; and information about the correct use and selection of dairy meal is not available to producers. As a result, the contents, nutrition profile and correct use of Kenyan dairy meals is unknown by producers; and all too often the supplements are used in a manner which is only marginally effective in supporting increased dairy production and productivity.

2.2.9. Smallholder dairy farmers in the focus areas do not understand dairy production. Far too many producers are using feeding practices that demonstrate a poor basic understanding of dairy production and management of replacement heifers, dry cows, and lactating cows. The common practice of prolonged milking leads to further delays in pregnancy and complicates nutritional management. 47% of the producers surveyed continued milking cows for excess periods of time, some for as long as 580 days. Well fed, high producing dairy cows need to be dried up after 220-270 days of production, (though extremely well managed animals can be milked for 300 days). Extracting milk from the cow beyond this time period means the cow is unable to accumulate the nutrients (especially calcium) needed to conceive and successfully carry a calf to parturition. Therefore, milking non-pregnant cows for extended periods of time delays pregnancy and reduces the amount of milk that might be produced during a normal lactation.

Finally, we encountered a nearly complete absence of farm level record keeping in the areas. Basic information such as calving dates, start of lactation, animal age, and feed costs and availability were sorely lacking. This information is required to inform management

[11] Kenya Standard (KS) 62:2009, ICS 65.120: Dairy Cattle Feed Supplements – Specification. 2009 (confirmed 2014)

decision making. The lack of information contributes to a misunderstanding of production requirements and actions needed to improve production and productivity.

2.2.10. ***The present regulatory system is not as conducive as it could be in terms of enabling increased dairy production and productivity.*** KEBS standard dairy meal and salt/mineral formulations are not based on current nutritional information. Therefore, feeding practices, dairy meals, and salt/mineral formulations are not based on current animal nutrient requirements. Furthermore, the regulatory system is not structured to encourage or support the development of improved products and formulations or provide participants with the tools to support new feed product development or innovation.

2.2.11. ***Increased forage production is essential to sustain and increase overall dairy production and productivity.*** Increasing dairy productivity requires basal rations with both the **quantity** and **quality** of forage needed to provide animals with a balance of essential macro nutrients and minerals.

2.2.12. ***Documented evidence on the benefits of using feed products is lacking.*** Dairy producers rely on word of mouth and on-farm experience to judge the effectiveness of incorporating new feedstuffs into their production system. This is a haphazard and expensive route to take for the producer, and greatly reduces their willingness to listen to promoters of improved feedstuffs. Further, producers are generally of the opinion that new feedstuffs are expensive because their effectiveness is so questionable. These conclusions tend to be right because any amount paid for a substandard, ineffective product is – by definition – too much. This same problem is seen with new and/or improved forage varieties being promoted by both private and public sector entities.

2.3 Principal Nutritional Constraints Limiting Smallholder Dairy Production in the KCDMS Areas

This section presents our analysis of prevailing nutritional constraints, how they can be mitigated, and the potential for increasing dairy production and productivity, while significantly reducing methane emissions intensity by adopting improved feeding practices. Remember that good ruminant nutrition relies upon the interaction of a complex set of biological factors. There are no shortcuts, and no single "one size fits all" solutions. There are only approaches and principals to be applied to specific situations. The two major nutritional issues encountered, in addition to the previously noted tendency to underfeed the animals, are:

2.3.1. ***Crude protein (CP) or net energy for lactation (Nel) are the limiting macro-nutrient factors*** found in the focus area (Table 7 below), depending on the basal ration. It is common for CP to be low in developing country basal rations because tropical forages are often quite low in protein. The shortfall in Nel is directly related to the majority use of Napier as a basal forage. Napier is one of the lowest ranked tropical forages with regards to the Nel energy fraction, as compared to the metabolizable energy (ME) fraction. This factor is especially acute with more mature Napier, which when cut after more than 60 days loses energy, with an accelerated decrease noted in Nel.

Table 7: Principal Macro Nutrient Deficiencies

(% of producers)

	Crude Protein	Net Energy for Lactation	Other
Lactating Cows			
Nyanza	35%	60%	5%
Western	36%	54%	10%
Eastern	80%	17%	3%
Dry Cows[12]			
Nyanza	73%	0%	3%
Western	59%	10%	3%
Eastern	68%	0%	0%

A two-step process is needed to resolve the identified issues of nutrient shortfall. Since the cause, and therefore the solution, to the observed deficiencies will be different from one farm to another, the first step is to identify the shortfall and its causes. ***For farms experiencing a shortage of protein*** (roughly one third of those in the Western and Nyanza, and nearly all in Eastern), the solution is fairly straight forward. The cause could be the feeding of overly mature forage (CP declines with maturity in forages.) or feeding a low protein content dairy meal. Once the cause of the shortfall is determined, additional protein can be added to the basal ration by using less mature forage, adding leguminous fodder (eg. lucerne or desmodium), feeding high protein supplements (soybean meal, cottonseed meal, etc.), or a combination of these practices. The recommended practice will depend on the severity of the shortfall, the availability of supplement options, and the changes needed in the operation.

For farms with a shortfall in Nel (more than half in Nyanza and Western) the situation is slightly more complicated. A shortage of this type is nearly always caused by deficiencies in the fodder portion of the diet. This requires a detailed analysis of the basal ration, followed by a comprehensive review of the forage base of the ration. Some correction to Nel intake can be made by changing concentrate feeding, such as adding molasses, ground maize or another high Nel feedstuff. However, if the shortfall is severe adjustments will be required in the forage portion of the ration, for example adding higher Nel forages such as potato vines, *Cyperus rotundas*, or *Paspalum Notatum.*

2.3.2. Macro minerals are not a principal limiting factor, but there is a shortage of calcium. The calcium/phosphorus (Ca:P) ratio should be between 1.7:1.0 and 2.0:1.0 for optimal reproductive performance. Ratios as low as 1.5:1.0 are acceptable, but not optimal. The prevailing Ca:P ratios we found are generally well below optimum levels, with nearly half of farms below the minimum requirement. The practice of extended milking combined with calcium deficient rations compounds delays in the reproduction cycle and decreases fertility.

[12] In Nyanza, Western and Eastern areas 24%, 28% and 32% of the dry cows respectively are currently not constrained by nutrient deficiencies.

The problem with a deficiency in the Ca:P ratio in the observed herds is that it is likely to be much worse than the survey numbers indicate. Roughly one third of the producers surveyed had a good Ca:P ration (1.7:1 or higher). Unfortunately, the vast majority of those in this group have good ratios because they feed a high concentration of maize stover. Maize stover is a very poor choice for dairy rations (see the General Findings section above), but it does have a very high Ca content. Improving productivity will require convincing producers to greatly decrease, if not eliminate, feeding maize stover, which will likely increase issues with Ca:P ratio. Fortunately, a shortage of Ca is one of the easiest nutrient deficiencies to address. Adding limestone to rations that are seriously deficient in Ca will easily correct the shortfall. For rations with more moderate shortages, improved dairy meal formulations and/or mineral supplements should provide relief. As with the macro-nutrient shortages, an analysis of the individual farms basal ration will pinpoint the degree of deficiency and point the way to the most cost effective and minimally invasive solution.

Overall nutrition management is summarized in Table 8 below. It categorizes producers into three groups based on a combination of their macro-nutrient quality (average TDN) and macro-mineral ration (Ca:P) scores. And it neatly summarizes the challenge facing KCDMS in reaching out to farmers to improve their dairy productivity.

Table 8: Nutrition Management

(% of producers)

Average TDN	**>58%**	**55%-58%**	**<55%**
Nyanza	32%	35%	32%
Western	33%	31%	36%
Eastern	40%	35%	25%
Ca:P Ratio	**>1.7**	**1.5 – 1.7**	**<1.5**
Nyanza	30%	32%	38%
Western	36%	5%	59%
Eastern	33%	25%	43%
Combined Score	**Good**	**Fair**	**Poor**
Nyanza	39%	33%	28%
Western	36%	28%	36%
Eastern	50%	25%	25%

Good Producers will likely experience only one or two of the principal issues outlined in the General Findings section. Fairly simple changes in their use of concentrates, and some adjustments to forage feeding and management will be enough to improve their productivity.

Fair Producers have tremendous potential for significant productivity gains. However, it will take more effort to adjust rations, feeding management, animal management and concentrate feeding to achieve those gains. Revised formulations in both dairy meal and mineral mixes will be very important for this group. They may also require some adjustment to the forage component of the ration, and possibly improved mineral supplementation. They have the potential for dramatic improvements in production with moderate effort.

Poor Producers have multiple issues that require concerted attention. For these producers (one-third of those surveyed in Nyanza and Western, and one-quarter of those n Eastern) lasting and high impact interventions are possible but will require a great deal of effort. These producers are basically transitioning from subsistence level farming to more commercial production and are experiencing many of the principal issues listed in the General Findings section. They need to greatly improve the forage component of their rations, combined with the use of dairy meal, salt/mineral supplements, and feed management practices. They will require concerted effort over a relatively long-term time period.

Improving these operations will require a detailed assessment of the issues on each farm, or set of farms, along with an analysis of the specific shortfalls encountered, prior to investment. Likely, the preferred manner to work with these producers will be to focus efforts at the cooperative level, allowing for a diffusion of the inherent risk, while at the same time identifying those individual producers with substantial merit. A good proportion of these producers will likely fail and cease dairy production. With well-planned and carefully focused interventions a majority will be able to make the transition to commercial production. But efforts with these producers are unlikely to have significant impact in the near term.

2.4 Lactating Cow Rations

With these factors in mind, we developed a series of rations for lactating cows based on our survey data to illustrate the impact that changes in feeding practices can have on milk production, and the potential for improving existing rations to increase productivity[13]. These rations show how substantial changes can be implemented by paying attention to the nutrient requirements of the targeted animals and the nutrient content of the available feeds. Please note that the basal ration selected for this demonstration is one of the lower producing combinations we found. We specifically selected this ration type for the illustration because it is common in the areas surveyed, especially Nyanza and the Western area, and provides a practical example of how a cow's diet can be improved to increase production and productivity. We have specifically kept improvements focused on using forage and feeds readily available in the focus areas, whose use would require only marginal changes in the production system of the farm.

Lactating Cow Ration 1 (LCR1): All rations assume a ***cow weight of 300 kgs*** – roughly equivalent to the average size found in the survey. In this case, the daily basal ration uses a mixture of mature Napier grass and Maize stover (80/20) as the forage base. Supplemental minerals provided equivalent to the average content analysis of locally available products. And, the dairy meal formulation in the example conforms exactly to the KEBS standard for nutrient content.

[13] In the rations presented **As Fed, DM, CP, DP, TDN, Ca** and **P** are expressed in **kilograms**. **DE, ME** and **Nel** are expressed as **Megacalories** (Mcals).

LCR1: Mature Napier/Maize Stover										
	As Fed	**DM**	**CP**	**DP**	**DE**	**ME**	**Nel**	**TDN**	**Ca**	**P**
KEBS Dairy Meal	2.00	1.76	0.28	0.20	6.28	5.49	3.27	1.30	0.0123	0.0070
Mineral Mix	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0093	0.0064
Napier Grass (Mature)	10.37	2.67	0.13	0.06	4.92	4.04	1.93	1.12	0.010	0.017
Maize Stover (Africa)	2.59	2.29	0.13	0.04	4.89	4.00	2.19	1.11	0.011	0.004
Total Consumption	**15.01**	**6.77**	**0.53**	**0.30**	**16.09**	**13.53**	**7.39**	**3.53**	**0.04**	**0.03**
Production Potential (kg)			2.8	1.9	3.5	3.6	1.5	3.1	9.5	12.1
							Digest	**52.1%**	**Ca:P**	**1.254**

Analysis: The potential milk productivity is between 1.5 and 3 liters per day. The nutrient shortfall most impacting productivity is Net Energy for Lactation (Nel). The digestibility of the ration is very low, due to the forage base, and results in a DM consumption of less than seven kilograms. Additionally, the Ca:P ratio is substandard, indicating delayed reproductive performance. An animal fed this ration would have a short (160 day) lactation, a long ICI (785 days), with a very low resultant annual milk production.

Lactating Cow Ration 2 (LCR2): In this case, the overly mature Napier grass and maize stover are replaced with Napier grass harvested at less than 60 days. All other feed inputs remain the same.

LCR2: Young Napier Grass Only										
	As Fed	**DM**	**CP**	**DP**	**DE**	**ME**	**Nel**	**TDN**	**Ca**	**P**
KEBS Dairy Meal	2.00	1.76	0.28	0.20	6.28	5.49	3.27	1.30	0.0123	0.0070
Mineral Mix	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0093	0.0064
Napier Grass (Young)	30.77	6.06	0.47	0.27	14.67	12.06	7.15	3.33	0.016	0.023
Total Consumption	**32.82**	**7.87**	**0.75**	**0.48**	**20.95**	**17.55**	**10.43**	**4.63**	**0.04**	**0.04**
Production Potential (kg)			5.3	5.4	6.9	6.8	5.6	6.6	8.1	13.4
							Digest	**58.8%**	**Ca:P**	**1.043**

Analysis: With this change milk productivity jumps appreciably as more nutrients of higher quality are consumed. The mix of greater nutrient density and higher digestibility result in a daily production of 5.5 to 6.5 liters. A cow fed this ration would also have a slightly longer lactation of 190 days. The ICI would stay the same because the Ca:P ratio is still below the acceptable level. It is worth noting that the change to less mature Napier increases the Nel fraction so that CP is now the limiting nutrient. DM consumption increases to nearly eight kg per day.

Lactating Cow Ration 3 (LCR3): The third ration is only modified slightly. We replaced the KEBS standard dairy meal with the best dairy meal found in Kenya based on our laboratory results.

LCR3: Young Napier plus Best Meal										
	As Fed	**DM**	**CP**	**DP**	**DE**	**ME**	**Nel**	**TDN**	**Ca**	**P**
Best Dairy Meal	2.00	1.86	0.39	0.30	6.95	6.19	3.65	1.58	0.0287	0.0132
Mineral Mix	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0093	0.0064
Napier Grass (Young)	32.68	6.44	0.50	0.29	15.58	12.81	7.60	3.53	0.017	0.024
Total Consumption	**34.73**	**8.35**	**0.89**	**0.59**	**22.53**	**19.00**	**11.25**	**5.11**	**0.06**	**0.04**
Production Potential (kg)			6.8	7.7	8.0	8.0	6.7	8.1	13.5	17.2
							Digest	**61.2%**	**Ca:P**	**1.257**

Analysis: The potential milk production increases by more than a liter per day just from using a better formulated dairy meal. Note that the KEBS dairy meal and the best dairy meal profile used here are actual products available in the Kenyan market for the same exact price. The increased digestibility and quality of nutrients in the Best dairy meal push DM consumption to over eight kgs. Also, with the increased Ca content of the best dairy meal, the Ca:P ratio has improved, though is still not in the acceptable range. With these improvements to diet, the lactation would be lengthened to around 200 days and the ICI reduced to around 550 days.

Lactating Cow Ration 4 (LCR4): In this ration, the intent was to boost both milk production and reproductive performance through nutrient balancing, while requiring a minimal change in the existing production system. To accomplish this, the amount of dairy meal was increased by one kg. and limestone was added as a source of Calcium.

LCR4: More Best Meal plus Limestone										
	As Fed	**DM**	**CP**	**DP**	**DE**	**ME**	**Nel**	**TDN**	**Ca**	**P**
Best Dairy Meal	3.00	2.80	0.58	0.46	10.43	9.28	5.48	2.37	0.0431	0.0199
Mineral Mix	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0093	0.0064
Limestone	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0181	0.0000
Napier Grass (Young)	30.51	6.01	0.47	0.27	14.55	11.96	7.09	3.30	0.016	0.023
Total Consumption	**33.61**	**8.91**	**1.05**	**0.73**	**24.98**	**21.25**	**12.57**	**5.67**	**0.09**	**0.05**
Production Potential (kg)			8.6	10.3	9.8	9.8	8.5	9.8	23.3	19.7
							Digest	**63.6%**	**Ca:P**	**1.768**

Analysis: Milk production jumps two liters, and the Ca:P ratio moves into optimal range simply by increasing dairy meal and adding a small amount of inexpensive limestone. With these changes, DM intake barely moves, but lactation length would surpass 270 days and the ICI would decrease to around 390 days – significant changes in productivity for minor changes in the ration fed.

Lactating Cow Ration 5 (LCR5): For the last ration, the goal was to maximize productivity without drastically changing the farming system. We accomplished this by formulating a dairy meal that more adequately meets the nutrient shortfall of a Napier based diet. To overcome Nel issues associated with Napier diets for high producing animals, we included maize bran – readily available in the project area. The "KCDMS Dairy Meal[14]" and the inclusion of maize bran represent increases in ration cost, but the improved formulation of the dairy meal allows us to exclude mineral mix, representing a cost savings.

LCR5: KCDMS Dairy Meal, Maize Bran										
	As Fed	**DM**	**CP**	**DP**	**DE**	**ME**	**Nel**	**TDN**	**Ca**	**P**
KCDMS Dairy Meal	4.00	3.73	0.93	0.81	13.91	12.38	7.31	3.15	0.1048	0.0377
Maize Bran	3.00	2.66	0.33	0.20	9.69	7.94	5.68	2.20	0.0085	0.0040
Napier Grass (Young)	22.09	4.35	0.34	0.20	10.53	8.66	5.13	2.39	0.012	0.017
Total Consumption	**29.09**	**10.73**	**1.60**	**1.20**	**34.13**	**28.97**	**18.12**	**7.74**	**0.13**	**0.06**
Production Potential (kg)			14.7	19.6	16.2	16.1	16.0	16.3	35.2	24.3
							Digest	**72.1%**	**Ca:P**	**2.149**

Analysis: Daily milk production nearly doubles to 16 to 19 liters. Furthermore, lactation would increase to a full 300 days, ICI would decrease to around 380 days.

Summary: The impact of feeding practices, summarized in Table 9 below, illustrates the degree of impact on dairy production and productivity that is potentially possible from very modest changes in feeding practices for the same cow. The impact of increased daily milk production is further amplified by increased length of lactation and decreased inter-calving intervals. Those changes are a direct result of increased DM intake and rumen throughput from improved digestibility (51% to 72%) and balanced macro nutrients and minerals.

Table 9: Potential Productivity Gains from Improved Nutrition

Lactating Cow Ration	Dry Matter (DM) Intake (kgs)	Daily Milk Production (liters)	Length of Lactation (days)	Inter-calving Interval (days)
Mature Napier / Maize Stover	6.77	1.5 – 3	160	785
Young Napier	7.87	5.3 – 6.6	190	785
Young Napier / Best Meal	8.35	6.7 – 7.7	200	550
More Best Meal plus Limestone (Ca)	8.91	8.5 – 9.8	270	390
KCDMS Dairy Meal plus Maize Bran	10.73	16+	300	380

2.5 Potential for Reduced Methane Emissions

Methane released from enteric fermentation, primarily of large domestic ruminants, is significant globally,[15] with the highest production of methane per unit of product being found in developing

[14] CP 25%, energy fractions as found in the Best Meal, Ca:P ration of 2.8:1

[15] Henning Steinfeld, Pierre Gerber, Tom Wassenaar, Vincent Castel, Mauricio Roasales, Cees de Haan, 2006, Livestock's Long Shadow: Environmental Issues and Options. FAO. Livestock, Environment and Development Initiative.

countries having poor livestock management practices. As stated in a 2013 FAO report, "Possible interventions to reduce emissions are thus, to a large extent, based on technologies and practices that improve production efficiency at animal and herd levels. They include the use of higher quality feed and ration balancing to lower enteric and manure emissions. Improved breeding and animal health help to shrink the herd overhead (i.e. unproductive part of the herd) and related emissions."[16] Well-nourished, healthy, productive cows emit less ruminant methane per unit of production, decreasing the emissions intensity.

Feed and nutrition directly affect an animal's productivity and health status as well as strongly influencing GHG emissions per unit of product. Low-quality and low-digestibility feeds result in relatively high enteric emissions per unit of meat or milk, particularly in systems with low productivity. Increasing forage digestibility and digestible forage intake will generally reduce GHG emissions from rumen fermentation per unit of animal product and are highly recommended mitigation practices.[17]

Generally, the level of methane production is directly related to the quantity (energy value) and inversely related to the quality (digestibility) of the feed an animal consumes. As the amount of feed consumed increases, the energy available to be converted into methane also increases. However, as the digestibility of the feed increases, the percentage of the energy that is converted to methane decreases. For this reason, methane production is calculated as a percentage of gross energy. In a feed ration that is highly digestible (>70% Total Digestible Nutrients or TDN), approximately 5.5% of the energy would be converted to methane. As the digestibility of a ration decreases, the percentage of energy converted to methane increases to as high as 7.5% (rations with a TDN <50%)[18].

These factors are reflected in the study focus areas. We have calculated annual methane production, annualized milk production, and CH4 emissions intensity for the different combinations of grazing systems and genetics encountered, as shown in Table 10 below. These category averages show methane emissions ranging from 57 to 110 grams per liter. For the entire data set of the survey, the averages ranged from 34 grams to over 300. In comparison, methane emissions per liter of milk produced in North America and Europe average from 15 – 20 grams.

Based on our illustrative rations, the potential impact on methane emissions from improved feeding in Kenya would be significant (Table 11 below). The very poor Basal Mature Napier / Maize Stover ration shows a very high amount of methane (292 grams) emitted for each liter of milk produced.

This is due to the relatively low production levels as a result of poor feeding practices. Simply changing to the Young Napier rations reduces methane emissions by over 50% to 135 grams per liter. Further improvements show the potential to reduce to 20 grams per liter.

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[16] Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G. 2013. Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations (FAO), Rome.

[17] Hristov, A.N., Oh, J., Lee, C., Meinen, R., Montes, F., Ott, T., Firkins, J., Rotz, A., Dell, C., Adesogan, A., Yang, W., Tricarico, J., Kebreab, E., Waghorn, G., Dijkstra, J. & Oosting, S. 2013. Mitigation of greenhouse gas emissions in livestock production – A review of technical options for non-CO2 emissions. Edited by Pierre J. Gerber, Benjamin Henderson and Harinder P.S. Makkar. FAO Animal Production and Health Paper No. 177. FAO, Rome, Italy.

[18] Options for Reducing Methane Emissions Internationally, Volume 1: Technological Options for Reducing Methane Emissions, US Environmental Protection Agency, Washington D.C. Report to Congress. 1993. Pp. 6-1.

Table 10: Methane Emissions by Grazing System/Genetics

Grazing System / Genetics	Annual Methane (kgs)	Annualized Milk Production (liters)	CH4 Emissions/liter (kgs)
Nyanza			
Aa	84.91	1,606	0.057
Ab	64.07	923	0.074
Bb	63.87	795	0.088
Western			
Aa	90.28	1,290	0.083
Ab	61.16	757	0.084
Ba	77.02	952	0.091
Bb	60.75	611	0.110
Eastern			
Aa	94.93	1,587	0.064
Ab	85.47	1,183	0.078
Bb	82.69	1,245	0.075

Table 11: Lactating Cow Ration Methane Emissions

Lactating Cow Ration	Annual Methane (kgs)	Annualized FCM Production (liters)	CH4 Emissions/liter (kgs)
Mature Napier/ Maize Stover	54.26	186	0.292
Young Napier	65.83	486	0.135
Young Napier/Best Meal	68.24	889	0.077
Best Meal + Limestone	74.63	2,148	0.035
KCDMS Meal	90.11	4,611	0.020

In conclusion, there is significant potential for increasing dairy production and productivity, while simultaneously achieving a significant reduction in methane emissions intensity from the adoption of improved feeding practices.

2.6 The Economics of Improved Dairy Nutrition

The economic impact of improved feeding and nutrition on dairy production and productivity is the result of combined changes in the cost of feeding the cows and changes in annual milk production. This analysis is constructed to answer specific questions about the economics of dairy production and productivity.

The first step was to calculate the daily cost of feeding a lactating cow (forage, dairy meal, salt/mineral) during her effective lactation period. These costs were calculated for each illustrative ration described in Section 2.2.1 as detailed in Table 12 below:

Table 12: Estimated Daily Feed Cost for Lactating Cows

Estimated Daily Feed Cost: Lactating Cow									
	Forage		Dairy Meal		Salt/Min		Limestone		Daily Feed
Ration	(kg DM)	KSh/kg	(kg)	KSh/kg	(kg)	KSh/kg	(kg)	KSh/kg	Cost (KSh)
1	2.67	17	2.00	35	0.05	250	0.00	30	**128**
2	6.06	17	2.00	35	0.05	250	0.00	30	**186**
3	6.44	17	2.00	35	0.05	250	0.00	30	**192**
4	6.01	17	3.00	35	0.05	250	0.05	30	**221**
5	4.35	17	7.00	35	0.05	250	0.00	30	**331**

The amount of forage is calculated as the DM equivalent of forage fed. We used data from the feed and fodder value chain assessment[19] to estimate the cost/kg of producing forage for the ration. We used dairy meal and salt/mineral costs gathered during the survey to derive an average dairy meal price of KSh 35/kg and an average salt/mineral mix price of KSh 250/kg. The price of crushed limestone is KSh 30/kg.

Note that dairy meal, salt/mineral supplements and limestone must be purchased by the producer and are therefore cash costs. Forage produced on the farm to feed cows has value, but not an immediate cash cost. We represent that value as a cost/kg for this analysis, understanding that its use is not generally recognized as a real cost by producers. We will refer to this difference throughout the analysis.

We assume that farmers are producing their own forage, which is valued at the cost of production. For Ration 1, we assume a zero cost for maize stover, with the DM amount shown only representing the mature Napier grass portion of the ration.

For Ration 5 we combined the total weight of dairy meal and maize bran in one cost item. We used a price 20% higher than the average price of dairy meal (KSh 42/kg vs. KSh 35/kg) to reflect the possibly higher cost of this premier feed. The combination of 3 kg of maize bran at KSh 25/kg and 4 kg of KCDMS dairy meal at KSh 42/kg resulted in a KSh 35/kg cost for the mixture – the same price as the average price of dairy meal.

Daily feed costs vary from KSh 128/day for Ration 1 to KSh 331/day for Ration 5. However, the daily cost of feeding a dairy cow during lactation is only part of the picture. The full picture requires including the cost of feeding dry cows. Using survey data as the base, we developed three illustrative Dry Cow Rations to complement the five Lactating Cow Rations.

[19] USAID-Kenya Crops and Dairy Market Systems (KCDMS) Feed and Fodder Value Chain Assessment Report, September 2018

Dry Cow Ration 1 complements Lactating Cow Ration 1. It is made up of mature Napier grass and maize stover, supplemented with mineral mix. The amount of Napier grass is increased slightly to substitute for the dairy meal portion of the lactating cow ration.

Dry Cow Ration 1 (DCR1)										
	As Fed	**DM**	**CP**	**DP**	**DE**	**ME**	**NEl**	**TDN**	**Ca**	**P**
Mineral Mix	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0093	0.0064
Napier Grass (Mature)	12.10	3.12	0.15	0.07	5.74	4.71	2.25	1.30	0.012	0.020
Maize Stover (Africa)	3.03	2.67	0.15	0.05	5.71	4.67	2.56	1.29	0.013	0.004
Total Consumption	**15.18**	**5.84**	**0.29**	**0.11**	**11.45**	**9.38**	**4.81**	**2.60**	**0.0337**	**0.0303**
Total Ad. Libidum	15.13	5.79	0.29	0.11	11.45	9.38	4.81	2.60	0.0244	0.0239
Maintenance			0.78	0.28	14.23	11.69	7.90	3.25	0.018	0.014
Excess (deficit)			(0.49)	(0.17)	(2.78)	(2.31)	(3.09)	(0.65)	0.0157	0.0163
								Ca:P	**1.112**	**1**

Analysis: This ration is deficient in all primary nutrients. And, with a Ca:P ratio of 1.1:1 there will be serious problems with reproduction. Dry cows on this type of ration will be slow to become pregnant, and low to replace Ca lost during lactation. These cows will generally perform poorly in terms of daily milk production and length of lactation once the cow calves and begins lactation.

Dry Cow Ration 2 complements Lactating Cow Rations 2 and 3. It consists of a forage diet (young Napier grass) supplemented with mineral mix, and with maize stover removed.

Dry Cow Ration 2 (DCR2)										
	As Fed	**DM**	**CP**	**DP**	**DE**	**ME**	**NEl**	**TDN**	**Ca**	**P**
Mineral Mix	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0093	0.0064
Napier Grass (Young)	35.91	7.07	0.55	0.32	17.12	14.08	8.35	3.88	0.019	0.027
Total Consumption	**35.96**	**7.12**	**0.55**	**0.32**	**17.12**	**14.08**	**8.35**	**3.88**	**0.0284**	**0.0333**
Total Ad. Libidum	35.91	7.07	0.55	0.32	17.12	14.08	8.35	3.88	0.0191	0.0269
Maintenance			0.78	0.28	14.23	11.69	7.90	3.25	0.018	0.014
Excess (deficit)			(0.23)	0.04	2.89	2.39	0.45	0.63	0.0104	0.0193
								Ca:P	**0.854**	**1**

Analysis: This ration remarkably improves the dry cow nutrition. Although Ca is still deficient, the increased availability of DP is much more important. However, with a Ca:P ratio of less than 1.5, the cow will still have reproductive issues, resulting in long inter-calving intervals, and relatively short lactations.

Dry Cow Ration 3 complements Lactating Cow Rations 4 and 5. It consists of a forage diet (young Napier grass) supplemented with mineral mix and limestone (calcium).

Dry Cow Ration 3 (DCR3)										
	As Fed	**DM**	**CP**	**DP**	**DE**	**ME**	**NEl**	**TDN**	**Ca**	**P**
Mineral Mix	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.0093	0.0064
Limestone	0.08	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.0272	0.0000
Napier Grass (Young)	35.11	6.92	0.54	0.31	16.74	13.76	8.16	3.80	0.019	0.026
Total Consumption	**35.24**	**7.04**	**0.54**	**0.31**	**16.74**	**13.76**	**8.16**	**3.80**	**0.0552**	**0.0327**
Total Ad. Libidum	35.11	6.92	0.54	0.31	16.74	13.76	8.16	3.80	0.0187	0.0263
Maintenance			0.78	0.28	14.23	11.69	7.90	3.25	0.018	0.014
Excess (deficit)			(0.24)	0.03	2.51	2.07	0.26	0.55	0.0372	0.0187
								Ca:P	**1.690**	**1**

Analysis: This is very nearly an ideal dry cow ration for Kenya. All nutrients are in proper order, with the exception of CP, and the Ca:P balance is in the required range for peak reproductive efficiency. Because CP is slightly deficient, and DP is just barely sufficient, providing .5 kgs per day of a protein source (Cottonseed Meal, Soybean meal) would be advisable. Additional protein could also be added by feeding two to three kgs of leguminous forage, such as lucerne or desmodium.

We then calculated the daily cost of feeding a dry cow (forage, salt/mineral) during her effective non-lactating period for each ration. These costs ranged from KSh 111/day to KSh 133/day, as summarized in Table 13 below:

Table 13: Estimated Daily Feed Costs for Dry Cows

Estimated Daily Feed Cost for Dry Cows									
	Forage		**Dairy Meal**		**Salt/Min**		**Limestone**		**Daily Feed**
Ration	**(kg DM)**	**KSh/kg**	**(kg)**	**KSh/kg**	**(kg)**	**KSh/kg**	**(kg)**	**KSh/kg**	**Cost (KSh)**
1	5.79	17	0.00	35	0.05	250	0.00	30	**111**
2	7.07	17	0.00	35	0.05	250	0.00	30	**133**
3	7.07	17	0.00	35	0.05	250	0.00	30	**133**
4	6.92	17	0.00	35	0.05	250	0.07	30	**132**
5	6.92	17	0.00	35	0.05	250	0.07	30	**132**

The daily feed cost for a lactating cow was multiplied by the annualized number of days milked in a year, and the daily feed cost for a dry cow by the annualized number of days not in lactation during the year, deriving total annual feed costs/cow as reflected in Table 14 below.

Table 14: Economics of Improved Dairy Nutrition

Estimated Break-Even Milk Price								
Ration	Annualized Feed Costs				Total	Annualized		Breakeven
	Lactating Cow		Dry Cow		Feed Cost	Milk Production		Milk Price
	KSh/day	# Days	KSh/day	# Days	per Year	ltrs/day	ltrs/year	(KSh/liter)
1	128	74	111	291	41,744	2.5	185	**226**
2	186	88	133	277	53,081	5.5	484	**110**
3	192	133	133	232	56,317	6.7	891	**63**
4	221	253	132	112	70,767	8.5	2,151	**33**
5	331	288	132	77	105,640	16	4,608	**23**

Total annualized feed costs per cow ranged from KSh 41,744 for Ration 1 to KSh 105,640 for LCR 5. The total annualized feed costs were divided by the annualized milk production for each ration to derive the ***break-even price*** needed to cover the costs of feeding the cow. Break-even prices ranged from KSh 226/liter for LCR1 to KSh 23/liter for LCR5.

Table 15: Annual Income/Loss per Cow

Lactating Cow Ration	Daily Milk Production (liters)	Total Annual Feed Cost (KSh)	Total Annual Income from Milk Sales	Profit/Loss per Cow (KSh)
Mature Napier/ Maize Stover	2.5	41,744	7,400	**-34,344**
Young Napier	5.5	53,081	19,360	**-33,721**
Best Meal	6.7	56,317	35,644	**-20,673**
+ Limestone	8.5	70,767	86,020	15,253
KCDMS Meal	16+	105,640	184,320	78,680

Note: Total Annual Income was calculated using a milk price of KSh 50/liter which is the average milk price in the regions of the study.

Analysis: It is tempting for smallholder producers to increase income by managing the cost of feed for a lactating dairy cow and comparing it with the amount and value of milk the cow produces. However, this approach leaves out the dry cow part of the picture. A more accurate view accounts for the total value of forage fed to the cows and specifically includes the value of feed provided to dry cows. Accounting for these two factors gives a much different perspective (Table 15 above).

This analysis reflects the complex challenges to increasing diary production and productivity. Farmers are generally very aware of the cash required to improve feeding. In fact, almost all the farmers we surveyed feed dairy meal and salt/mineral supplement. But they do not perceive the true cost of producing milk because the value of forage fed is spread across the entire year.

For example:

- The ration combination with the lowest annualized cost of feeding (KSh 41,744) has the highest break-even price (KSh 226/liter).

- The ration combination with the highest annualized cost of feeding (KSh 105,640) has the lowest break-even price (KSh 23/liter).

Understanding this analysis is complicated by the difference between actual cash costs and the value of fodder. As noted previously, producers are very aware of the cost of purchasing dairy meal, salt/mineral supplements and limestone. But they generally do not recognize the value of the fodder which they raise and feed as a real cost. Therefore, producers tend to have little idea of the actual costs involved in feeding their dairy cows.

With that qualification in mind, consider the practical dynamics of improving nutrition and moving up the scale from one ration to another:

- ***LCR1:*** A producer at this level is operating at less than subsistence. They are generating some milk for family use, and some for cash income. But a production level of 2.5 liters of milk/day barely covers the KES. 128/day cost of feed during lactation.
- ***LCR2:*** A farmer producing enough forage for this ration (.5 ha) can improve milk production to 5.5 liters/day and extend lactation from 160 to 190 days. This generates enough income to cover the KES. 186/day cost of feed during lactation, but not enough to cover dry cow feeding costs.
- ***LCR3:*** A producer who feeds a higher quality dairy meal than the KEBS standard will also feed 2 kg more forage (increased throughput), improve production to 6.7 liters/day for a 200-day lactation period, and shorten the inter-calving interval by 235 days. The big impact is in having fewer non-productive days of feeding. Feed costs during lactation increase to KES. 192/day and cash income nearly double. Income still does not cover the KES. 56,317 annualized cost of feeding the cow. But this producer is approaching profitability.
- ***LCR4:*** The threshold to profitability is crossed with one small dietary change – adding supplemental calcium to the ration. This increases milk production to 8.5 liters/day, extends lactation dramatically to 270 days, and reduces the inter-calving interval to 390 days. Annual feed costs increase by 25%, but cash income more than doubles – enough to cover feed costs with KES. 15,000+ remaining for other expenses. This individual is no longer a farmer who owns dairy cattle, but a dairy farmer.
- ***LCR5:*** Producers that cross the profitability threshold and are ready to make the move to higher level production. This means feeding 7 kg per day of custom dairy meal and maize bran, with production increasing to 16 liters/day for a 300-day lactation period. Annual feed costs increase by 50%, but income more than doubles as profits increased fivefold.

2.7 Questions: The following are answers to specific question arising from the analysis:

- **What is the area of forage grass (napier, brachiaria, Boma Rhodes) needed to feed a cow for a year?**

  A producer needs ***.45 hectares of Napier***, ***.37 hectares of Boma Rhodes***, or ***.29 hectares of brachiaria*** to feed a dairy cow for one year. This calculation is based on the amount of forage needed in the illustrative rations, and forage yields as reported in the feed and fodder value chain assessment.

- **What are the "break even" production parameters for a smallholder dairy operation?**

  Dairy cows need to produce an average of ***8.5 liters of milk/day*** for a ***270-day lactation period*** and have an ***inter-calving interval of 390*** days to cross the

profitability threshold. (DCR4). ***Note:*** *there is no reason that a cow fed LCR4 cannot achieve these parameters.*

The smallholder parameters for high producing dairy cows are ***16 liters of milk/day*** for a ***300-day lactation*** and an ***inter-calving interval of 380*** days. (LCR5).

- **What is the "break-even" milk price for a smallholder producer?**

  The break-even price for a smallholder producer dairy cow with Ration 4 production parameters is ***KSh 33/liter***.

  The break-even price for a smallholder producer dairy cow with the Ration 5 production parameters described above is ***KSh 23/liter***.

- **What does it cost to improve nutrition and increase milk production?**

  The estimated annualized cost of feeding a dairy cow with Ration 4 production parameters is ***KSh 70,767***.

  The estimated annualized cost of feeding a dairy cow with Ration 5 production parameters is ***KSh 105,640***.

- **What is the benefit of improving nutrition and increasing production?**

  The estimated annualized income from a smallholder dairy cow with Ration 4 production parameters is ***KSh 86,020***.

  The estimated annualized income from a smallholder dairy cow with Ration 5 production parameters is ***KSh 184,320.***

- **How profitable is it for a smallholder producer to milk one or two cows?**

  A smallholder farmer with two milk cows at Ration 4 production parameters would have a net surplus (annual income minus the cost of feed) of ***KSh 30,506.***

  A smallholder farmer with two milk cows at Ration 4 production parameters would have a net surplus (annual income minus the cost of feed) of ***KSh 157,360.***

In summary, a smallholder farmer with cows producing an average of less than 8 liters/day/of milk is operating at a subsistence level and is not being compensated for growing and collecting the fodder needed to feed his/her cows. The scale of the loss is masked by the steady stream of income from milk sales, and the "hidden costs" of feeding dry cows during extended inter-calving intervals. Producers at lower levels of production feel the economic squeeze without understanding what is happening. At these levels, a producer would be better off selling his/her cows and producing fodder for sale. An economically viable operation is one where the producer makes the nutritional changes needed for his/her cows to produce an average of 8.5 liters of milk, extend lactation to 270 days, and decrease the inter-calving interval to 390 days.

2.7 What the Local Feed Industry Can Do to Mitigate Constraints

There are a variety of issues facing the Kenyan feed industry. Most are inter-related and will need to be addressed for the country's dairy sector to improve production and productivity. There is also a key structural issue with the forage and fodder value chain which requires attention. The major issues that the study found are as follows:

The Kenyan dairy industry does not have access to the tools and information needed to improve dairy nutrition, production and productivity. A standard component of producing concentrate feedstuffs for dairy production is ascertaining the nutrient profile of the raw materials used, and check testing of the finished product.

Raw material testing provides the manufacturer with a full nutrient profile of the material to be used so that the efficacy of the feedstuff and its value relative to comparable alternatives can be determined. Concentrate feeds, in this case dairy meal, are then manufactured based on formulations developed to provide a specific set of nutrients based on the needs of the target animal. End-product testing is used to verify that the finished product conforms to the set formulation in providing the quantity and quality of nutrients desired.

Private laboratories are available in Kenya to test using NIR (Near-Infrared Spectrophotometry). NIR is widely used in the feed industry and very effective for testing forages. But it is woefully inaccurate when used to test formulated feeds. In addition, the prices charged are far too expensive ($100-$120/sample) for regular sampling and testing of raw material and products. What is needed for accurate nutrient assessment is Wet Chem Analysis (WCA). This procedure, which is fairly common in other countries, is not commercially available in Kenya. Some of the larger feed mills send samples to Europe for testing, but the vast majority of medium and small mills have no such option. These feed millers are using guess work to ascertain the nutrient value of ingredients and their contribution to a finished product. Without access to reliable testing as a quality control measure, concentrate feeds are poorly formulated, not balanced, and often contain shortfalls of significant nutrients.

A clear example of the problems arising from the unavailability of proper testing is illustrated in Table 16 below. The Kenya Bureau of Standards (KEBS) Dairy Meal Supplement Specifications prescribe a standard for both "standard" and "high quality" dairy meal. Kenyan feed mills that produce dairy meal are required to meet the KEBS standard in order to market their product. To determine how well the industry was meeting this goal we collected samples of Kenyan dairy meal and had them analyzed at a commercial testing facility in the U.S. This laboratory[20] is an ISO certified facility, and processes feed samples from the Western part of the U.S. As shown below, out of 15 dairy meal samples we gathered and tested, only three met the KEBS minimum dairy meal standards for both protein and energy content.

[20] Soiltest Inc. Moses Lake, Washington

Table 16: Nutrient Profiles of Kenyan Dairy Meals[21]

ID#	DM	CP	DP	DE	ME	NEM	NEL	TDN	Ca	P
Standard Dairy Meal										
1	91.9%	21.5%	17.1%	3.69	3.28	2.72	1.93	83.7%	1.56%	0.72%
2	91.9%	15.0%	10.6%	3.68	3.26	2.71	1.93	83.4%	0.92%	0.79%
3	93.5%	16.6%	12.2%	3.60	3.19	2.64	1.89	81.7%	4.48%	0.83%
4	92.3%	11.5%	7.1%	3.47	3.05	2.53	1.81	78.7%	2.81%	1.01%
5	93.9%	14.2%	9.8%	3.45	3.03	2.51	1.80	78.2%	1.97%	0.84%
6	94.5%	12.3%	7.9%	3.35	2.93	2.43	1.75	76.0%	6.44%	0.68%
7	92.7%	13.1%	8.7%	3.28	2.87	2.37	1.71	74.5%	2.12%	0.95%
8	94.0%	20.2%	15.8%	3.26	2.84	2.35	1.69	73.9%	1.85%	0.86%
9	93.3%	14.3%	9.9%	3.17	2.76	2.28	1.65	72.0%	1.30%	0.91%
KEBS	88.0%	15.9%	11.5%	3.57	3.12	2.58	1.86	74.0%	0.700%	0.400%
ID#	**DM**	**CP**	**DP**	**DE**	**ME**	**NEM**	**NEL**	**TDN**	**Ca**	**P**
High Yield Dairy Meal										
10	93.2%	20.7%	16.3%	3.73	3.32	2.75	1.96	84.6%	1.54%	0.71%
11	92.0%	14.8%	10.4%	3.58	3.17	2.63	1.88	81.3%	0.91%	0.63%
12	92.4%	10.8%	6.4%	3.40	2.98	2.47	1.77	77.1%	1.24%	0.95%
13	93.4%	17.3%	12.9%	3.36	2.94	2.43	1.75	76.1%	1.83%	0.85%
14	93.8%	19.1%	14.7%	3.33	2.91	2.41	1.73	75.5%	4.01%	0.82%
15	93.5%	15.7%	11.3%	3.17	2.75	2.27	1.64	71.9%	1.56%	0.98%
KEBS	88.0%	19.3%	11.5%	3.57	3.12	2.58	1.86	74.0%	0.700%	0.400%

The lack of testing facilities is the number one issue facing the feed industry in Kenya. Until feed manufacturers can regularly test raw material and analyze finished products, it will be extremely difficult for the industry, and the dairy farmers they serve, to increase productivity.

The overall purpose of dairy meal standards is regulatory, not supportive. The KEBS standards are too prescriptive to be practical and are not enforced in a way that encourages the feed industry to adapt to changing needs or innovate and develop new products for Kenyan conditions. As a result, the regulatory structure is not as conducive as it should be in terms of creating an enabling environment for dairy sector development. Work needs to be done to transform feed sector policy to allow for more industry participation in setting the standards and certifying compliance.

[21] For this table DM is listed on a % basis, CP, DP, TDN, Ca and P are listed on a %DM basis. DE, ME and NEL are listed on a Mcals/kg DM basis.

Kenya Bureau of Standards (KEBS) standards for dairy meal need to be updated. The KEBS standard was developed based on nutrition knowledge and practices in North America and Europe dating from the 1960's and 1970's. It has been updated and confirmed, most recently in 2013. But its nutrient profiling is still outdated, and its applicability to Kenyan conditions, questionable. Basal rations based on tropical climate forages are far different from those found in temperate climates. Tropical forages generally have lower levels of macro-nutrients and digestibility. In addition, the quality of the tropical nutrients, primarily the energy fraction, is very different from common temperate basal rations. As a result, dairy meals formulated to the KEBS standard appear only marginally effective as a supplement for the observed basal rations, and those that do not meet the Standard yield even poorer results. An alarming factor in the standard is that it allows meat and bone meal to be used in formulating dairy meal. It is well known and documented that using meat and bone meal (MBM) as a feed additive is responsible for the spread of bovine spongiform encephalopathy (BSE). Therefore, the use of MBM in ruminant rations is illegal in nearly every country in the world. The KEBS standard should be reviewed and updated based on modern nutrition management and the basal rations fed in the country. Also, the KEBS standard should be expanded to include standards for both seasonal and productive differences.

Feed industry needs to provide producers with access to the information needed to improve dairy nutrition, production and productivity. Although quite common in other countries, dairy meal is not labeled regarding contents (ingredients) and nutrient profile, or with relevant instructions for usage. All that is known is that the dairy meal must be roughly equivalent to the KEBS standard. The only recommendations for usage that are available appear to be antidotal or word of mouth, mainly through the feed retailers. There is no documented evidence to back it up the recommendations, and no advice on calibrating usage based on the weight of the animal being fed. Given the broad range of cow weights that exist, this last item is very important information for the producers. Therefore, the contents, nutrition profile and correct application of Kenyan dairy meals and supplements is unavailable to producers. At best, it could be assumed to conform to the KEBS standard, but that Standard is copyrighted material, and not available to the public without payment. Feeding recommendations are often ignored, and commonly used recommendations are almost uniformly ineffective in supporting increased dairy production and productivity. As part of policy and practical recommendations to the feed industry, KCDMS should lobby for making the Standard freely available to the public and promote a "feed tag" policy to mitigate the issue of lack of product knowledge available to the end user.

Forage value chain participants focus on the agronomic aspects of improved forages but completely ignore the nutritive aspects. There are a variety of private and public forage improvement efforts underway in Kenya. New forage varieties are being promoted, improved seeds and planting material imported from other countries, and information widely disseminated. However, nearly all the efforts related to forage improvement focus on the agronomic aspects of forage production. There is quite a bit of information available on how to grow different forages, costs of production, and yield potential. But there is very little information available regarding the nutrient profiles or optimal harvest stage for these new forage varieties, and how they can best be used to improve dairy production. For producers to incorporate new varieties of forage into their production system, they need to fully understand the nutrient profile of the crop and how to insure optimal nutrient supply through timely harvesting. KCDMS should make a concerted effort to work with the various forage value chain participants to develop and disseminate this information,

Salt/mineral supplements in the Kenya market are formulated for temperate climates. There is a broad array of salt and mineral formulations available in the Kenyan market, with a wide variety of formulations (see Annex 4). Moreover, the use of supplements is common, with 85% of surveyed producers using some type of salt/mineral supplement.

This is good, because the macro mineral content and balance of the basal rations is poor and severely constrains milk production and reproductive efficiency. However, most of the products available are formulated for temperate climate dairy production. As a result, they are largely inadequate to balance the macro mineral needs of tropical dairy cattle – especially with regard to the balance of calcium and phosphorus in the diet. Additionally, there are even some products being used by a substantial number of producers (34%) that are detrimental (due to high phosphorus content) to the macro mineral situation and exacerbate the already poor balance. Nevertheless, there are several available products which would work well in the observed basal rations. Presumably, KCDMS cannot recommend a specific company's products, but the project should find a way to disseminate basic information regarding the type of formulations that will work best with the basal rations observed. Depending on the basal ration fed, mineral mixes fed should have a Ca:P ratio of at least 2.5:1 and possible as high as 3.0:1.

3. RECOMMENDATIONS

We conclude that there is tremendous potential to significantly increase dairy production and productivity in the KCDMS focus areas. In our opinion, it is possible to increase annual milk production of producers in these areas by two to four times the amount that we observed in the study. The nutritional obstacles to exploiting this potential are significant but can be overcome with focused efforts.

The main obstacles on the producer side are a lack of knowledge of proper dairy management practices, poor forage crop management, imbalanced basal rations in both macro nutrients and macro minerals, and an overall lack of proper dairy nutrition knowledge and practices. Industry issues are the inability to properly determine the nutrient content of raw materials and finished products, poor understanding of the nutrient requirements of animals being fed, and a general lack of practical information and instructions for product use. Revisions to GOK feed policies are also needed to overcome producer and industry obstacles and modernize the sector, especially with regard to feed standards and regulatory systems.

The approach to overcoming these obstacles must focus on nutrition. On the operational side, what nutrients are deficient and why? Is it a lack of producer understanding of nutrition and proper feeding practices? Is it issues with forage availability? Is it inappropriate use of (or poor-quality) supplements? Designing solutions requires a clear understanding of what is causing the problem. This "nutrient centric" view needs to be the foundation of all efforts to improve dairy production and productivity.

This section outlines our specific recommendations for overcoming the present barriers to increased productivity and enabling dairy producers in the KCDMS focus areas to transition from subsistence dairy activities into full commercial dairy production.

3.1 Dairy Value Chain Producer Needs: The following is a summary of recommended interventions at the producer level to support increased dairy production and productivity:

3.1.1. Extensive training in basic dairy/nutrition management: To overcome the fundamental lack of practical dairy nutrition and management skills in the KCDMS areas, it is essential that extension personnel and producers be trained in basic feeding and nutrition principles and applications. ***We recommend an extensive ruminant nutrition training program*** focused on developing private sector nutrition advisors. The program should include development of appropriate extension materials, training of trainers, and multi-media advertisements. The program will focus on addressing the basic shortcomings noted in the General Findings section to help individual producers make the transition from subsistence dairy activities to commercial dairy production.

3.1.2. Encourage better forage utilization and basal rations: Several programs are underway in Kenya to increase forage availability and introduce improved forage varieties. However, these efforts are unlikely to succeed if producers do not learn to use their forage resources properly. To apply their training, producers need better information and advice on the nutrient profile of different forages, harvesting practices to ensure quality and nutritional value, feeding forage mixes (grass/legumes), and supplying the total quantity of feed their animals need. ***We recommend a comprehensive forage and basal ration information program*** to compile and disseminate available information on the nutrient content of forages, yields and optimal nutritional value, as well as the costs and benefits for common forages encountered during this study. This data should be readily available from research organizations, universities and private sector entities.

3.1.3. Access to improved dairy meal formulations: Producers who are feeding better quality basal rations can make the best use of supplements specifically formulated to mitigate nutrient shortfalls and increase productivity. ***We recommend providing producers with nutritional information on available dairy meals, and recommendations on the amounts to feed based on the size of their animals.*** This will encourage development of improved formulations, and of separate feed formulations based on basal ration and season.

For example, producers feeding 300kg cows young Napier grass or young Napier grass with Green Desmodium will require formulations with dry matter nutrient profiles[22] as represented in Table 17:

Table 17: Example Dairy Meal Nutrient Profiles (%DM)

	Dairy Meal Nutrient Profile				
Lactating Cow Basal Rations	**CP**	**ME**	**Nel**	**Ca**	**P**
Napier Grass	22%	3.32	1.96	1.75%	0.70%
Napier & Desmodium	21%	3.32	2.25	1.40%	0.70%
	Dairy Meal Nutrient Profile				
Dry Cow Basal Rations	**CP**	**ME**	**Nel**	**Ca**	**P**
Napier Grass	18%	3.00	1.80	1.75%	0.70%
Napier & Desmodium	17%	3.00	1.80	1.40%	0.70%

Producers feeding other basal rations will require different formulations tailored to their situation, which shows the importance of helping feed mill operators work with their producer customers to determine the best ration formulations for their specific conditions.

3.1.4. Use of appropriate mineral supplements: Most salt and mineral supplements available in Kenya are less than adequate for producers in the KCDMS areas. The bulk of these products are not formulated based on tropical feeding requirements and are inadequate to balance Kenyan macro-mineral requirements. There are a few products available in Kenya that can be usefully fed, but lack of producer knowledge and general availability are obstacles to their widespread adoption. Producers need nutritional guidance on how best to use these products. For example, depending on the basal ration fed, mineral mixes fed should have a Ca:P ratio of at least 2.5:1 and possible as high as 3.0:1.

[22] ME and Nel as Mcals/Kg

We recommend fully defining and mapping macro mineral deficiencies in the basal rations in the various areas. With this information implementers can identify appropriate mineral supplements, develop recommendations, and undertake outreach efforts to inform producers of appropriate use**.**

3.1.5. Access to nutrition advice: Dairy farmers need access to professional advice and counsel on animal nutrition and feeding to make the best possible use of the resources at their disposal to increase production and productivity. There appears to be a scarcity of ruminant nutrition professionals in Kenya with the practical knowledge of on-farm feeding practices and nutritional needs to fill this need.

We recommend actions to develop a corps of field nutritionists trained in proper dairy nutrition management to advise farmers.

3.2 Feed and Forage Value Chain Supplier Needs: The following is a summary of the recommended interventions at the industry level to support increased dairy production and productivity:

3.2.1. Access to information on nutrient content: Formulation of more effective dairy meals and supplements starts with the quality of the raw materials. Feed mills need access to better information on the nutrient profile of their raw materials and the ability to randomly test their finished product. As noted in Section 2.3, the lack of feedstuff testing facilities is the number one issue facing the feed industry in Kenya. Until feed manufacturers are able to regularly test raw materials and analyze finished products, it will be extremely difficult for the industry, and the dairy farmers they serve, to increase productivity. The equipment and skills needed to perform WCA of feedstuffs is fairly common, and there may very well be a number of commercial laboratories in Kenya that could conduct feedstuff analysis. ***We recommend an assessment of commercial laboratory capacity in Kenya to identify what is needed to make available the needed analytical services required by the industry.*** The assessment will inform development of interventions to make those services widely available.

3.2.2. Access to nutrition advice: The present system in Kenya which produces only two general types of dairy meal is seriously hampering the development of better on-farm animal nutrition. Feed mills need access to professional advice and counsel on the variation of nutritional needs, ranging from the different classes of animals (lactating, dry, heifer, calf) to know how best to meet those needs. Advice is needed on the proper use of nutrient profiles in formulating appropriate feeds for local conditions. Feed processors also need advice on adjusting their formulations depending upon material availability and cost, while maintaining quality, and the use of appropriate manufacturing techniques. ***We recommend expanding the previous recommendation (#7. above) to develop a corps of field nutritionists trained in proper dairy nutrition management to include professionals that can advise feed mills as well.***

3.2.3. Increase access to information on the nutritional status of client dairy animals: The effectiveness of dairy meals, supplements and improved forages is founded on an understanding of the nutrient needs of the animals at the farm level, and physical factors impacting recommended use (genetics, size, etc.). This study found serious nutrient deficiencies among dairy producers in the KCDMS areas. Suppliers in the feed and forage value chain need to be made aware of the nutritional deficiencies faced by producers, and the farm level need for dairy meals, supplements and forages designed to meet those needs. ***We recommend developing a program to compile and disseminate information on***

dairy cattle nutritional needs to suppliers to help them develop products to meet those needs.

3.2.4. Publicize nutritional guidelines for improved forages: A range of forage improvement activities in Kenya are either underway or in the planning stages. The effectiveness of those efforts is largely dependent upon the effective use of the forage produced, based on their nutritional profiles. ***We recommend a comprehensive industry program to compile information on nutrient content, dry matter production and digestibility, and the costs and benefits of new forage varieties***. This information would then be disseminated by the forage suppliers to inform dairy producers' selection of new forages that best fit their production system.

3.2.5. Support a program of demonstrative feeding trials: Even with the best supplement formulation and forage use data, dairy producers must be convinced of the benefits of using a product to make the effort to incorporate it into their operations. Traditional marketing approaches (radio, print ads, extension materials, etc.) help build awareness, but are not enough to convince producers to try new products. Feed and forage demonstrations at the farm level do more to convince producers of the benefits of new products and practices than any advertising could ever accomplish. ***We recommend working with producer cooperatives and locally based feed/forage suppliers to establish short term feeding trials that demonstrate the effectiveness of the new inputs over the current basal rations***.

3.3 Regulatory Issues: The following is a summary of the recommended activities to address policy and regulatory issues in support of increased dairy production and productivity.

3.3.1. Review, revise and update industry regulation. The KEBS standard for Dairy cattle feed supplements does not reflect the realities of dairy nutrition in Kenya. Limited to only two feeds, it does not encourage improved nutrition or new product innovation, or support increased dairy production and productivity. Simply put, there is no benefit to having KEBS set required nutrient profiles of feeds for dairy producers. They are not able to understand what is needed at the farm level. And, no single ration formulation can mitigate nutritional issues for the entire industry. (There is no such thing as one size fits all). Lastly, it is not easily available to the public, as it is copyrighted material. ***We strongly recommend a comprehensive review and reconsideration of the standard, seeking a new regulatory framework for the industry.*** Specifically, this framework would:

a. **Set minimum nutrient profile requirements:** The new framework would specify the minimum nutrient requirements for products to be marketed as dairy meal and/or supplements. They would focus on meeting the basic nutrient requirements of the animal class in question, allowing and encouraging manufacturers to exceed those standards without penalty.

b. **Specify unallowable ingredients:** A crucial role of the new system is to specify what raw materials cannot be included in dairy feeds (for example, blood and bone meal) with reference to international regulations.

c. **Set upper limits:** As is currently done, the new system would set upper limits for the presence of certain elements (aflatoxin, non-protein nitrogen, etc.)

d. **Require a labeling system:** This new system would establish norms for labeling products and specify the information to be included on labels to inform producers and help them balance their on-farm rations. These feed tags, attached to every package

of dairy meal and feed supplements, would contain a list of ingredients, nutrient profile, and instructions for use calibrated by animal size.

e. **Approve and support third party certification system for the industry:** As the final step in modernizing the Kenyan feed industry, we recommend that a system be established whereby third-party certification can be recognized as an alternative means of certifying dairy meals and supplements. Experience in many other countries has shown that this approach provides proper oversight, leads to innovation, and makes the feed industry more responsive to their customer base.

We suggest an approach which starts with establishing a broadly-based committee of industry stakeholders, supported by experts in nutrition and feeding. This committee would discuss and set basic minimum requirements for a variety of feeds and supplements (dairy meals, lactating cow products, dry cow products, heifer products, calf grower, etc.) to replace the existing standard. The committee would consult reference materials, including existing standards from other tropical countries (from Africa, Asia and Latin America) to carry out its task and produce an initial draft. That draft should be made available to the public for comment, as it is developed, before being formalized. Once formalized, the set of standards should be made readily available for public use.

4. CONCLUSION

There is significant potential for increasing smallholder dairy production and productivity in the focus areas, and increasing producer income, while simultaneously achieving a significant reduction in methane emissions intensity by adopting of improved feeding practices. Actions in support of improved practices will only be successful if they encourage producers to make the nutritional changes needed for their cows to produce an average of 8.5 liters of milk, extend lactation to 270 days, and decrease the inter-calving interval to 390 days. Achieving that goal will require an integrated approach to improving basal nutrition at the producer level by making available more appropriate forages and feed/supplement formulations to mitigate nutritional issues, as well as modernizing the regulatory framework for the feed industry.

5. ANNEXES

Annex 1: Raw Dataset

Farm Number	Interview Date	County	Con	Gen	Adult Cows	Currently Dry	Currently Lactating	Daily Liters Milk	Days in Lactation	Months at First calf	Days ICI
1	04/02/19	Migori	B	b	2	0	2	4.0	270	20	427
3	04/02/19	Migori	B	b	2	0	2	5.5	270	48	549
4	04/02/19	Migori	B	b	3	0	3	6.0	240		440
5	04/02/19	Migori	B	b	1	0	1	3.3	210	29	458
6	04/02/19	Migori	B	b	3	1	2	5.3	180	36	580
7	04/02/19	Migori	B	b	4	1	3	4.3	165	30	427
8	04/02/19	Migori	B	b	2	1	1	6.4	150	42	488
10	04/02/19	Migori	B	b	2	1	1	5.0	180	48	519
11	04/02/19	Migori	B	b	2	1	1	7.0	150	28	549
12	04/02/19	Migori	B	b	1	0	1	4.8	105	30	458
13	04/02/19	Migori	B	b	1	0	1	4.5	210	30	458
15	04/03/19	Homabay	B	b	4	2	2	5.0	195	31	491
16	04/03/19	Homabay	A	a	2	0	2	9.5	300	25	574
17	04/03/19	Homabay	B	b	2	0	2	5.0	270	26	503
18	04/03/19	Homabay	B	b	2	0	2	9.0	180	29	1,065
19	04/03/19	Homabay	B	b	3	1	2	4.5	210		549
20	04/03/19	Homabay	B	b	4	1	3	7.0	280	27	549
21	04/03/19	Homabay	B	b	2	0	2	9.0	300	28	519
22	04/04/19	Kisumu	B	b	3	1	2	9.0	255		579
23	04/04/19	Kisumu	A	b	5	3	2	5.0	180	28	458
24	04/04/19	Kisumu	A	a	2	1	1	12.5	300	25	427
25	04/04/19	Kisumu	A	a	3	0	3	10.0	214	27	562
26	04/04/19	Kisumu	A	a	5	3	2	12.0	214		562
27	04/04/19	Kisumu	B	b	3	0	3	9.3	270	34	832
28	03/04/19	Kisii	B	a	2	0	2	11.0	180	27	455
29	03/04/19	Kisii	B	b	4	0	4	6.4	165	22	549
30	03/04/19	Kisii	B	b	2	0	2	7.5	180	24	669
31	03/04/19	Kisii	A	b	2	0	2	8.8	240	27	739
32	03/04/19	Kisii	B	b	2	1	1	7.0	208		579
33	03/04/19	Kisii	B	b	2	0	2	3.8	180	24	608
34	03/04/19	Kisii	B	b	1	0	1	8.5	208	34	579
35	04/04/19	Kisii	A	a	3	2	1	8.0	165	27	549

Farm Number	Interview Date	County	Con	Gen	Adult Cows	Currently Dry	Currently Lactating	Daily Liters Milk	Days in Lactation	Months at First calf	Days ICI
36	04/04/19	Kisii	A	a	2	0	2	11.5	210	26	699
37	04/04/19	Siaya	A	b	1	0	1	9.0	210	30	456
38	04/04/19	Siaya	A	b	3	0	3	7.0	180	27	731
39	04/04/19	Siaya	B	b	3	3	0	5.2	180	33	989
40	04/04/19	Siaya	B	b	2	1	1	5.0	150	27	458
41	02/04/19	Vihiga	B	b	2	0	2	8.0	150	30	668
42	02/04/19	Vihiga	A	b	7	1	6	10.0	270	48	1,065
43	02/04/19	Vihiga	A	a	4	0	4	6.4	270	27	641
44	02/04/19	Vihiga	A	a	2	0	2	7.0	225		732
Farm Number	Interview Date	County	Con	Gen	Adult Cows	Currently Dry	Currently Lactating	Daily Liters Milk	Days in Lactation	Months at First calf	Days ICI
45	02/04/19	Vihiga	A	a	8	0	8	8.0	300	33	663
46	03/04/19	Bungoma	B	b	2	1	1	5.5	195	36	547
48	03/04/19	Bungoma	A	b	3	2	1	5.0	240	33	635
49	03/04/19	Bungoma	B	b	2	0	2	5.5	240	44	427
50	03/04/19	Bungoma	B	b	3	0	3	5.0	180		1,204
51	03/04/19	Bungoma	B	b	3	1	2	7.0	150	48	565
52	03/04/19	Bungoma	B	b	4	1	3	8.8	150	24	557
53	03/04/19	Bungoma	B	b	12	6	6	5.0	180	29	472
54	04/04/19	Bungoma	B	b	2	0	2	4.5	180		427
55	04/04/19	Bungoma	B	b	2	1	1	5.0	180	31	662
56	04/04/19	Bungoma	B	b	3	1	2	5.0	180	30	685
57	04/04/19	Bungoma	B	b	3	2	1	6.0	180	31	549
58	04/04/19	Bungoma	A	b	10	2	8	6.4	270		731
59	04/04/19	Bungoma	B	b	2	0	2	5.3	200		1,007
60	04/04/19	Bungoma	B	b	5	0	5	3.0	190	31	880
61	04/04/19	Bungoma	B	b	3	1	2	6.0	188	26	670
62	04/04/19	Bungoma	A	b	2	0	2	7.0	200		641
63	04/04/19	Bungoma	B	b	3	2	1	3.5	160		580
64	04/04/19	Bungoma	A	a	3	2	1	7.3	270		671
65	04/04/19	Bungoma	B	b	5	1	4	4.6	195		580
66	02/04/19	Kakamega	B	b	2	1	1	9.0	190	30	458
67	02/04/19	Kakamega	B	a	2	1	1	11.8	240	24	771
68	03/04/19	Kakamega	A	a	3	1	2	8.3	188		793
69	03/04/19	Kakamega	B	b	2	1	1	12.0	176		702

Farm Number	Interview Date	County	Con	Gen	Adult Cows	Currently Dry	Currently Lactating	Daily Liters Milk	Days in Lactation	Months at First calf	Days ICI
70	04/04/19	Bungoma	B	a	8	3	5	6.2	190		722
71	04/04/19	Bungoma	B	b	2	0	2	5.0	165		458
72	04/04/19	Bungoma	B	b	3	0	3	3.0	165	48	503
73	04/04/19	Bungoma	A	b	2	0	2	4.0	210	48	488
74	04/04/19	Bungoma	A	a	3	0	3	10.5	210	33	442
75	02/04/19	Kakamega	A	a	5	3	2	14.5	300	25	395
76	02/04/19	Kakamega	B	b	4	2	2	4.5	183	36	427
77	04/04/19	Bungoma	A	b	4	3	1	10.0	180		1,105
78	03/04/19	Kakamega	A	a	2	0	2	8.5	228	26	619
79	03/04/19	Kakamega	B	a	12	4	8	4.6	180	30	604
80	02/04/19	Kakamega	B	a	3	1	2	9.0	240	28	471
81	04/11/19	Taita Taveta	A	a	3	1	2	12.0	300	27	437
82	04/11/19	Taita Taveta	A	a	3	1	2	10.0	210	27	397
83	04/11/19	Taita Taveta	A	a	2	0	2	10.0	180		541
84	04/11/19	Taita Taveta	A	a	2	0	2	10.0	165	28	488
85	11/04/19	Taita Taveta	A	a	2	0	2	11.0	300	28	488
86	10/04/19	Taita Taveta	A	a	2	0	2	3.8	195	33	493
Farm Number	Interview Date	County	Con	Gen	Adult Cows	Currently Dry	Currently Lactating	Daily Liters Milk	Days in Lactation	Months at First calf	
87	10/04/19	Taita Taveta	A	a	3	0	3	10.0	165	27	747
88	10/04/19	Taita Taveta	A	b	2	0	2	6.0	200	39	641
89	10/04/19	Taita Taveta	A	b	2	0	2	5.8	200	27	580
90	10/04/19	Taita Taveta	A	a	2	0	2	8.0	300	29	946
91	10/04/19	Taita Taveta	A	a	2	0	2	9.0	300	32	854
92	10/04/19	Taita Taveta	A	b	2	0	2	6.8	280		732
93	12/04/19	Taita Taveta	A	b	3	0	3	9.1	195	27	698
94	12/04/19	Taita Taveta	A	a	2	0	2	10.0	255	45	542
95	12/04/19	Taita Taveta	A	a	8	2	6	13.0	285	25	470
96	11/04/19	Taita Taveta	A	a	4	2	2	16.0	300	29	397
97	11/04/19	Taita Taveta	A	b	4	1	3	15.0	270	27	568
98	11/04/19	Taita Taveta	A	a	3	1	2	7.5	270	28	458
99	11/04/19	Taita Taveta	A	a	2	0	2	13.0	240	31	713
100	11/04/19	Taita Taveta	A	b	3	0	3	8.5	180	30	488
101	10/04/19	Makueni	A	b	3	1	2	10.0	180	25	603
102	10/04/19	Makueni	A	a	6	3	3	11.6	180	33	810

Farm Number	Interview Date	County	Con	Gen	Adult Cows	Currently Dry	Currently Lactating	Daily Liters Milk	Days in Lactation	Months at First calf	Days ICI
103	10/04/19	Makueni	A	a	3	1	2	9.0	300	33	534
104	10/04/19	Makueni	A	a	1	0	1	15.0	300	51	650
105	10/04/19	Makueni	A	a	1	0	1	11.0	180	34	549
106	10/04/19	Makueni	A	a	5	0	5	12.0	300	27	487
107	10/04/19	Makueni	A	a	4	0	4	12.0	300	25	397
108	10/04/19	Makueni	A	a	4	2	2	9.0	210	48	900
109	10/04/19	Makueni	A	a	5	2	3	10.0	280		705
110	10/04/19	Makueni	B	b	2	1	1	12.0	195	27	494
111	11/04/19	Makueni	A	b	5	2	3	11.0	210	27	458
112	11/04/19	Makueni	A	a	2	0	2	10.3	270	29	591
113	11/04/19	Makueni	B	b	4	1	3	9.3	210	27	598
114	11/04/19	Makueni	B	a	3	0	3	7.6	300	30	1,023
115	11/04/19	Makueni	B	b	7	0	7	10.4	300	31	458
116	11/04/19	Makueni	B	b	5	2	3	7.8	180	33	918
117	11/04/19	Makueni	B	b	2	0	2	6.0	240	20	427
118	11/04/19	Makueni	B	b	7	2	5	6.8	240	29	628
11911	/04/19	Makueni	B	b	6	0	6	8.0	180	36	733
120	11/04/19	Makueni	B	b	7	2	5	8.1	300	29	377

Annex 2: Data Collection Schedule

Team / Region	Monday 1/04/2019	Tuesday 2/04/2019	Wednesday 3/04/2019	Thursday 4/04/2019
NYANZA				
Team 1 Zablon and Faith	Training and pre-testing	**Migori (07 farmers)** Chamgiwadu DFCS Bernard Omolo -0723-905983	**Kisii (09 farmers)** Bomabobo DFCS Laban Nyamasenge -0724-936910	**Siaya (04 farmers)** Yala DFCS Jerry Oluoch-0721-224514
Team 2 Isaac and Kevin		**Migori (07 farmers)** Rongo DFCS James Juma - 0728-108718	**Homabay (07 farmers)** Kasibodo DFCS Mr Denise Ogalo –0711-203041	**Kisumu (06 farmers)** Osiepe Practical Action Hezekiah Omenda – 0722-248002
WESTERN				
Team 3 Josky and Charity	Training and pre-testing	**Vihiga (05 farmers)** Vihiga Dairies Alex Imbugi - 0711-712464	**Bungoma west (08 Farmers)** Kikayi DFCS. Patrick Masikini – 0720-303627	**Bungoma West (07 Farmers)** Kikayi DFCS. Patrick Masikini – 0720-303627
Team 4 Linus and Gabriel		**Kakamega (05 farmers)** Kakamega DFCS *(2)* Patrick Juma 0728-768594 Ikolomani Dairies *(3)* Geoffrey Oyodi -0724-660800	**Kakamega (04 Farmers)** Soy Herdsmen Farmers Co-op Frederick Mukweyi 0722-942541	**Bungoma North (11 Farmers)** Naitiri Dairy *(6)* Mr. Wekesa 0728-840822 Madafa Dairy *(5)*
Team Region	**Tuesday 09/04/2019**	**Wednesday 10/04/2019**	**Thursday 11/04/2019**	**Friday 12/04/2019**
EASTERN				
Team 5 Charity and Gabriel	Travel to Wote / preparation and allocation of survey areas	**(10 farmers)** Kikima DFCS Matilda - 0725319497	**(10 farmers)** Kathozweni DFCS Jacob Musyoka (Vice –chair)	**Data clean up**
Team 6 Kevin and Issac		**(07 Farmers)** Tangho CBO Cecil Miller – 0703-270665	**(10 Farmers)** Washami CIG Cecil Miller – 0703-270665	**(03 Farmers)** Washami CIG Cecil Miller – 0703-270665

Annex 3: List of Interviewees

Organization	Contact	Email
Dellosa Farmer's Cooperative Society	Dr. Josephine, Advisor Jackson Ehadi, Chairman	joseongoma@yahoo.com
Vihiga Dairies	Alex Imbugi, Operations	
Omwambya Women's Group	Martin Oyondo Sebastian Asemboh	
Shephard Millers	Jackson Kimanayi, Manager Moses Odhiambo	Jacksonkimanayi6@gmail.com
Animal Science Dept. Maseno University	Dr. Chrilukovian B. Wsike	wsikebwire@gmail.com
Cool Trends Investments	Paul Omanga	
Sakina Feeds – SIMAGO	Peter Onyago, Director	
Lake Feed Millers	Joshua Okolo, Manager	
Nyando Basin Lofoda Enterprises	Joe Outo, Chairman	
SIDAI Africa, Limited	Dr. Christie Peacock, Chair Duncan Kimani, Regulatory Dr. Rezin Odede, Tech. Dir. Office Cell Number	christie.peacock@sidai.com duncankimani@sidai.com ochieng.odede@sidai.com
MolaPlus	Henry Ambwere, Chairman	Molaplus7@gmail.com
Comfort Feeds	Josephine Kirui, Manager	josephine@comfortfeeds.co.ke
Hika Animal Feeds	Wanjiru Burugu	hikafeeds@yahoo.com
Association of Kenya Feed Manufacturers AKEFEMA	Dr. Humphrey Mbugua, Association Manger	assoc.man@akefema.or.ke haumbugua@yahoo.com
Brown's Food Co.	Purity Mbogo, Sales and PR Delia Stirling, Comm. Dir.	reservations@brownscheese.com dstirling@brownscheese.com
Business Edge Cons.	Robert Kariuki, Exec. Dir.	robertkariuki@gmail.com
Dicova Africa Consulting	Gregory Sikumba, Director Technology/R&D	Gsikumba @dicovaafricaconsulting.com
Lucsom Services, Ltd.	Devan Khagram	Devan.khagram@lucsom.com

Annex 4: Common Salt/Mineral Formulations Available in Kenya

There is a broad array of salt and mineral formulations available in the Kenyan market, with a wide variety of formulations as represented in the table below. The samples highlighted in green are the formulations best suited for the basal rations encountered in the study survey.

Product	% Salt (NaCl)	% Calcium (Ca)	% Phosphorus (P)
1	29.5	26.6	2.6
2	23.8	23.3	6
3	20	20	11
4	25	20	12
5	30	20	1.5
6	30	19	18
7	25	19	6
8	22	19	11.5
9	15	18	12
10	25	18	12
11	20	17	11
12	18	15	12
13	18	15	6
14	25	13	10
15	28	7	5
16	83	2.4	10

Annex 5: Survey Feedstuffs

Survey Feedstuffs	
Bean Straw	*Phaseolus Vulgaris*
Corn Silage (dough)	*Zea Mays*
Leucana Hay	*Leucaena Leucocephala*
Maize Cob	*Zea mays*
Maize Stover (Africa)	*Zea Mays*
Banana Leaves	*Musa Paradisiaca Sap.*
Banana Stems	*Musa Paradisiaca Spp.*
Beard grass	*Brachiaria brizantha*
Calliandra	*Calliandra callothyrsus*
Drumstick tree	*Moringa oleifera*
Forage mix	*Various*
Leucaina	*Leucaina leucocephala*
Napier Grass	*Pennisetum purpureum*
Potato Vines	*Solanum tuberosum*
Rhodes Grass	*Chloris Gayana*
Signal grass	*Brachiaria decumbres*
Green leaf desmodium	*Desmodium intortum*
Sugar Cane	*Saccharum Officinarum*
Sweet potato vines	*Ipomoea batatas*
Maize, ground	*Zea Mays*
Molasses	*Saccharum Officinarum*
Potato Peelings	*Solanum tuberosum*
Wheat Bran	*Triticum Spp.*
Wheat Middlings	*Triticum Spp.*
Brewers Grains, Wet	*Various*
Cottonseed Meal	*Gossypium Spp.*
Dairy Meal	*Various*
Soybean Meal	*Glycine Maximum*
Sunflower Cake	*Helianthus Annus*
Generic Grass hay	*Various*
Mineral Mix (Famas)	*N/A*
Macklick Block	*N/A*

Unga Dairy Meal	*Various*
Red salt	*N/A*
Unga Super Macklick	*N/A*
Bidco Dairy Meal	*Various*
Survey Feedstuffs (cont)	
Salt lick	*N/A*
Collard Greens	*Brassica oleracea*
Dairy Meal	*Various*
Collard Greens	*Brassica oleracea*
Finger Millet Stalks	*Pennisetum glaucum*
Coriander	*Coriandrum Sativum*
Fugo Dairy meal	*Various*
Ground Beans	*Phaseolus vulgaris*
Dicalcium phosphorus	*N/A*
Lantana	*Lantana Camara*
Mola plus mineral	*N/A*
Macklick Dry	*N/A*
Empire Feed Dairy meal	*Various*
Fairdeal Dairy meal	*Various*
Fair deal Bio Plus	*Various*
Eastern Millers dairy meal	*Various*
Acacia seeds	*Acacia nilotica*

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FEED THE FUTURE KENYA CROPS AND DAIRY MARKET SYSTEMS ACTIVITY

KENYA

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