Animal Production Society of Kenya

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Livestock Transformation Agenda: Towards Climate Smart Livestock Production Systems

The Animal Production Society of Kenya 2019 Scientific Symposium

THEME

Livestock Transformation Agenda: Towards Climate Smart Livestock Production Systems

April 9-11, 2019 at Hotel Waterbuck, Nakuru

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PREFACE

The APSK annual scientific symposium provides a platform for stakeholders – professionals and practitioners - to share their work and help shape the emerging national agenda on a wide range of livestock production issues. The timing and subject are critical, coming at a time when Kenya seeks to balance overall economic growth with the challenges of feeding a growing population, and using its natural resources sustainably. Therefore, every one of these annual meetings focuses on a major contemporary issue or sets of issues which require attention.

Agriculture in Kenya generally, and livestock production specifically, is at crossroads. There are persistent food shortages arising from rapidly increasing human population, amidst inability to significantly increase productivity. This is being compounded by a host of other trends: urbanization, policy environment and associated impacts particularly on small producers with limited abilities to compete in input and output markets. Aging farming community, climate change and its complex relationships with livestock production systems, and low investments in agriculture are other emerging trends for consideration.

It is determined that demand for livestock products in Kenya will increase several folds by 2050. The trend of increased demand is currently not matched by increase in productivity. Yet, this growing demand for livestock products presents an opportunity for Kenya: in the form of contribution towards economic growth, as well as to the resilience and productivity of producers' livelihoods, and to the food security. This is well articulated in the government development blue print – generally - prioritized and summarized as The Big Four.

However, unmanaged increases in livestock production could also results in increased pressure on natural resources (particularly water and land), increased levels of greenhouse gas emissions, and the potential for more people to contract zoonotic diseases. It is also recognized that smallholders in mixed crop-livestock farming systems will continue to be the main producers of ruminant (cattle, goat and sheep) products until 2050. For monogastrics (such as chickens and pigs), most of the expansion will be through intensive production systems. While the smallholder will remain critical in dairying and chicken sub-sectors in Kenya, livestock development strategies and plans are currently not being intentional and deliberate in addressing some of the key challenges facing value chains in which smallholders operate. Key issues here are access to inputs – including land, financing, appropriate genetics, feeds, and animal health services as well as markets.

The APSK 2019 scientific symposium provided opportunity for rational discussions on these livestock trends and sought ways of addressing the associated challenges while harnessing existing opportunities and innovations under the overarching theme **"Livestock Transformation Agenda: Towards Climate Smart Livestock Production Systems"**. The various exciting presentations and panel discussions provided unmatched opportunities for interactions and networking. They were delivered in five subthemes: a) climate smart livestock systems and environment: identifying and addressing the convergences, b) pastoral livestock systems: which way now? c) opportunities and prospects for transforming ruminant livestock systems in Kenya, d) transforming poultry and pig systems: options for future, and e) policy, value chains, markets, gender, social safeguards and other cross-cutting issues affecting livestock production.

We would like to express our gratitude and special thanks to the sponsors of the conference. We thank presenters and authors of papers, our colleagues on the symposium organizing committee, institutions and individuals who assisted in one way or the other, and the esteemed

conference participants. The venue, setting and the overall conference atmosphere provided opportunity for networking by participants from across the globe.

After the symposium, presenters and authors were asked to submit or revise their papers, taking into account the issues raised during the symposium discussions. The papers were then subjected to light technical reviews and language editing, therefore, ensuring that intellectual content remains that of the authors. The APSK does not necessarily share the views expressed in this proceeding; responsibility for its content rests entirely with the authors.

It is our hope that the APSK 2019 scientific symposium proceedings will provide useful reference material for those interested in understanding the major trends and associated issues covered during this scientific symposium.

Signed April, 2019

Dr. Samuel M. Mbuku
Chairman, Animal Production Society of Kenya

SPEECH BY DR. ANDREW TUIMUR, CHIEF ADMINISTRATIVE SECRETARY, MINISTRY OF AGRICULTURE LIVESTOCK FISHERIES AND IRRIGATION AND CHIEF GUEST DURING THE OFFICIAL OPENING OF THE ANIMAL PRODUCTION SOCIETY OF KENYA SCIENTIFIC SYMPOSIUM AND EXHIBITION FROM 9TH TO 11TH APRIL 2019 AT THE HOTEL WATERBUCK IN NAKURU

Distinguished guests,

Ladies and gentlemen,
It gives me great pleasure to be with you here today, to officiate this special occasion of the Animal Production Society of Kenya (APSK) Scientific Annual Symposium and Exhibition. The occasion provides a unique opportunity for the Animal Production Professionals, farmers, pastoralists, development partners, academia, public and private service providers and stakeholders in the Livestock Sector, to share their work and help shape the emerging national agenda on a wide range of livestock production issues. I thank the APSK leadership for making this happen.

Ladies and gentlemen,
It is the goal of the Government to eradicate poverty, illiteracy and diseases. Moreover, at the global level, Kenya subscribes to the 17 Sustainable Development Goals (SDGs); which came into effect in 2015. Of the 17 SDGs, five are of relevance to the growth of the Agriculture sector namely; **SDGs 1**: End poverty in all its forms everywhere, **SDGs 2**: End hunger, achieve food security and improved nutrition and promote sustainable agriculture, **SDG 5**: Achieve gender equality and empower all women and girls, **SDG 8:** Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all; and **SDG 10**: Reduce inequality within and among Countries.

Ladies and Gentlemen,
At the Continental level, Kenya subscribes to all the tenets of the African Union (AU) and its organs. Relevant to the agriculture sector and the livestock sub-sector, is the Comprehensive African Agriculture Development Programme (CAADP) under African Union Development Agency-NEPAD (AUDA-NEPAD), and the renewal of the CAADP commitments in 2014 through the Malabo declaration in which the African heads of state resolved to;

- enhance investment finance in agriculture at 10% of public spending targets,
- end hunger by 2025,
- half poverty by 2025, through inclusive agricultural growth and transformation,
- boost intra-African trade in agricultural commodities and services, and
- Enhance accountability to actions and results.

Ladies and gentlemen,
The livestock industry is a key driver of Kenya's economy. It is crucial in enabling Kenya attain the ultimate goal of becoming a **'Middle–income'** Country by the year 2030. Moreover, the sector employs close to 50% of Kenya's Agricultural labour force and is a primary source of livelihoods for over 6 million Pastoralists and Agro-pastoralists in the Arid and Semi-arid Lands (ASALs).

Furthermore, the sector accounts for about 12% of the entire GDP and 42% of the agricultural GDP. It also supplies the domestic requirements for meat, milk and dairy products, and other livestock products and accounts for 30% of the total marketed agricultural products. The sector earns the Country substantial foreign exchange through export of animals, hides and skins, dairy products and some processed products.

Ladies and gentlemen,
At the national level, the Kenya Vision 2030 remains the economic blue print to guide the country's development agenda in the coming years. The aim of Vision 2030, is to create "a globally competitive and prosperous Country with a high quality of life''. In the Vision agriculture and livestock sectors are envisaged to be innovative, commercially-oriented and modern.

Ladies and gentlemen,
Vision 2030 is implemented through five year Medium Term Plans (MTPs) and since inception two MTPs have lapsed and presently, MTP III, runs from 2018 to 2022. During MTP III agriculture is expected to grow at a rate of 7% through implementation of several measures that include increasing production and productivity; disease and pest control; crop and livestock insurance; post-harvest losses management, market development, natural resource management, increased investment in the sector, strengthening institutions, policies and systems; increasing youth and women participation in crop and livestock production, and implementation of regional and international protocols and commitments.

Ladies and Gentlemen,
The Agriculture Sector Development Strategy (ASDS) of 2010 to 2020 was developed to guide the contribution of the agriculture sector to the vision 2030, has undergone a review due to changes in the operational environment. The new strategy- Agriculture Sector Transformation and Growth Strategy (ASTGS) focuses on Agricultural Transformation from small scale subsistence production to a sustainable, equitable and remunerative agricultural sector.

Ladies and gentlemen,
Agriculture Sector Transformation and Growth Strategy has prioritized five policy and investment goals for the national and county levels namely:

- Food, feed and nutrition security,
- Manufacturing and agro-processing,
- Eradication of extreme poverty,
- Increasing productivity and competitiveness, and
- Wealth and job creation.

Ladies and Gentlemen,
The Government has spelt out the **"Big Four"** priority areas in which to focus for the next five years 2018-2022; namely;

i) Food and nutrition security;
ii) Manufacturing and agro-processing;
iii) Universal health care, and
iv) Affordable housing.

Moreover, the gap between supply and demand of livestock and livestock products is expected to widen in the foreseeable future. Therefore, Animal Production Professionals have a critical role to play in the actualization of the **Big Four Agenda** and bridging the gap between supply and demand.

Ladies and Gentlemen,
Besides the foregoing, the lack of consistent, integrated strategies that focus limited resources on identified and attainable goals remains a major constraint to livestock development. There is obviously a need for an effective policy framework that will optimize development resources and provide the necessary support and economic environment to allow a country's livestock resources to express its potential.

Recognizing the challenges and the opportunities, the Ministry embarked on a lengthy, inclusive, participatory and truly consultative process that reviewed the Session Paper No 2 of 2008 on National Livestock Policy. It is expected that the Policy changes envisioned in the reviewed Livestock Policy 2019 will revitalize the Livestock Sector and guarantee sustainability of livestock farming as a major economic thrust in the country.

Ladies and gentlemen,
As you are aware, APSK draws its membership from Ministries, Departments and Agencies; Research Institutions, Universities and the private sector, and to date has an active membership of 500.

The objectives of APSK include provision of a common forum for exchange of ideas; dissemination and adoption of technologies; support to members in self development; strengthening of regional and global

linkages; contribution to the development of animal production related policies, and provision of professional advice on the development of the livestock industry; and will contribute greatly towards the realization of the **"Big Four''** development agenda. Therefore, a highly skilled human resource is required to provide services at all levels of the livestock value chains development.

Ladies and gentlemen,
The APSK has faced many challenges including a low capital-base and a lack of a legal statute for the registration, licensing and regulation of Animal Production Professionals and Technicians in Kenya. However, the biggest challenge is the perception that: **"Anyone can do Animal Production**".

Ladies and gentlemen,
To ensure that Animal Production is increasingly seen as a true, top-notch profession, coupled with the critical role it plays in the livestock industry, the development of the Animal Production Professionals and Technicians Bill, 2019 is timely and welcome.

The Bill, once enacted into Law, will provide for the training, registration and licensing of Animal Production Professionals and Technicians; and ensure proper regulation of the standards and practice of the Animal Production profession.

This will eventually bring sanity to the practice of Animal Production and, advise the Government on matters relating to Animal Production, prescribe the curriculum of instruction and courses, approve and oversee continuous professional development and facilitate internship programs. Working closely with APSK and other stakeholders, the Ministry will fast-track this proposed Law.

Ladies and Gentlemen,
The Government gave an undertaking to support internship programs for early career graduates. I direct all state departments and agencies in the Ministry to enforce this **directive** without fail. To avoid any doubt, all state departments and agencies at the Ministry should file annual returns for internship programs to my office every year.

Ladies and Gentlemen,
The theme of Animal Production Society of Kenya 2019 Scientific Symposium and Exhibition – ***"Livestock Transformation Agenda: Towards Climate Smart Livestock Production Systems''*** is apt.

In line with the Symposium theme, there will be presentations of research findings, topical panel discussions and exhibitions by stakeholders. The theme will further give impetus to the realization of the Vision 2030, ASTGS, SDGs, and the ''Big Four'' Agenda.

Ladies and gentlemen,
I am aware that the finalization of the Animal Production Professionals and Technicians Bill, 2019 and the implementation of APSK 2018-2022 Strategic Plan, requires substantial resources. I want to assure APSK leadership and its members that the Government through the Ministry will continue to support the Society.

Ladies and gentlemen,
I look forward to receive a copy of proceedings for this meeting. It is now my pleasure to declare the 2019 APSK Scientific Symposium and Exhibition officially open.

Thank You Very Much and May God Bless You

POLICY, VALUE CHAINS, MARKETS AND OTHER CROSS – CUTTING ISSUES AFFECTING LIVESTOCK PRODUCTION

The Draft Animal Production Professionals and Technicians Bill 2019

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Abstract
The draft Animal Production Professionals and Technicians Bill 2019 is for an Act of Parliament to provide for the training, registration and licensing of Animal Production Professionals and Technicians; to provide for the regulation of the standards and practice of the Animal Production profession and for connected purposes. The proposed law will establish a Board to be known as the Animal Production Professionals and Technicians Board. The object and purpose for which the Board is established shall be to exercise general supervision and control over the training, registration and licensing of animal production professionals and technicians, provide for the regulation of the standards and practice of the animal production profession in Kenya and to advise the Government in relation to all aspects thereof. Specifically, the Board will (a) advise the Government on matters relating to animal production training, research, practice and employment, animal feed standards and safety, animal production tools and equipment, animal genetic resource management, range management, marketing of livestock and livestock products and other issues relating to production of foods of animal origin; (b) prescribe in consultation with such training institutions as the Board may approve, the curriculum of instruction and courses of training for persons seeking registration under this Act; (c) prescribe the personnel and physical facilities for training of persons seeking registration under this Act; (d) consider and approve the qualification of animal production professionals for the purpose of registration under this Act; (e) license and regulate animal production extension service providers, animal production consultants and animal production input suppliers; (f) develop and publish a code of ethics which shall be binding on all registered persons; (g) regulate the professional conduct of registered persons under this Act, and take such disciplinary measures as may be deemed appropriate to maintain proper professional standards; (h) approve, oversee continuous professional development and facilitate internship programmes; (i) register and maintain a register of all persons registered under this Act; and (j) hear and determine such matters placed before the Board as may relate to the professional conduct of animal production professionals and technicians.

Keywords: Bill, registration, licensing, Board, professionals, technicians

Fundamentals for Successful Writing of a Scientific Paper for Publication in Reputable Journals

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Abstract
Advancement in scientific fields are primarily achieved through discoveries from methodical scientific research whose findings are made available via publications. Although there are many forms of scientific publications, the most important is the peer-reviewed journal article. Therefore, something this important should be done well using universal guidelines. The good news is that vast majority of journals have adopted a simple structure. Though with some variations, most journals use Introduction, Methods, Results and Discussions format popularly referred to as 'IMRaD'. In this universal format, the

Introduction section is where the background of the problem, justification for addressing it and specific answers or objectives to be sought through research are stated. Well explained methodologies are then deployed to provide the answers, which when accomplished, the findings are presented in the Results section as evidence. Since the evidence alone does not explain itself, the results must be interpreted and explained to have value, hence the need for their Discussions and drawing Conclusions and/or Recommendations. A good guideline highlight fundamentals for successful writing of a good scientific paper meant for publication in reputable journals by following the IMRaD format. It goes further to provide guidelines on how to craft a Title for the paper, writing an Abstract and presenting Figures and Tables of results. Other ingredients include how supporting literature should be reviewed, cited and listed. The article further stresses the importance of reading, understanding and adhering to the Authors' guidelines of the specific journal where the paper is to be submitted.

Institutional niches for enhanced enforcement and compliance with dairy farm inputs quality standards: The case of Kenya

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Abstract
The dairy industry is Kenya's single largest agricultural subsector. However, the industry's growth and competitiveness are constrained by among other things sub-standard service provision,d input supply and weak policy and institutional infrastructure for sector governance. There is a growing concern about the decreasing quality of animal feeds that may be compounded by lack of inadequate enforcement mechanisms of requisite quality standards stipulated by the government authorities. This calls for investigation about the problem, its magnitude and necessary measures that can be put in place to curb the situation. This policy study was undertaken to understand the dynamics behind the perceived failures in implementation and enforcement of policies in feed quality, genetic resources and veterinary services; and how this may be improved. This study exposes weaknesses in the quality standards enforcement mechanisms ranging from individual capacities and recruitment of relevant expertise at the institutional level (education) and government/counties. The study recommends the need to develop quality standards enforcement mechanisms/frameworks that embrace incentives for compliance, performance for service providers and learning processes both at the macro (national) and micro levels.

Key Words: Input, supply, policy, quality standards, animal feeds.

Introduction

There is a growing concern about the decreasing quality of animal feeds (dairy meal, minerals and related administration), genetic resources (artificial insemination, semen and livestock breeding stock) and veterinary services (veterinary drugs, administration of drugs, treatment and licensing). This is compounded by lack or inadequate enforcement mechanisms of requisite quality standards stipulated by the government authorities. Arguably, enforcement of quality standards and regulations can work (a) to penalize those who consciously violate such standards and regulations, and (b) to create awareness about the hazards that the standards and regulations intend to prevent. The enforcement of standards and compliance have been affected by major reforms in public agricultural services including decentralization and privatization of dairy inputs services affecting many countries including Kenya (Sen and Chander, 2003; Smith 2001). A number of empirical studies record that these reforms were perpetuated by a number of institutional factors like political environment, governance structures and financial constraints (Amankwah *et al*., 2014). Other studies that have employed strategic niche theory for system innovation have further identified institutional factors associated with dynamics of structural transformation (Schut *et al*., 2015). This paper draws insights from these studies to interrogate the dynamics involved in enforcement of and compliance with dairy farm inputs quality standards in the

Kenyan context. The main motivation behind this study is to understand the dynamics behind the perceived failures in implementation and enforcement of policies in feed quality, genetic resources and veterinary services; and how these may be improved. This study would hopefully lead to improved compliance with respective policies in the input and service supply chain in the Kenyan dairy sector.

Methodology

Strategic niche theory for system innovation

Regimes remain stable because of path dependence and resources that have been invested. There is an inherent danger of existing institutions to become locked-in into the existing regime. There is need to manage expectations and tensions in the transitional phase, including understanding and negotiating new roles and tasks for the actors in the regulatory implementation regime (Schut *et al*., 2011). This study interrogates the enforcement of dairy input quality standards regime from an institutional system innovation perspective. This can provide space for experimentation, learning and negotiation towards a regime change aligned to needs of a system (Smink *et al*., 2015: Klerkx *et al.*, 2013). Consequently, focus would aim at understanding systemic constraints associated with regulations and enforcement and opportunities for institutional innovation informed by joint vision for collective action. System innovation's intervention and learning methods take into consideration dialogue and negotiation; stakeholder experimentation; reflection and joint learning (Schut *et al.*, 2015).

Field work

The study was carried out by African Centre for Technology Studies (ACTS) and Egerton University in partnership with Wageningen University, Netherlands under the ADIAS project – "*Assessing and supporting input and advisory service systems for resilient market-oriented smallholder dairy systems in the Kenya*". Primary and secondary data comprising qualitative and quantitative measurements were collected for the study. Preliminary review of secondary data provided a link to primary data collection via face to face interviews with various stakeholders along the dairy value chain. Interviews were conducted using structured questionnaires that were developed to suit different categories of respondents. Focus group discussions were also undertaken using a checklist that guided in the discussions. Interviews from the two groups of respondents (key informants and farmers) were analyzed to identify key themes that denoted similarities or variations in perception about quality standards of animal feeds, genetic resources and veterinary service provision.

Results and discussion

The analysis of secondary data and field data exposed issues around dairy farm inputs quality standards and enforcement which were categorized in various sub themes for reporting purposes.

The Kenyan dairy farm inputs quality standards regulatory environment

Kenya has a vibrant dairy industry with an estimated annual milk production of 537 million litres (KNBS, 2018). Small scale dairy farming predominates in the sector and produces 80% of the total milk produced in the country (SNV, 2013). This in turn provides a market base the various dairy inputs including animal feed, genetic resources and veterinary services and drugs used in milk production within these farms. In its National Policy Paper (Sessional Paper No. 2 of 2008), the GoK committed to facilitate growth of the dairy industry by providing an enabling legal environment. This included the already established statutory body Kenya Bureau of Standards (KEBS) that is charged with enforcement of standards and certification of all products and services in the country (Snipes, 2014). The standards developed by KEBS are aimed at ensuring that the products from manufacturers are not only fit for their purposes but also specifies requirements that enhance maintenance of quality. KEBS together with other statutory boards ensures adequate monitoring and enforcement mechanisms are in place so as to maintain quality standards of dairy inputs. Despite the quality standards of dairy inputs in place, there is reduced productivity within dairy farms due to poor animal husbandry, low quality dairy inputs, decline in genetic base and effects of animal diseases (MoALF, 2013).

Animal feeds

The standards of producing manufactured animal feed are set by KEBS who are mandated to ensure they meet the required specifications. These are aimed at minimizing farmers' exploitations by scrupulous traders and animal feed manufacturers. During the study, majority of the respondents had an overall perception that regulations ensuring quality dairy feeds are not fully implemented on enforced. All the focus group discussions had a general consensus that the regulations were not being implemented and enforced as compared to 67% of the key informants who also felt the same against 33% who felt otherwise. Further probing indicated negligence and laxity by regulators as main reasons for inadequate enforcement of dairy standards. On the level of satisfaction about the quality of animal feeds, 74% of the key informants were dissatisfied as opposed to 26% who felt otherwise. The dissatisfaction was further explained by farmers accessing low quality animal feeds at high costs. This was further ascertained when 6 out of the 7 FDG's conceded to accessing low quality feeds at high costs. Farmers in the study ascertained the decreasing quality of manufactured animal feeds which mimics previous study by Technoserve (2008) that reported varying and inconsistent quality of animal feeds which dairy farmers are attributed to. Further, weak legal and institutional framework may perpetuate farmers' exploitation by scrupulous animal feed manufacturers and traders. This is further accelerated by the high number of feed manufacturers who either produce substandard products that do not comply with the set standards or use poor quality ingredients in their course of production.

Genetic resources

Smallholder dairy farmers access superior genetic resources through various breeding technologies including artificial insemination (AI) (SNV, 2013). The access and use of these technologies are aimed at improving the genetic potential of the dairy herd. This coupled with good dairy management practices ensures increased performance especially from exotic dairy herd mostly preferred by smallholder farmers within the Kenyan highlands (Bebe *et al.*, 2003). Previous study by (MoA andI, 2018) reported that despite use of technology especially AI in improving the genetic potential of the herd, they are faced with several challenges involving low quality semen, unfavourable policies and legal frameworks to sustainable genetic resources. These challenges coupled with inadequate monitoring and quality standards enforcement mechanisms, have decreased the quality and use of genetic resources advocated for increased productivity within the dairy herd. Our study shows that all the FGD's (100%) conceded to being dissatisfied with the quality of semen they access for insemination which they mostly attributed to negative consequences including increased repeat insemination services per cow and low conception rates. This makes use of bull services appealing. A farmer reported "*I decided to go back to use of bulls because I got undesirable calf and different breed from dam after using AI*". Another farmer reported that "*when you use AI, you will be forced to serve twice or thrice for the cow to conceive which is expensive*". This, overtime will lead to low genetic quality of dairy cows and consequently poor genetic resources among smallholder dairy farmers as previously reported by Technoserve, (2008). In relation to costs versus quality, 6 out of the 7 FGD's (86%) conceded to accessing low quality genetic materials at high costs compared to 14% who accessed low quality genetic materials at low costs. The impact of cost on accessibility of quality genetic resources has also been reported in various previous studies. The high cost of genetic resources limits some farmers from accessing right quality genetic resources for production and reproduction (ILRI, 2015). Arguably, the supply of quality genetic materials is hampered either by high cost of accessing the same reducing accessibility direct costs involved in their production or by inaccessibility or inadequate handling procedures that could otherwise compromise the quality (SNV, 2013).

Veterinary services

Animal health service provision which largely depends on effective disease control is essential to a vibrant dairy industry for increased productivity (MoALF, 2013). The Kenya Veterinary Board (KVB) is mandated to exercise general supervision and control over the training, business, practice and employment of veterinary surgeons and veterinary paraprofessionals in Kenya. According to our study, there are many qualified veterinarians who opted to venture into other businesses due to the fragmented and uncontrolled nature of the industry. This in the long run poses serious animal health and production threats either in treatment or prevention measures. It also affects ultimately the consumer of dairy products through zoonosis and drug residues. The study showed higher levels of dissatisfaction by most

of the key informants on the quality of veterinary services. Most of the FGD's felt satisfied with these services and this could be attributed to the complete/partial recovery of sick animals upon treatment by the technicians. In relation to costs, 3 out of 7 of the FGD's conceded to high quality veterinary services coming with high cost while 4 out of 7 were of the opinion that low quality services are provided despite the high cost.

Stakeholders perspectives about dairy farm inputs quality standards and enforcement

This study exposes weaknesses in the quality standards enforcement mechanisms ranging from individual capacities, recruitment of relevant expertise at the institutional level (education and government/counties) etc. Interviewees noted that the type of monitoring mechanism used depend on the state (policies and regulations development and implementation by regulators), while the dairy inputs system is highly privatized (e.g. genetic resources, farm inputs rationing and production by suppliers, stockists etc). Efficient enforcement and compliance of quality standards and cost of dairy input seem to be interrelated. Soliciting for advisory services that pertain quality standards may attract additional cost in addition to the cost of the service. This can be interpreted in two ways. First, it is possible that the service providers have inadequate capacity and skills to provide requisite advisory service related to quality of inputs. Second, the service providers may be profit driven.

Understanding quality standards enforcement and compliance from a niche regime perspective

How are standards expected to enhance efficiency in compliance and enforcement? This study argues that the current regulatory structure (regulations, regulatory agencies, input suppliers e.t.c.) presents a dominant regime that constrains or enables niche level enforcement or compliance. At the policy level the development of regulations and structures for implementation; training of service providers at technical vocational colleges and universities; the county governments support etc are among several examples that demonstrate how the dominant regime supports quality standards enforcement and compliance. This regime on the other hand has not embraced a transformed advisory service commensurate with the reforms in the dairy sector. For instance, the reforms in the farm inputs service delivery necessitated review of regulatory policies or new institutional arrangements that accommodated new actors (private sectors, associations e.t.c.) and their respective capacity needs and interests. This has implications because old institutional setting may hinder new ways of working (Nettle *et al.*, 2013). There is minimal empirical evidence to show whether the reforms were factored in the regulatory system implementation infrastructure.

Policy recommendations

There is need to develop quality standards enforcement mechanisms/frameworks that embrace incentives for compliance, performance for service providers and learning processes both at the macro (national) and micro levels. At the micro level, perhaps the starting point should be experimentation/testing with one or few counties, before expanding to the other counties. The study identifies a number of recommendations.

Integrated approach to quality standards enforcement and compliance

The findings of this study calls for a holistic approach to regulatory enforcement that enables a quality standards monitoring system that enhances self-regulation. This has implication for capacity development.

Developing systemic capacity for regulatory compliance and enforcement

A number of questions may help to guide in capacity building and skills development.

- How can the government support development of skills in regulatory compliance and monitoring of quality standards for extensionsists, veterinarians, inseminators etc in a way that this capacity can be embedded in their work; or training curriculum?
- How can skills on monitoring of quality standards be embedded in the capacity of the other stakeholders like suppliers of dairy farm inputs?
- Penalties for non-compliance versus enhancing motivation for compliance?

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Characterization of fish markets for small scale farmers in Kenya

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Abstract
A study was conducted to determine the characteristics of fish markets for small scale fish farmers in four Counties in Kenya, namely, Kirinyaga, Busia, Kakamega and Migori. Objectives of the study were to assess the social-economic characteristics of fish farmers, determine the main factors that influence fish markets and evaluate the main production and marketing challenges. Participants in the study were selected from active fish farmers, traders and consumers through stratified, purposive sampling where care was taken to include women fish farmers who practiced fish farming individually or in groups. Data was collected using semi-structured questionnaires for each group of participants. Global Positioning system (GPS) co-ordinates were taken for all areas visited in the study. Most of the fish farmers were between 40 – 60 years. Gender influenced the level of education attained by participants where majority of women had only attained a primary level of education. Majority of farmers in Kirinyaga County stocked mixed sex tilapia, while in all male tilapia were stocked in Kakamega and Busia. Fish took between 8 – 9 months to attain an average weight of 280 grams. The most important market outlets for farmed fish were neighbors, friends, relatives and other social networks at the pond site. Most consumers preferred wild to farmed fish. The most popular product transformation activities were descaling and gutting. This study came up with two recommendations; there is need to promote collective marketing among the fish farmers and also train farmers on suitable value addition techniques.

Key words: Fish markets, gender, Tilapia, value addition, Busia, Kakamega, Migori, Kirinyaga

Background

In Kenya, aquaculture was popularized through the Fish Farming Enterprise and Productivity Program which was implemented between the financial years 2009 to 2013. Under this Programme fish farming was funded in 160 political constituencies (KMFRI 2017). In each of these constituencies, farmers benefited from funds for construction of ponds, provision of fingerlings and feeds, supply of harvesting nets, training, provision of market infrastructure, and provision of on-farm feed mixing and pelletizing machines. Fish processing infrastructure was built in five counties namely: Migori, Kakamega, Nyeri and Meru. The total installed capacity of these processors is approximately 3000 tons/year (KMFRI 2017) but current production is below the installed capacity.

Despite the massive government investment in fish farming, there are still several key challenges such as low volumes of fish produced and marketing of farmed fish by small scale farmers. Consequently, a study was conducted to evaluate production and marketing characteristics of farmed fish among small scale producers in Kenya. Specific objectives were to identify the key social economic factors that influence production of farmed fish, to determine the challenges faced in production and to evaluate the main factors that influence marketing of farmed fish among small scale farmers in Kenya.

Materials and Methods

Study area

The study was conducted in four counties of Kenya, namely: Kirinyaga County in Central Kenya, Busia and Kakamega Counties in Western Kenya and Migori in the Lake region. All the areas selected for the research work have a high potential for production of farmed fish and were among the Counties covered by the Fish Farming Enterprise and Productivity Project. In addition women fish farmers were supported by the Kenya Women Holdings through provision of loans and capacity building in fish farming in the four counties.

Sampling procedure

Participants were drawn from active fish farmers in the selected areas. The selection was stratified purposive sampling where respondents were choosen from sub-counties representing areas where fish farming was practiced. Within these sub-counties, care was taken to include men and women fish farmers engaged in fish farming individually or in groups. Information was collected from 321 fish farmers, 66 fish traders and 82 consumers in the counties stated above. Secondary data was collected using documents from County Directors of Fisheries and Fisheries Extension officers.

Data collection and analysis

Data was collected using semi-structured questionnaires for each group of participants. Global positioning system (GPS) co-ordinates were taken for each homestead included in the study. Secondary data was collected using documents from the State Department of Fisheries in Nairobi and from County Directors of Fisheries and Fisheries Extension officers. Key informant interviews were conducted with County directors of fisheries, fisheries officers and leaders of fish farming clusters among others.

The collected data was cleaned, edited, sorted and entered into the computer. Descriptive statistics consisting of frequencies, means and modes were computed for different data categories to facilitate comparisons. Statistical Package for Social Sciences (SPSS version19.0) was used in the analysis.

Results and discussion

Table 1 shows the age and level of education of household heads in the Four Counties. In all the Counties, households headed by men were over 85% of total, while those headed by women were between 11 – 15 % of the total. Majority of household heads were between 41 and 60 years. Migori County had the highest percentage of young household heads (20 – 30 years) compared to other counties.

Table 1. Age of household heads

Age of household head by County					
County	Between 20 and 30 years	Between 31 and 4o years	Between 41 and 50 years	Between 51 and 60 years	Above 61 years
	%	%	%	%	%
Busia	1.4	16.2	33.8	23.0	25.7
Kakamega	3.1	14.1	32.8	26.6	23.4
Kirinyaga	4.8	12.9	22.6	32.3	27.4
Migori	18.6	16.3	16.3	30.2	18.6
Overall	5.8	14.8	27.6	27.6	24.3

Table 2 shows that gender influenced the level of education where majority of women (53.3%) had only attained Pre-Primary level of education. In all counties except Kakamega, no women among those sampled had attained University education. The level of education of farmers influences the adoption of fish farming technologies. Studies by Kimenye (2001) showed that formal education was positively correlated to the probability to adopt farming technologies.

Table 2. Level of education of household heads

Level of education of household head by County				
County	Gender	Preprimary/ Primary	Secondary/vocational	Post-secondary/university
Busia	Male	37.7	49.2	13.1
	Female	60.0	40.0	0.0
Kakamega	Male	15.8	54.4	29.8
	Female	42.9	0.0	57.1
Kirinyaga	Male	18.4	61.2	20.4
	Female	42.9	57.1	0.0
Migori	Male	65.7	20.0	14.3
	Female	66.7	33.3	0.0
Overall	Male	31.7	48.5	19.8
	Female	53.3	33.3	13.3

Majority of the fish farmers sampled in Mwea stocked mixed sex tilapia (57.1%), while farmers in Kakamega and Busia mainly stocked mono-sex tilapia (Table 3). In Migori, 45% and 47% of farmers stocked mixed sex and mono-sex tilapia respectively. In the four places sampled, very few farmers kept catfish.

Table 3. Species of fish stocked

Percent Species of fingerlings stocked in ponds by county				
Fish Specie	Busia	Kakamega	Kirinyaga	Migori
	%	%	%	%
Tilapia (mixed sex)	28.0	29.4	57.1	44.9
Tilapia (mono sex)	53.3	57.4	20.0	46.9
Cat fish alone	12.0	5.9	14.3	6.1
Catfish and tilapia	6.7	7.4	8.6	2.0

The major challenge reported by most fish farmers was the high price of fish feeds as reported by 29.8 % and 28.9% of farmers in Busia and Kirinyaga respectively, and 24% and 20.3% of farmers in Kakamega and Migori Counties respectively (Table 4). Farmers reported that feeds were very expensive, not easily available and that the feeds available were of low quality. The second challenge reported was predators, followed by lack of markets and theft of fish respectively

Table 4. Ranking of challenges experienced by farmers.

Percent challenges facing fish farmers				
Challenges	Busia	Kakamega	Kirinyaga	Migori
	%	%	%	%
High feed prices	29.8	24.0	28.9	20.3
Pond management	2.5	2.3	2.8	3.1
Predators	17.2	19.3	16.1	20.3
Lack of credit	0.0	0.0	1.1	3.1
Limited capital	2.5	1.2	4.4	7.8
Lack of technical/knowledge	.5	2.3	3.9	10.2
Lack of market	11.1	9.4	18.9	.8
Theft	9.1	12.3	5.0	10.9

On average, tilapia took between 8 – 9 months before they were harvested. This meant that only one cycle of fish could be produced per year, which limited the size of market for farmed fish. Growth of tilapia fish is influenced by main factors such as water temperature and pond depth, (El Sayed *et al.*, 1996). According to Pouomogne and Ombredane (2015) feed management is also another factor that influences the growth of Tilapia fish among other management practices. In studies on semi intensive systems tilapia took on average 6 – 7 m to grow to a weight of 250 grams.

The number of fish harvested determines the size of the fish market. Generally, most farmers stocked 1000 fingerlings in a pond measuring 300 square metres making a stocking density of 3.3 fish per square metre. This was the stocking density recommended under the Fish Farming Enterprise and Productivity Project. The highest number of fish were harvested in Kakamega (662.4 pieces), followed by Migori (636 pieces) and Busia (595.4 pieces) and Kirinyaga respectively (192.8 pieces of fish) (Table 5). There were high pre-harvest losses in all the Counties.

Table 5. Mean number of fish harvested

Mean number of fish harvested by county				
County	Mean	N	Min	Max
Busia	595.4	54	50.0	2900.0
Kakamega	662.4	55	35.0	2500.0
Kirinyaga	198.2	45	18.0	1000.0
Migori	635.6	35	100.0	1900.0
Overall	527.8	189	18.0	2900.0

The main markets for farmed fish in all the Counties sampled were neighbors, friends and relatives and other social networks at the pond site. Most farmers complained that in this type of marketing, prices offered for fish were low, and in some cases, they were compelled to sell the fish on credit terms. The other important markets were the traders who bought fish at the pond, while other fish were delivered to markets. In all Counties, only a small percentage of fish were delivered to a collection point. There were no organized markets as most farmers sold fish as they matured.

Value addition included any activity that improved on the existing products. The most popular product transformation activity carried out was de-scaling and gutting, which was done by majority of farmers sampled in Busia (38.5%), Kirinyaga 72.7 %) and Kakamega (80.4%) respectively. This study reveals that most of the farmers sampled in Migori did not do any processing before selling their fish. Table 6 gives a summary of the outcome.

Table 6. Households doing value addition

Percent of households doing value addition by county				
Process	Busia	Kakamega	Kirinyaga	Migori
	%	%	%	%
Gutting	38.5	72.7	80.4	0.0
Filleting	0.0	0.0	0.0	0.0
Smoking	7.7	1.8	0.0	0.0
Frying	53.8	25.5	19.6	0.0

Conclusions

Majority of fish farmers were between the ages of 41-60 years. Most men had attained a secondary school education while most women had only a primary level education. The main challenges experienced by fish farmers were high cost of feeds, low quality of feeds and scarcity of feeds. The average fish maturing period was 9 months thus presenting one production cycle per year. In order to access bigger and more lucrative markets locally, regionally and globally, there is need to improve production efficiency and the size of fish produced. Fish markets were unstructured and not organized. For most farmers, the markets consisted of social networks such as family, neighbors and friends who bought fish at the pond during the day of harvesting. The most common value addition done on harvested fish was descaling and gutting. In Busia, this was done by farmers as a service to people purchased fish and did not necessarily lead to price increases. In Kakamega and Kirinyaga, descaled and degutted fish fetched a higher price than whole fish which was not added value. This study came up with two recommendations; there is need to promote collective marketing among the fish farmers and also train farmers on suitable value addition techniques.

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Strengthening of National Dairy Development Policy and Related Strategic Plans for Enhanced Dairy Productivity

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Abstract

Agriculture is the backbone of the Kenyan economy the most important sector and dairy is one of the largest contributors. Several policies and strategic plans (SP) such as; Strategy for Revitalization of Agriculture and National Dairy Development Policy (NDDP) have been developed over time to enhance agricultural and economic productivity. The objectives of this study were to critically analyse agricultural SPs in the context of NDDP, to identify gaps between the SPs and the policy and propose policy recommendations on strengthening the links between the two for improved dairy productivity. Policy documents and SPs related to the two were also collected and analyzed. The results showed that there is a strong link between the NDDP and the Ministry's SPs. Hence, if the strategic plan is implemented as set out, the policy issues and policy objectives will significantly be achieved, and the dairy industry would go a long way in improving the sector's productivity. However, it appeared that the policy and strategic plan have inadequate latitude for private participation and self regulation. Hence, there is need to strengthen the policies through a comprehensive review to embrace self regulation and public-private partnership. Also, agricultural development being a devolved function calls for enhanced involvement of county governments. Hence, these policies can be strengthened through improved participation of the county governments in their development and implementation processes. More innovative ways of resource mobilization for effective policy implementation also need to be explored.

Key words: Dairy, strategic plan, policy, strengthening

Introduction

Agriculture, contributes around 25% of the GDP, and employs 75% of the national labour force (Republic of Kenya, 2007). Therefore, it is the most important sector in the economy. The importance of the sector in the economy is also reflected in the relationship between its performance and that of the key indicators like GDP and employment. Trends in the growth rates for agriculture, GDP and

employment, show that the declining trend experienced in the sector's growth especially in the 1990s, is reflected in the declines in employment and GDP as a whole (Alila and Atieno, 2006).

Kenya is one of the largest producers of dairy products in Africa with a herd of 3.5 million exotic cattle, 14.1million indigenous cattle, 27.7 million goats, and 2.9 million camels (Kimani and Irungu 2008, GoK 2009). Cattle account for 88% of the milk produced while the rest comes from camels and goats. On-farm milk production has remained low due to poor animal husbandry, low quality feeds, and declining genetic base among others. The dairy industry policy in Kenya was last reviewed in 1993. However, over the years new opportunities and challenges have emerged in the industry necessitating the need to have a current and accommodative dairy policy.

In 2002, the Government developed Economic Recovery Strategy for Wealth and Employment Creation (ERS) and was successfully implemented in the period 2003-2007. At the same time, the Strategy for Revitalization of Agriculture (SRA, 2004-2014), was developed and implemented as the sector vision meant to respond to the decline witnessed in the agricultural sector. National Dairy Development Plan and Ministry of Agriculture, Livestock and Fisheries Strategic Plan (2013-2017) were developed based on Kenya Vision 2030 and its Second Medium Term Plan (MTP), the Constitution of Kenya and agriculture sector policies. It also built on the successes and lessons learnt during implementation of the first MTP and previous Strategic Plans (2008 -2012) of the former Ministries of Agriculture, Livestock and Fisheries Development.

Objectives

1. To critically analyze the agricultural strategic plan (2013-2017) in the context of the national dairy development plan
2. To identify gaps if any, between the strategic plan and the dairy development policy
3. To propose policy recommendations on strengthening the policies for efficient strategic plan implementation and improved productivity.

Methodology

This work focused entirely on the critical review of policy documents and strategic plans in the dairy value chain context. The main policy documents that were reviewed were accessed from government institutions and the internet. Though the main focus was the National Dairy Development Policy (NDDP, 2013) and Ministry of Agriculture, Livestock and Fisheries Strategic Plan (SP, 2013-2017), other related policy documents where this policy was grounded were also reviewed. These included Vision 2030, ERS and SRA. Other related policies that were examined included; Agricultural Sector Development Strategy (ASDS), National Land Policy (NLP), National Livestock Policy and National Animal Breeding Policy among others. In the SP, strategic issues, objectives and proposed interventions were critically looked at, to establish their links with the NDDP's policy issues, objectives and proposed interventions.

Results national dairy development policy

Table 1. Main policy issues, problems and proposed interventions for strengthening policies and strategic plan implementation

Policy issue	Problem	Key Policy constraints	Proposed policy interventions
Dairy breeding	Diminishing quality of animal genetic resource	• Inefficient breeding programmes • Long calving intervals • Limited genetic evaluation • High cost of AI services and breeding stock	• Strengthening of breeders organization • Maintaining the regulatory and supervisory roles in breeding • Establishment and maintenance of gene banks • Development and strengthening breeding strategies

Policy issue	Problem	Key Policy constraints	Proposed policy interventions
Extension and advisory services	Dwindling farmer to staff ratio	• Low funding • Farmers' inadequate capacity to invest on new technologies	• Privatization of extension and advisory services • Development of legal instruments and modalities for restructuring extension and advisory • Strengthening the link between research and extension • Outsourcing of extension services
Animal health and veterinary services	Ineffective disease and pest control, leading to high incidences of livestock diseases	• Poor delivery and low funding of animal health and veterinary services • Tick control challenge • Conflicting and ineffective legislation to deal with disease control	• Privatization of animal health services • Reform the regulatory framework and attendant institutions for efficient delivery of animal health services • Facilitating para-veterinary working to practice through legislation
4 Dairy feeds and feeding	Inadequate feeding	• Lack of animal feed policy • Obsolete legislation (Fertilizers and Animal Feedstuffs Act).	• Promotion of alternative feed formulations and research to produce crops specifically for feed. • Increased private sector investment in small-scale and farmer-based animal feed supplement formulation • Increased investment in dry season feed • Repealing of Animal Feedstuff Act for its strengthening • Self-regulation in the feed industry
5.Dairy research	Underutilization of the existing dairy research capacity	• Poor prioritization of research agenda • Inadequate funding for dairy research • Inadequate coherence in research findings dissemination • Research focus predominantly in production, leaving other segments of the value chain	• Strengthening of research-extension-client linkage • Strengthening of dairy research • Enhance commercialization of research products • Expansion and diversification of sources of dairy research funds
Milk processing	Unstable processing sector	• Low production of long-life products to enhance rural and regional markets penetration. • Processors operating under capacity • Low demand for pasteurized milk	• Create tax incentives for cooperatives and private sector to invest in milk processing • Support investment in long-life milk products • Encourage milk processors to engage in milk collection in the rural areas

Policy issue	Problem	Key Policy constraints	Proposed policy interventions
Milk packaging	Unhygienic and unfriendly environment for packaging materials	• High cost of packaging materials • Shift towards use of inappropriate packages and unpackaged milk	• Promotion of development and adoption of cost effective milk packaging • Discourage use of packaging materials that are not environmentally friendly • Encourage local initiatives that use locally available materials in milk packaging
Quality control and assurance	Hygiene and quality standards of milk handled by informal marketing channels not guaranteed	• High cost of milk testing equipment • Inadequate skills on the use of the equipment • Inadequate milk quality assurance	• Putting in place quality testing and assurance systems • Incentives for milk testing equipment procurement and installation • Stakeholders sensitization on drugs safe use at the farm level • Strict enforcement of quality standards

Ministry of Agriculture, Livestock and Fisheries Strategic Plan (2013-2017)

Table 2. Livestock Strategic Issues, Objectives and Proposed Interventions for Enhanced Implementation

Strategic Issue	Objectives	Proposed Interventions
Inadequate policy and legal framework • The desire for an innovative, commercially oriented and modern agriculture as outlined in Kenya Vision 2030 continued to be undermined by weak policy and legal framework	To create an enabling environment for agricultural development • develop policies and legislations that attract investments in the sector.	Develop/ review the relevant agricultural policies • Develop 15 new policies that include Agriculture Policy; Veterinary Policy etc • -Develop/review strategies/legal and regulatory framework
Low productivity in the Agricultural Sector • Use of improved technologies by small scale farmers is still limited • Inadequate research-extension and farmer linkages • Inadequate demand-driven research and limited access to affordable credit.	To increase productivity and outputs in the Agricultural sector • Strengthen research, technology development and transfer • Promote access to agricultural inputs and financial services • Disease and pest control • Enhance animal genetics	• -Enhanced collaborative research • Enhanced advisory services and technology transfer • Enhance access to affordable and quality inputs like feeds, drugs etc; • Promote access to affordable credit. • Develop contingency plans for control and management of trans boundary pests and diseases • Develop strategies for surveillance and monitoring of animal diseases, antimicrobials and pesticides resistance development • Strengthen production capacity for the Kenya Animal Genetic Resource Centre (KAGRC)

Strategic Issue	Objectives	Proposed Interventions
	• Enhance livestock vaccine production at KEVEVAPI	• Increase the capacity for KEVEVAPI to produce adequate and improved vaccines.
Food insecurity • The strategic grain reserve inadequate to meet the Country's strategic food requirements • Many challenges that limit farmers' capacity to fully exploit their land and animal resources for sustainable economic and social development.	To enhance national food and nutrition security • Diversification and expansion of strategic food reserves. • Establishment of agriculture and livestock insurance	• Diversifying the strategic food reserves to include beans, rice, powdered milk, canned beef and tinned fish • Establishing fodder banks along stock routes and construct hay storage facilities in strategic areas. • Initiate and implement a public-private partnership insurance scheme to cushion livestock, fish and crop farmers from risks
Inadequate market access and unfavorable trade environment • Limited value addition and high production costs makes Kenyan agricultural exports less competitive in global markets.	To improve market access and trade for agricultural products	• Promote local and export markets • Establish export zones (establishing disease free zones, export abattoirs and slaughter houses etc) • Enhance capacity for compliance with domestic and export trade measures (Undertaking annual inspection and licensing of export slaughter houses, undertaking inspection and approval of milk processing plants etc.) • Enhance value addition for agricultural products (enhance capacity of county institutions on value addition; promote agriculture processing industries in the rural areas etc.)
Weak institutional capacity • Most government agencies face various challenges like inadequate technical capacity, organizational culture and accountability, conflicting mandate etc.	To strengthen institutional capacity • Institutional reforms • Information and communication management • Strengthen monitoring and evaluation • Develop information products and distribution mechanisms	• Undertake reforms and restructure sector institutions and parastatals for improved efficiency. • strengthen information and communication technology capacity, and establish agriculture information and knowledge management system. • Develop and implement a monitoring and evaluation framework to ensure delivery of key outputs in an efficient and effective manner. • Identify capacity gaps; develop and implement plans for capacity

Strategic Issue	Objectives	Proposed Interventions
	• Enhance capacity of the ministry for service delivery	development and mainstream youth, gender etc. • design appropriate information products and distribution channels (leaflets, brochures etc).
• Low Involvement of Youth in Agriculture	• To increase youth involvement in agriculture	• Promote new farming technologies • Technical and vocational training of youth in agriculture.

Monitoring and evaluation

The SP proposes putting in place a strong monitoring and evaluation system linked to the National Integrated Monitoring and Evaluation System (NIMES) that would ensure that the set targets and outputs are realized as outlined in the SP. It also has clear timelines on when monitoring and evaluation will be conducted and clearly defined roles of the actors from the policy makers to the implementers at the County level. The framework further indicates that all programmes and projects will have a dedicated budget to facilitate M andE operations and capacity building. The proposed M andE framework has clearly set out performance indicators at both national and ministerial levels. These include; National level- contribution of agriculture to national GDP, number of policies, legal frameworks and standards developed/reviewed and percentage growth of agriculture Gross Domestic Product. Ministerial level- average yield per unit of production for key commodities (litres of milk per cow per day), number of hay bales reserved and number of livestock breeds produced in national farms, among others.

Discussions

From the results, it is evident that there is a strong link between the national dairy development policy and the ministry's strategic plan. An elaborate monitoring and evaluation framework with clear performance indicators at both levels of governments is evident. It is also evident that if the strategic plan is implemented as set out, the policy issues and policy objectives will significantly be achieved in the set out timelines. The roles of various actors and partners in the agricultural/dairy industry are also well spelt out in the SP and therefore, if they play their set out roles well, the policy interventions will be achieved and hence highly contribute to the improvement of the dairy industry and agricultural sector at large. Policy document and strategic plan documents are also very explicit that the government has a very big role to play in terms of regulation, resources provision as well as implementation of the SP, with insignificant explicit contribution of the private sector and other partners. This may be an impediment to the implementation process, particularly at resources provision level. Though agricultural development is a devolved function, the policy document and the SP are not explicit on the roles of devolved governments, and their involvement in policy and SP development process.

Conclusion

National Dairy Development Policy is derived from earlier policies such as VISION 2030, ERS and SRA. Agriculture, Livestock and Fisheries Strategic Plan (2013-2017) is well linked to the NDDP and hence, if well implemented, the dairy industry will go a long way in contributing to improving the agricultural sector productivity. It can also be concluded that though the policy and SP documents have inclusions on private sector participation and public-private partnerships; it is not very explicit and hence, puts government at the forefront in policy development and strategic plan implementation, with limited room for self regulation in the industry. The policy also puts the government at the core of resource mobilization for sector development. The policy is therefore broadly weak on issues of private participation, self regulation and resource mobilization and there is need for its strengthening to improve the sector's productivity.

Recommendations

There is need to strengthen the existing polices and strategic plans. This can be done through their continuous review to enhance self regulation in the industry, public-private partnership and innovative ways of resources mobilization. Agricultural development is a devolved function in the current

constitution and hence the County governments have important and fundamental roles to play in policy development and implementation. Therefore, to strengthen the existing policies and strategic plan, there is need to enhance county governments' participation in all agricultural sector's policies and SP development, implementation and resources mobilization.

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A Policy Brief on Adopting the Somali Camel for Enhanced Profitability and Pastoral Resilience in northern Kenya

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Summary
Persistent drought and high temperatures in Isiolo and Marsabit counties of northern Kenya repeatedly devastate livestock herds particularly cattle making the pastoralists less resilient, more vulnerable to climate change and poor. In a bid to address this challenge, the IGAD funded 'Enhancing Resilience of Livestock-based Livelihoods in Northern Kenya' project sought to improve livestock productivity through promotion of adoption of Somali camel breed and capacity building on improved management of the same. The project also sought to understand marketing and estimate potential profitability of Somali camel rearing in northern Kenya as a business. Through the project, trainers were trained and facilitated to train 240 peri-urban Somali camel producers in Isiolo and Marsabit on breeding, health,

other management aspects and marketing. The project team conducted an impact study where positive stories of change were recorded from producers who had adopted the improved Somali camel management technologies. The stories confirmed that producers who hitherto made zero money from their camels had started making a net profit of up to KES. 42,000 a month from sale of 20 litres of milk daily from 5 milking camels; producers had adopted a new grazing management strategy that ensured daily access of the camel milk market and conservation of grazing areas around settlements; motor bikes had been adopted as means of hauling milk from the interior to collection centers thus creating jobs for the youth; producers had owned up that before the training, their camel health management knowledge and skills were limited and were yearning for more and, the beneficiary producers were spending more money on production inputs. These stories demonstrated impact of the interventions by the project. What this means in terms of policy is that the county governments of Isiolo and Marsabit need to appreciate the huge business potential in Somali camel rearing and the magnitude of positive change that can be brought about by capacity building of producers on improved camel management technologies and agree to allocate more funds in support of livestock production extension services. Further, the two governments should have a policy to ensure regular and reliable availability of quality Somali camel breeding bulls to producers in order to improve productivity and positively transform the economic fortunes of their people.

What was the issue?

Persistent drought and high temperatures in Isiolo and Marsabit counties of northern Kenya repeatedly devastate livestock herds particularly cattle making the pastoralists less resilient, more vulnerable to climate change and poor. The poverty index in the two counties was recently calculated at about 70%, compared with the national average of 48% (Government of Kenya, 2013). Apart from climate change, livestock productivity around which the local economy revolves has been hampered by factors including poor management and breed choice. Climate predictions in northern Kenya indicate that mean temperatures may increase 3–4°C by 2100 leading to even less water being available for livestock and natural pasture production. In response therefore, the 'Enhancing Resilience of Livestock-based Livelihoods in Northern Kenya' project sought to improve livestock productivity through promotion of adoption of Somali camel breed and capacity building on improved management of the same. The Somali camel breed produces more milk, gains more weight and produces more meat, fetches higher price in the market and has higher load capacity compared to other breeds of camel in Kenya. Considering that feed resources will become more scarce in future owing to climate change and human activities, it makes sense to keep few but more productive animals that will also help in climate change mitigation by releasing less greenhouse gas to the atmosphere. The project also sought to understand marketing and estimate potential profitability of Somali camel rearing in northern Kenya as a business.

What did we do?

The project intervention activities included sensitization and awareness creation of advantages of Somali camel compared to other breeds and livestock species, capacity building on selection and breeding, health among other management practices and marketing. The capacity building activities mainly focused on the peri-urban production system and was implemented through training of trainers, covering theory and field demonstration sessions. The trainers subsequently trained a total of 240 Somali camel pastoralist in selected sites in Isiolo and Marsabit counties. The project technical team monitored and evaluated the program and collected impact data. In implementing the activities, the project team worked closely with field extension personnel to ensure sustainability of the efforts beyond the project implementation period.

Figure 1. An animal health theoretical and practical session in progress in one of the sites training in Kipsing

Figure 2. A practical session on live weight estimation in another working site

What did we learn?

Somali camel keepers require capacity building in most management aspects, with priority on breeding and health in order to optimize performance of the genetically high potential camel. The need for training is higher in Marsabit County where commercial rearing of Somali camel is in the formative stage.

In areas where camel production system is commercialized, farmers tend to invest more in production inputs (upwards of KES. 46,000 for an average herd of 35 in Isiolo), commit more time in managing the camels and adopt improved management knowledge and technologies in pursuit of profit. This makes camels in such a system perform better compared to the conventional subsistence oriented production system. The former and latter were the cases in Isiolo and Marsabit, respectively.

Taking cognizance of pastoralists who managed the Somali camel using indigenous knowledge and attained at least KES. 10,000 per month in Isiolo, training camel keepers on improved camel management technologies and practices has potential for increased profitability. . However, this calls

for revival and strengthening of extension service in Isiolo and Marsabit counties where the service is currently limited.

Stories of change

During a monitoring and evaluation visit to some of the working sites, the following emerged; Speaking to two Somali camel keepers who benefited from training, the farmers were emphatic that "the idea of

camel milk marketing was very exciting and that one of them was selling 20 litres of camel milk daily earning a net of KES. 1,400 after paying the transfer costs. This translated to a monthly net income of KES. 42,000. The other farmer was selling 10 litres of milk daily earning KES. 21,000 a month. Unlike the situation prior to the training, the farmers reported that they purchased mineral salts for camels to enhance health and milk yield. The group of trained farmers held a meeting after the training and agreed on a grazing management strategy that would ensure continuous delivery of milk to the market. The strategy entailed herding lactating camels in groups of 3 – 4 and in locations accessible by motorbikes to facilitate milk collection every morning. The strategy also required relocation of some camel herds closer to the main road to Isiolo to avoid overgrazing in areas around market centers and to ensure milk is directly collected by the vehicle transporting milk to Isiolo town". This was a crucial story of change considering that in late 2014 when the project was starting, not a single drop of camel milk was being sold from the area, yet there was a high concentration of camels and surplus milk was being wasted. However, the project technical team on two occasions engaged and challenged the local pastoralists to consider selling the milk and demonstrated to them through simple calculations that the milk would indeed pay with the use of motorbikes which were already available in the market centre. As the project team was visiting the site for monitoring and evaluation, camel milk marketing had already started as illustrated in the following pictures;

Figure 3. A motorbike (*boda boda*) rider ferrying 90 litres of Somali camel milk from a site called Barambate to Kula Mawe market Centre, with target of Isiolo Market

In total, there were six *boda bodas* (motorbikes) transporting about 400 litres of camel milk to Kulamawe to link with the vehicle transporting camel milk to Isiolo town. The milk was generating about KES. 25,000 daily for the local camel keepers and had created some jobs for the youth (*boda boda* riders) who were earning KES. 600 to 1000 every morning from milk transportation.

In another site called Shurr in Marsabit county, camel milk business had also started as a result of the project interventions and the team in fact met one Toyota Land Cruizer on the way to the site for monitoring and evaluation, ferrying milk to Marsabit town and gathered that 2-3 such vehicles were picking camel milk every morning and delivering the same to town. In another site called Kipsing in Isiolo County, the project team interviewed two beneficiaries of the training as illustrated in the following picture;

Figure 4. A member of the project team interviewing two beneficiaries of the training

The team captured stories such as the following: camel keepersyearned for more interventions because they initially assumed they had adequate knowledge in camel management but the training proved them wrong; they were impressed by the health management practical training which exposed them to the right drugs for treating, correct dosage determined on the basis of live weight of camels, correct route of administration for various drugs; they had learnt how to manage ticks in the camel nostrils using pour-ons which had previously proved very difficult for them and the training had built their confidence in managing camels. The farmers confirmed that the few camels treated during the practical training had recovered despite having been sick for long prior to the training. The farmers had also learnt how to manage breeding especially crossbreeding Turkana or Rendille camel with the Somali camel by buying bulls instead of the females as had been the practice before. Having been sensitized on the price of camels in the main markets, the farmers had realized they had been exploited by the traders who had bought their camels very cheaply for a long period and making a kill from the same in the main markets. The farmers confirmed that after the sensitization meeting and the training, the number of Somali camels brought to the market for sale had significantly reduced as they discussed how to deal with the problem of exploitation. The feedback further indicated they had embraced marketing of camel milk seriously saying the local demand was high. One of the farmers had two milking camels from which he was selling 5 litres of milk daily earning KES. 500 (about 5 USD) i.e. a 100 per litre. He had two wives and the money was shared between the two, each getting KES. 200 every day while he retained KES. 100. He said that following the training, he would manage the camels better to increase milk yield and increase the daily revenue.

These stories clearly demonstrate change and impact of the project interventions.

What are the policy implications?

The county governments of Isiolo and Marsabit should consider the following priorities:

- Promoting rearing of Somali camel particularly in the peri-urban areas by putting in place strategies that will ensure availability of breeding stock particularly bulls, training farmers on improved management technologies and marketing, either singly or in liaison with other stakeholders. This would guarantee farmers reasonable income thus making them more resilient to climate variability.
- Recognizing the importance of extension service in improving livestock productivity and agreeing to commit financial resources in support of the same.

What next?

- Devising strategies to avail Somali camel breeding material to camel pastoralists in Isiolo and Marsabit counties.
- Initiating capacity building on most of the management aspects of Somali camel especially in Marsabit County where commercial rearing of the camel is in the formative stage.

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Gender issues along the meat value chain: The case of beef marketing in Kenya

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Abstract

Gender responsiveness enables identification and integration of gender concerns in development initiatives. The livestock industry in Kenya is a major source of livelihood for many in the rural and urban areas. The industry has significant potential towards promoting gender equity among the input suppliers, producers, processors and traders. A market study to assess the roles, access and control of benefits in the beef value chain was conducted in rural and urban markets in Eldoret and Nairobi towns. The qualitative data collected showed that though both men and women were involved in the beef value chain with clear roles, significant gender differences existed, hindering equal participation and benefits for women. However, more men compared to women were involved in purchasing live cattle for slaughter and selling raw beef, boiled meat, and roasted beef *(nyama choma*). Women were - engaged

in different beef value addition activities such as cooking, selling meat and and beef dishes. Women reported lack of necessary support from their spouses to do business. In addition, they faced gender-related constraints including sexual harassment. The working hours, environment and worker preferences favored men more than women. These findings point to the importance of inclusion of a gender perspective in livestock development and commercialization initiatives to ensure that gender concerns are identified and appropriate strategies put in place to ensure equal benefits for men and women towards improved livelihoods and wellbeing.

Key words: Gender, Beef , Value chain, Men, Women, Marketing

Introduction

Gender is globally recognized as important in achieving outcomes for rural development. Numerous efforts have been made at the international level towards ensuring that gender is mainstreamed in the development agenda (IFAD, 2010). These include international mandates (ILO, CEDAW, Beijing Platform for Action, MDGs) that national governments are signatories and inclusion of the need for gender responsiveness in Kenya's policy documents (PRSP, ERS, Vision 2030, NASEP, GoK, 2007). Gender inequality has negative affects on development efforts and presents a challenge for sustainability of development gains at individual, household and country level (SID 2010).

Gender mainstreaming is now a globally accepted strategy for promoting gender equality. This ensures that gender perspectives are central in all activities from policy development, research, advocacy/dialogue, legislation, resource allocation, planning, and implementation, to monitoring and evaluation of programs and projects (UN Beijing Platform for Action,1995). It is important that programs and projects are clear on objectives and how they relate to gender and equity issues. Gender as a cross-cutting socio-cultural issue determines how women and men actors participate and benefit from the various agricultural value chains in society (Farnworth, 2011).

Beef cattle are slaughtered, processed and marketed throughout the year without defined seasonality. Most households in the African rural society have access to livestock and are involved in the value chains activities. Men's and women's roles within the beef value chain differ from region to region as well asaccess and control of resources and benefits. Depending on the community, male-tasks include; herding, sourcing for feed and fodder, fencing, construction of housing and veterinary services. Women take charge of feeding, watering and caring for young and sick animals. Both men and women play major roles in processing, value addition and marketing of beef and their products. However, gender inequalities exist in that men and women do not have equal control over the production or benefit from their labour in the value chain. In most cases women lose control of the value chains particularly when the products achieve higher economic importance (Manfre, 2013).

Gender mainstreaming efforts in the beef and milk value chains require an understanding of the existing relations and associated gender inequalities and their implications on chain development initiatives. This enables development agents to develop appropriate gender integration strategies that ensure both men and women participate and benefit from the livestock sector. This study sought to understand participation of men and women in beef industry in Kenya with particular emphasis on processing and marketing.

Methodology

The study was conducted in wholesale and retail beef markets in the Nairobi main beef markets in Burma and ten beef retail shops (butcheries) within Nairobi and Eldoret towns in Nairobi and Uasin Gishu Counties respectively. Qualitative data was collected through literature review, interviews with individual traders, observations and photographs. A total of 8 beef traders (male traders-3, female traders -5) involved in the trade as wholesalers, brokers and retailers; and 10 workers in the meat market (male workers-5 and women workers-5) in each town. The interviews were guided by a check list focusing on gender issues in the beef value chain from sourcing of the beef cattle for slaughter to value addition of the beef. The data collected was analysed by identifying, examining and interpreting it to capture the

gender issues/concerns in the beef value chain. The information which was backed with photographs and information from literature was synthesized.

Results

Types of beef traders

The rural and urban beef value chains were slightly different in terms of the types of traders involved in the chain. Four different types of beef traders (wholesalers, brokers, retailers and processors) were identified in the urban beef chain compared to two types of traders in the rural town namely the retailers and processors. However, both men and women were involved in the market value chain segment with more men compared to women. Wholesalers inurban markets were involved in buying and slaughtering of live cattle, delivering and selling beef in designated wholesale meat markets such as Barma market in Nairobi. Wholesalers sometimes travelled long distances for example from Nairobi to buy cattle for slaughter from individual farmers or from livestock cattle markets in rural areas such as Basil in Kajiado County. Live cattle were then either slaughtered in slaughterhouses within the buying areas and/or transported live for slaughter in a slaughter house closer to the wholesale market e.g. Dagoretti slaughter house in Nairobi County before transportation of beef to wholesale markets and/or retail shops commonly known as butcheries for sale to consumers.

Brokers, commonly referred to as middlemen were mainly involved in buying of whole carcasses and/or part of the beef from wholesalers at the main meat markets. These type of traders comprised more men compared to women. Unlike wholesalers who mostly bought and slaughtered cattle based on market demand, brokers ordered and/or bought beef from wholesalers to deliver orders by different institutions including schools, hospitals, military camps, hotels and/or retail outlets such as butcheries.

Retailers comprising both men and women bought live cattle and slaughtered for sale directly to consumers in rural towns and/or bought small quantities of beef from wholesalers at the meat market like urban retailers who then sold off the beef in small quantities directly to small hotels (food kiosks) and consumers.

Gender and gender roles in the beef value chain: market segments

Gender differences and concerns in the beef value chain affected how men and women participated and benefited from the chains. Men and women engaged in similar and sometimes different roles in beef value chain. Both men and women traders were engaged in sourcing and buying of cattle for slaughter as well as selling raw beef. Traders in Nairobi markets had to be at designated cattle market and/or at the slaughter houses in Bassil and Dagoretti markets, which served as the main sources for Nairobi markets mostly early in the morning, between 5am and 6am. In addition to strong negotiation skills, physical strength was necessary for one to get the best animals at the lowest price possible from the markets, a power that women lacked. This resulted in women losing the best bet cattle. In some cases, men would forcefully pay for the animal (cattle) identified and negotiated by women traders. The results further revealed that both male and female traders sourced for cattle for slaughter while selling raw beef at the market store was done by male and female traders and male and female workers. The cleaning, cutting and chopping of meat in preparation for roasting and boiling was done by male and female workers but with male workers doing most of the work. Male workers also slaughteredcattle, loaded meat on and off the vehicle and bicycles, lit the meat grills and *jikos*, cleanedmeat stores (places where the beef was displayed for sale), and provided security. Male workers also roasted and served roasted meat and wooed customers to eat the roasted beef while female workers cooked and served fried and boiled beef dishes. Both male and female workers were involved in preparation of beef value added products (roast, boil and fry), accompaniments mainly *mukimo* (green maize mashed with potatoes and green vegetables) and ugali. Both male and female workers washed protective clothing, with women doing most of the work (Table 1).

From these results though, women have ventured into the business but men still dominated. Women seemed to engage more on activities associated with women socially and culturally, which also had lesser benefits for women compared to their male business counterparts earning a living from the beef

value chain. Roasting of beef was most popular and paying for value added beef products was dominated by males. This may be due to cultural beliefs, stereotypes and/or the nature of the work which further disadvantages women in the beef value chain. It was of concern that the few women who owned *nyama choma* kiosks faced gender-specific challenges such as sexual harassment and discrimination from their male business colleagues and customers.

Table 1. Activity profile for the beef value chain

Activity	Gender Involvement			
	Male traders	Female traders	Male Worker (MW)	Female Worker (FW)
Sourcing and buying of the live cattle for slaughter	x	x	-	-
Slaughtering of the cattle	-	-	x	-
Loading on and off of the carcass (beef)	-	-	x	-
Cutting/chopping of the raw meat (beef)	x	-	xx	x
Selling of raw meat (Beef)	x	x	x	x
Cleaning of premises (floor)	-	-	xx	x
Washing of protective clothing	-	-	x	xx
Preparation of beef for roasting and boiling	-	-	x	x
Lighting of roasting grillers/jikos	-	-	x	-
Roasting and serving of beef	-	-	x	-
Cooked and served fried and boiled beef dishes	-	-	-	x
Preparation of beef accompaniments (Mukimo and Ugali)	-	-	x	x
Wooing the customers to buy beef	-	-	x	-
Clearing of the utensils	-	-	x	xx
Provision of security	-	-	x	-

Key = xx- more involvement x- less involvement

Gender access to and control over resources in the beef value chain

Male and female traders had equal opportunities in the access to and control over beef value chain resources., . However, male traders had better access to animals (cattle) for slaughter and customers (for buying meat or carcasses once at the main meat market in the town) compared to women traders. Of importance was that both male and female traders, and workers reported not having had access to any formal education and training on meat handling (Table 2).

Table 2. Access and Control Profile

Resource/ benefits	Access				Control			
	MT	FT	MW	FW	MT	FT	MW	FW
Resources								
Business premises	x	x	-	-	x	x	-	-
Business license	x	x	-	-	x	x	-	-
Medical certificate	x	x	x	x	x	x	x	x
Employment	x	x	x	x	x	x	x	x
Cattle for slaughter	xx	x	-	-	x	x	-	-
Education and training on meat handling	-	-	-	-	-	-	-	-
Lack of customers	xx	x	x	-	x	x	x	x
Benefits								
Financial	xx	xx	x	x	xx	x	x	x
Tips from customer	-	-	x	x	-	-	x	x
Social status	x	x	-	-	x	x	-	-

Key = xx- more involvement x- less involvement

Gender challenges and constraints in the beef value chain

The male and female traders alike faced constraints such astravelling long distances in search of animals for slaughter, unavailability of quality beef cattle, high market price fluctuations and high competition at the main beef market (Burma market). Traders with high quality beef ended up selling the beef at lower prices due to influx of low quality beef that was allowed into the market by the persons entrusted

with the running of the market by the authorities, laxity of law enforcers (meat inspectors) resulting in high competition withlow quality meat, uncontrolled preservation of unsold beef exposing consumers to high food safety risks, and long working hours. In addition, women experienced sexual harassment and disrespect from their male colleagues in business or workers. Other challenges included harassment of traders and workers by the local authorities, high cost licenses, lack of adequate customers, poor water supply and poor maintenance of the general market in terms of cleanliness.

Discussions

The beef value chain plays a key role as a source of income and livelihood for both rural and urban households. However, gender differences and concerns affected how men and women participate and benefite from the chain.Men have dominated the most profitable segments of the beef value chain starting from production to marketing, reducing the opportunity for women to benefit fully form the chain. However, this has been changing slowly with more women venturing into the value chain from rearing of beef cattle which has traditionally been in men's domain (DNA, 2018). Some of the challenges of the beef business for both men and women include the odd hours of transacting business particularly sourcing and slaughtering beef cattle which had to be done in the wee hours of the morning. Sometimes traders had to travel in the night and/or put up in areas closer to the cattle markets. This exposes traders (men and women) to several challenges including abandoning their reproductive roles, sleeping away from their spouses which can expose them to sexually transmitted diseases and contacting HIV among other challenges. Working away from home including temporary migration such as the one occasioned by traders going far from their homes to source for cattle for slaughter have been identified as some of the drivers of sexually transmitted disease including the HIV (Weine, and Kashuba, 2012). Women also lost the opportunity to buy the best animals for slaughter as some of the men would use their masculine power to pay for the cattle at the expense of the woman, just because of her gender inclinations. Similar, results have been seen in many other fields such as politics that render women as subordinate to men and men try to flex their masculine power over women (Keskin, 2018). In recent times, women have also ventured deeply into the beef value despite the stiff competition from male counterparts and sexual harassment from colleagues and customers. However, results from this study show male dominance on beef segment particularly of the most popular value added beef product, the roasted meat. This may be attributed to social, cultural and traditional norms and briefs that led to women being more responsible for rearing of livestock and not engaging in the meat activities including value addition and marketing. Over the years, this had been dominated by men denying women the opportunities to draw equal benefits from the value chain. Yet, new family trends and patterns have led to changes in gender roles, especially the expansion of female roles to include economic provision for family (Olah *et.al.* 2014).

Conclusion and Recommendation

Gender mainstreaming is crucial since women though responsible for the bulk of the work along the livestock value chains tend to lose out at the marketing segment. Livestock development projects need to review existing technologies and products in order to identify and promote those that have a high potential towards enabling women to participate and benefit from all the livestock value chains including beef. As earlier recommended by Njuki *et.al.*, (2010) strategies aimed at encouraging and reducing women's loss of income resulting from increased commercialization along the value chain ought to be enhanced. All development interventions targeting any segment of the chain should be responsive to gender needs of all stakeholders for efficiency, effectiveness and sustainability of the value chain. Measures should be taken on all those who violate meat work ethics and failure to adhere to meat inspection and food safety as illustrated in the meat policy. This will ensure equal competition for all beef traders as well as food safety for the consumers. Reduction of gender inequalities in the beef value chain can also be improved and enhanced by establishing cattle markets closer to rural and urban meat markets and creating more awareness on the need for both men and womento venture into the business. This will not only ensure equal access and benefits for men and women in trade in terms of accessing and buying live cattle for slaughter but will also enhance family relationships and wellbeing.

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Access and Use of Information in Dairy: A Case Study of Meru and Uasin Gishu Counties, Kenya

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Abstract
Access to information is a major determining factor in adoption of dairy technologies. Insufficient information impedes the use of technology to improve the quality and safety of dairy products. A survey was conducted in 274 smallholder dairy households in Meru and Uasin Gishu Counties in Kenya. The objectives of the study were to determine the type and source of information used, and the level of information use. Descriptive statistics were used to analyse the data.

The information obtained was mainly from input suppliers, milk buyers and farmers. Information on quality aspects in dairy was minimal with 17% of the respondents indicating that buyers provided information on quality and standards of milk. Majority (90%) of the respondents reported that no member of their family had been trained on value addition. Those who were trained accessed the training from the government.

The smallholder dairy actors mainly interacted with other players in the dairy value chain for information, but had weak links with regulators and providers of quality and safety standards. The present sources of information (suppliers and consumers) bring about information asymmetry. In addition, smallholder dairy actors did not actively look for other sources of information, thus relying on traditional knowledge from the government. The service provider institutions should provide more information on quality and safety. In addition, the smallholder dairy actors should be proactive in looking for the information.

Keywords: Smallholder dairy, quality and safety, sources of information.

Introduction

Dairy is one of the most important agricultural sub-sectors in sub-Saharan Africa (SSA), with a huge potential for alleviation of poverty and improving food security and nutrition. Raw milk production is a major source of employment for the rural population. Of the milk produced and sold in Kenya more than 80% comes from the smallholder players, the informal sector (GoK 2008). Milk production in SSA is characterized by high dependency on rain-fed fodder hence the industry experiences sharp fluctuations in milk production throughout the year. According to Kipkirui (2012) productivity is extremely low, with some countries in Africa recording as low as 174 Kg/cow/year compared to over 12,000 Kg/cow/year in developed countries. Scarcity of feed resources and their poor quality are major constraints to improving production and reproduction performance (Ngendello *et al.*, 2013). Improved supplementation of dairy cows has been shown to increase milk yield in Coastal Kenya by about 19% to about 2,195 litres/cow/lactation (Muraguri *et al.*, 2004). Smallholder dairying in particular improves the household productivity and market participation by the poor (ILRI, 2007). One of the strategies to increase productivity is through improved access to knowledge by smallholder producers.

Dairy is a significant source of income and employment in Kenya. Milk is part of the farm produce that generates cash on a regular basis and it is one of the foods consumed by almost all Kenyans of all ages in large quantities (Mulford, 2013). According to FAO (2011), at the farm level, dairy activities are estimated to generate, for every 1,000 litres of milk produced daily, about 23 full-time jobs for the self-

employed, 50 permanent full-time jobs for employees, and three full-time casual labour jobs, making a total of 77 direct farm jobs per 1,000 litres of daily production, or a total of about 841,000 full-time jobs (585,000 for full-time hired workers and 256,000 for self-employed/farm owners). In the processing sector, 13 jobs are generated for every 1,000 litres of milk handled, or a total of about 15,000 jobs. The informal sector accounts for about 70% of the jobs in dairy marketing and processing, generating 18 employment opportunities for every 1 000 litres of milk handled, or a total of 40,000 jobs.

Dairy marketing particularly in Eastern Africa region is dominated by the informal sector collecting raw milk from the farmers and selling it unprocessed directly to consumers. This brings to the fore issues of quality and safety. A study on Food Safety Risk Analysis conducted in Tanzania showed that milk marketed by smallholders directly to consumers or through intermediaries had unacceptably high numbers of bacteria, and the probability of consuming milk containing *bacillus cereus*, a toxin-producing pathogen, was as high as 22% (Kilango, 2010). There is low usage of technologies and practices that would ensure high quality milk production, processing and marketing. Value addition and vertical integration of dairy value chains remains a challenge especially in smallholder dominated production systems. Producers are scattered and may not be producing enough milk to attract processors through bulking. Moreover, there is the policy and institutional environment within which smallholder actors should operate to which they have limited knowledge of.

From the foregoing paragraph it is apparent that dairy plays a significant economic role in the livelihoods of smallholder dairy farmers. However, dairy is an enterprise that is information-intensive, making information the main determining factor in the adoption of dairy technologies, but still a challenge to smallholder dairy farmers. This information can come from the government, the private sector, and farmers' organisations. It is on this premise that the study was conducted to understand the access and use of information among smallholder dairy farmers in Meru and Uasin Gishu Counties in Kenya. The overall goal was to improve access to information to the smallholder dairy producers in Meru and Uasin Gishu Counties. The specific objectives were to:

a) Determine the type and source of information used by smallholder dairy farmers
b) Determine the level of information use among smallholder dairy farmers
c) Give recommendations that will improve access to information by smallholder dairy farmers.

Relevant information to adoption is important especially in specialised technologies like those in dairy. Changes in consumer tastes and preferences due to increased income, and requirements by regulatory bodies for high quality and safety standards has created new opportunities for increased dairy products in the region. In the East African Community region, high demand for dairy products exists due to the increased demand for quality and safety. This demand is partially met by large producers and processors in the region, or through importation. This trend leaves out the smallholder dairy farmers from the emerging benefits in dairy. The willingness to pay for value added dairy products appears to be influenced by consumer considerations for quality and safety (Makokha and Fadiga, 2010). From the consumer and regulatory perspectives, milk and valued added products produced by small and medium enterprises are of low quality and safety standards which leads to low demand of local products compared to imports. A study on Exploiting Market Opportunities for Value Added Dairy and Meat Products in the East and Central Africa (ECA) region shows that consumers in both conventional and niche markets expect dairy products to be of high quality and safe with regard to hygienic handling, taste and flavour, shelf life and packaging (Kurwijila *et al.*, 2011).

Methods

In each county, a sampling frame from the area Agricultural Officers and collective action groups was obtained, from which simple random sample of 300 households was obtained. After data cleaning, a sample of 274 households (140 from Meru and 134 from Uasin Gishu County) was obtained and interviewed in the year 2013 usinga structured questionnaire. Data was entered and analysed usingStatistical Package for Social Scientists (SPSS). Descriptive statistics by use of percentages were used to analyse the data.

Results and Discussion

Only 24% of the respondents had a tertiary level of education. It is known that education is useful in understanding messages, especially in dairy where a lot of information is required. Lapar and Pandey (1999) and Feder *et al.*, (1985) singled out the importance of education in technology adoption. It creates new interests, broadens expectations, and generates a consciousness of deprivation, thus prompting educated people to seek for ways to improve their condition. Therefore, a low level of education may imply less efforts in looking for information.

Over 90% of the respondents marketed their milk individually. From a sample size of 273, 89% sold their milk in raw form, 58% had no quality requirements from their buyers and 78% were not aware of any national or international standards for milk and dairy products. About 66% (n=256) had inadequate skills in animal husbandry and 55% (n=253) had inadequate information on new technologies. These statistics depict the smallholders' low quality and safety levels of the milk, and the low levels of information on quality and safety.

Markets for raw milk were easily available. However, about 80% (n=194) said they did not get good prices for their milk, 43% (n=273) said they had no bargaining power and 63% (n=219) said they had weak contractual arrangements with their buyers. Fresh milk is highly perishable, thus buyers take advantage of this by offering low prices, especially during times of glut. Value addition would be the best strategy to increase the shelf life of milk and fetch higher prices. Information from buyers was mainly on costs and prices, new market trends and available business services (56%, n=256). Only 17% of the respondents said they got information from buyers on market requirements/quality standards. About 64% (n=259) of the respondents said the information they got from their suppliers was mainly on the suppliers' products and services. However, 23% of them said the information received from their suppliers was unreliable. The buyers and sellers of milk in the dairy value chain are more concerned with the profits than with the quality and safety of milk. The dairy regulators in the value chain can give information that increases the quality and safety of milk.

About 90% (n=273) of respondents said no member of their family had been trained on value addition. The few who were trained accessed the training from the government. Thus, knowledge used by the households was mainly from other farmers or traditional knowledge. This result depicts the fact that there is a huge deficit in knowledge on value addition, but the government may not have the capacity to provide this information.

Provision of regulatory services in the dairy sector is solely the work of the government. Figure 1 shows the proportion of households that were influenced by regulatory boards in different aspects of dairy.

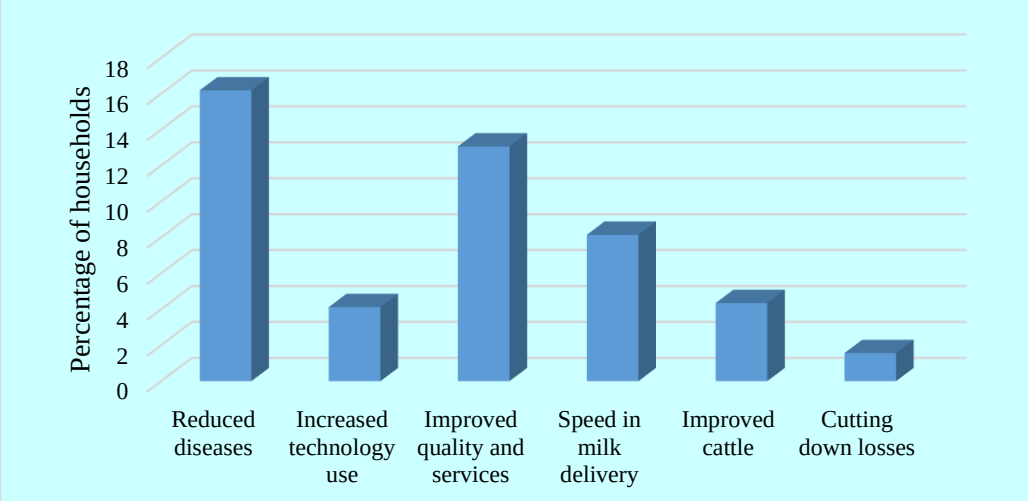

Figure 1. Percentage of households influenced by regulatory institutions in various factors in Meru and Uasin Gishu Counties

Generally, less than 20% of the respondents said they have been influenced by the regulatory institutions in conducting their dairy activities. About 16% of the respondents were influenced by regulatory boards to control diseases. Only 14% of the households had been influenced by the regulatory boards to improve the quality and safety of milk. Influence in increased speed in milk delivery and acquisition of improved dairy cattle breeds was reported by only 9% and 5% of the respondents respectively.

Conclusions and Recommendations

This study showed that the smallholder dairy actors mainly interacted with other players in the dairy value chain for information, and had weak links with regulators and providers of quality and safety standards. The results depicted minimal interventions made by regulatory boards in giving information to smallholder dairy farmers. The present sources of information (suppliers and buyers) may bring about information asymmetry; where the farmers have limited knowledge on better prices and markets to the advantage of their buyers and suppliers, and very limited knowledge of quality and safety. This may bring about exploitation of the farmers by other players and a failure to access better markets.

The standards for quality and safety were low and limited intervention by regulatory bodies. The farmers had made minimal effort in acquiring information on their own.

The government should step up efforts in increasing awareness on the potential benefits from dairy. This would create demand for services to increase quality and services and there will also be efforts to comply with the rules and regulations in dairy so that they can acquire better markets. The private sector would then be encouraged to invest in smallholder dairy farmers.

The Kenya Dairy Board and the Kenya Bureau of Standards should be involved more in dairy. The smallholder dairy farmers are at a very low level of knowledge regarding their policy and institutional environment within which they should operate. Farmers to organise collective bargaining for better prices and sound contractual agreements. It is through collective efforts that they can also seek for information on production and value addition.

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Transforming Livestock Sector in Kenya: Exploring the Future to Formulate Resilient Sector Policies

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Abstract

Kenya is in the midst of unprecedented demographic, socio-economic, policy and technological transformation. In the next three decades, population growth is expected to double (96 million) and nearly 50 percent of the population will live in urban areas. GDP per capita is projected to increase by 142 percent by 2050. These transitions will have major implications for Kenya's agriculture, including an exponential growth in demand for animal source foods. Available projections suggest the Kenyan livestock sector will go through enormous changes in the coming decades. The sheer numbers are impressive: Demand for livestock products will surge, with consumption of many types of meat almost tripling. It is estimated that, by 2050, milk and beef production will increase by 191 and 153 percent, respectively, and poultry production by 447 percent. The livestock standing stock will pass from 14 to 30 million Tropical Livestock Unit (TLU), with the cattle population increasing from 18.5 to over 35 million head and the poultry flock from 35 to 166 million birds. Although the projections do not provide succinct details on how the transformed livestock sector will impact society, they point to a multiple of opportunities, challenges and threats. For example, livestock farmers will have the opportunity to expand production and marketing to meet the growing demand for animal source foods. At the same time, there could be increased risks of outbreaks of emerging infectious diseases associated with higher animal and people densities, increased challenges in managing animal waste, which could also be considered an opportunity to produce green energy. To better tap into these opportunities and more effectively address the challenges, the Government of Kenya and FAO through the implementation of Africa Sustainable Livestock 2050 project has developed long-term scenarios for the livestock sector which, by exploring in details the foreseen opportunities and issues, provide evidence to the government to take action now

in order to ensure the livestock sector grows a sustainable trajectory. The scenarios show, on the one hand, that there will be increased risks of emerging infectious diseases and of inappropriate use of antibiotics in animal farming as well as increased pressure on natural resources. While many of these issues are already addressed by the current policy framework, current policies marginally focus on emerging farmers – the semi-intensive producers who are anticipated to become a major player in the future livestock sector – and lack to appreciate the fast rate of urbanization, with Kenya in 2050 anticipated to be largely an urban country while, today, it is still rural. This requires a rethink on value chains approach and the role of previously excluded actors such as city governors in supporting sustainable livestock chains. Re-considering the current policy framework in view of the above findings, and generally using a long-term perspective to policy making, is essential to put in place resilient policies which will ensure a sustainable livestock sector in the long run.

Key words: Livestock, Transforming, Resilience, Infectious diseases, Food

Economic Losses due to Poor Welfare of Meat Chickens in Kenya

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Abstract

The World Organization for Animal Health (OIE) defines Animal Welfare as how well an animal is coping with the environment where it lives. This definition is based on the five basic freedoms: freedom from hunger and thirst; freedom from discomfort; freedom from pain, injury and disease; freedom to express normal behaviour and freedom from fear and distress. As a follow up on the study on the impact of environment on the welfare of broiler chickens and specifically to determine if the farmers were making any losses due to poor environment, handling, transportation and slaughter process World Animal Protection constituted a study in collaboration with University of Nairobi and one of the large poultry producers in Kenya. The primary data was collected from medium to large scale broiler farmers within four counties – Nairobi, Kiambu, Machakos and Kajiado while additional secondary data was collected from condemnations and rejects at a large scale processing plant in Kiambu.

The study indicated that around 6% of the birds die due to the birds being kept in poultry houses which are poorly ventilated with inadequate and often wet litter compounded with poor hygiene. The report estimates that for an average farmer having a flock of 22,000 birds this loss is equivalent to KES 24,002 per crop. The study further revealed that poor handling when the birds are being caught and loaded to the crates to take them to the processing plants leads to bruises on the breasts, thighs and wings of the birds. In some instances, the birds even end up with broken legs and wings. The bruising and fractures can also occur during transportation if the road is uneven and the drivers don't drive carefully. Birds with bruises and broken limbs are downgraded i.e. they don't earn the premium price from the processors. The study estimates that averagely 0.77% of the farmers production in each crop was downgraded causing the farmer a loss of KShs 48,415. The report estimates that approximately 1.18% of the birds arrive at the processing plant when already dead due to suffocation. Such birds are outrightly rejected by the processing plant leading to the farmer losing a further KShs 80,934 per crop.

In conclusion, the study shows that large scale meat chicken farmers are losing slightly over KES153,000 per crop due to poor animal welfare practices on the farm and during transportation. This reduces their potential earnings by almost 20%.

Key Words: Birds, Poultry, Producers, Medium, Large scale, Broiler, Farmers

Gender Dynamics in Indigenous Poultry Enterprise Ownership and Newcastle Disease Control in South Eastern Kenya

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Abstract
Women are perceived as the main actors in poultry production and to this end, efforts by research and Development (R andD) agencies to promote poultry production as a development tool towards women empowerment is ongoing. This study presents an analysis of sex- and age-disaggregated data from a poultry enterprise survey of 511 indigenous poultry keepers in Machakos and Makueni counties. The objective of the study was to assess the extent of ownership of indigenous poultry enterprises by women; and understand gender dynamics in control of Newcastle disease which is a major constraint limiting poultry production. Among other results, the study revealed that less than half (46.2%) of indigenous poultry enterprises in the study area were owned by female poultry keepers. Female adults were lagging behind in poultry production with the smallest flock sizes and highest mortality rates attributed to Newcastle disease.

Keywords: Women, Gender, Indigenous poultry, Ownership, Newcastle disease.

Introduction

Rural poultry flocks account for 60-90% of the poultry population in lower and middle income countries (Akinola and Essien, 2011) and are an important source of food, nutrition and income security. Meat and eggs from indigenous chicken are a source of nutritious food including essential macro and micro nutrients, and the role of indigenous chicken in income generation is well recognized (Wong *et al.*, 2017). According to Moerad (1987), indigenous chicken provide more than 25% of the monthly household income while 35% of women's income is derived from poultry production (Alabi *et al.*, 2006). Taking cognizance of women as the main actors in poultry production, and the role of indigenous chicken in food, nutrition and income generation, numerous research and development (R andD) agencies are promoting poultry production as a development tool towards women empowerment. However, there is a dearth of empirical evidence on the extent of ownership of indigenous poultry enterprises by women.

Newcastle disease is a threat to poultry production worldwide and a major constraint with a significant economic impact in Kenya ((Njagi *et al.*, 2010, Kapczynski *et al.*, 2013, Otim *et al.*, 2007, Kitalyi, 1998, Olwande *et al.*, 2016). It is highly contagious and severe, causing mortalities (Mortality is defined as the proportion of deaths within the flock) as high as 100%), with outbreaks occurring once to twice each year (Olwande *et al.*, 2016). However, gender dynamics in control of Newcastle disease are not well understood. To fill these knowledge gaps, this study sought to analyze the extent of ownership of indigenous poultry enterprises in Machakos and Makueni Counties and gender dynamics in control of Newcastle disease.

Methodology

The study utilized primary data collected in a poultry enterprise survey carried out between July – August 2018. The target study population was indigenous chicken enterprises in Machakos and Makueni Counties. The two counties were purposively selected, the criterion being areas where promotion of indigenous and improved indigenous chicken had been conducted by a development agency Farm Inputs Promotion Services (FIPS). Random sampling of households keeping indigenous and improved indigenous chicken was done, within purposively sampled sub-counties and wards where the promotion had been conducted. A general question 'Who owns the poultry enterprise?' was asked within each sampled household as a first step to determine who the potential enterprise owner/respondent would be. Four questions termed as a 'bundle of rights' on ownership of the poultry enterprise (listed in Table 1) were posed to the 'self-reported owner(s)'.

Table 1. Bundle of rights questions used to determine ownership of poultry enterprise

	Questions
1	Did you buy / provide the money to buy the eggs (for hatching) / chicks / chicken?
2	Do the chicks / chicken belong to you to the extent that no one can take them away?
3	Would you give away / sell the chicks or chicken to a friend or a relative without consulting anyone on the decision to give away / sell?
4	If you sell the chicken, would you keep the income / money and use it without consulting anyone?

Source: Authors, adapted from Behrman et al., 2014; Johnson et al., 2016

Responses to the 'bundle of rights' questions were used to determine who owned the poultry enterprise and categorize appropriately. If the 'self-reported owner(s)' answered in the affirmative to 3-4 questions, the enterprise was categorized as individually-owned. Individuals owning poultry enterprises were further disaggregated by sex. Self-reported owners answering 0-2 questions in the affirmative were grouped together with respondents who reported their enterprises were jointly-owned. Upon obtaining written consent to participate in the study, 511 poultry enterprise owners were interviewed using a semi-structured questionnaire which had been programmed in Epicollect® data collection web and mobile application, and pretested. Data on poultry enterprise ownership, flock sizes and Newcastle disease dynamics was collected. Data cleaning and analysis was done using Statistical Package for Social Sciences (SPSS). Descriptive statistics comprising of means and percentages were used to characterize the poultry enterprises.

Results and Discussions

Ownership of poultry enterprises

Using the 'bundle of rights' questions to determine ownership of the poultry enterprise, the study revealed that poultry enterprises were owned by young and old men and women as shown in Figure 1.

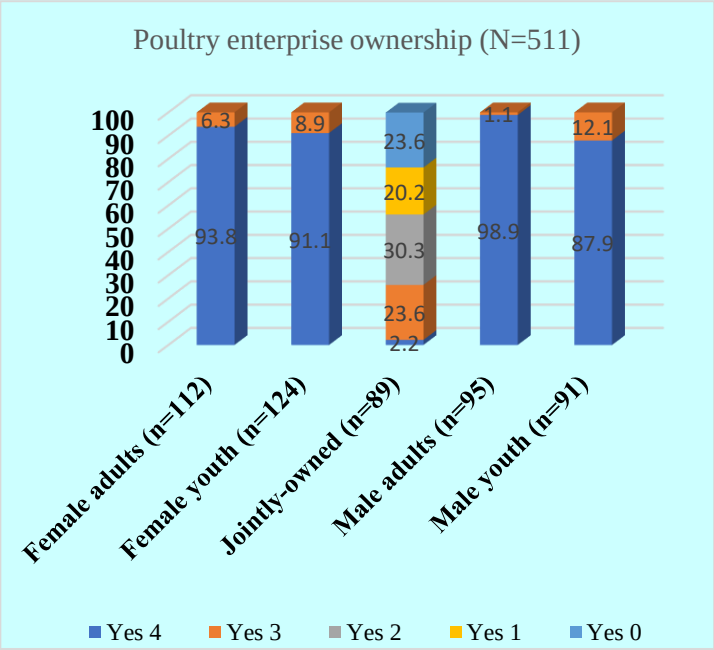

Figure 1. Ownership of the poultry enterprise

This finding revealed that less than half (46.2%) of indigenous poultry enterprises in the study area were owned by female poultry keepers, 36.4% were owned by male poultry keepers while 17.4% were jointly-owned by more than one individual. This finding contradicted the general perception that rural poultry

enterprises are mainly owned by women, and calls for further studies in other parts of the country to assess whether patterns of ownership of indigenous poultry enterprises are different.

Flock sizes

The study revealed relatively small flocks of mature indigenous poultry kept in the study area as shown in Figure 2.

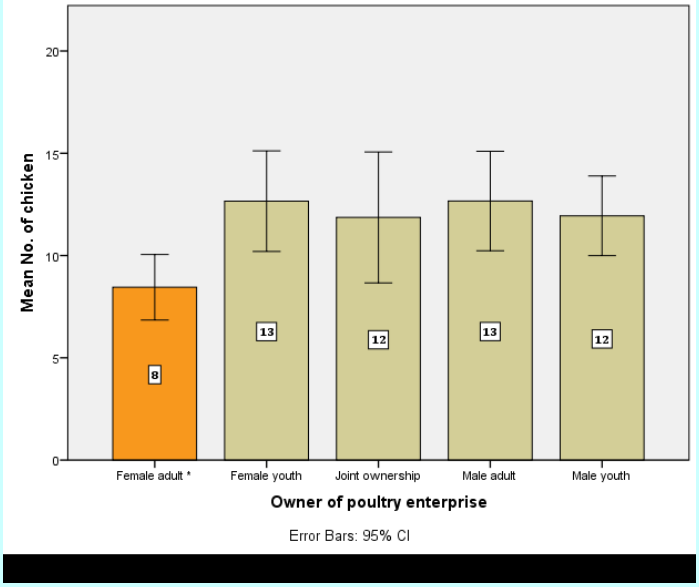

Figure 2. Size of flocks kept

Female adults kept the smallest number of indigenous poultry ($p<0.05$). This finding revealed further contradiction of the popular perception that poultry belong to women, hence the apriori expectation was that women would keep larger flock sizes. This finding justifies further research to identify gender and age-specific needs, preferences and constraints prior to rolling out interventions targeting empowerment of women through indigenous poultry production.

Newcastle disease outbreak

Respondents indicated months of the year when they experienced Newcastle disease incidences in their indigenous poultry as shown in Figure 3.

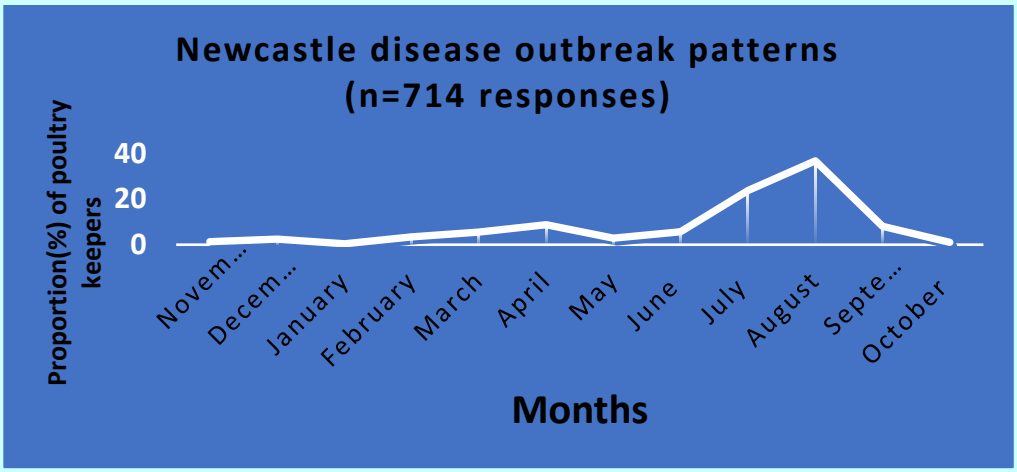

Figure 3. Newcastle disease outbreak pattern

The results showed that Newcastle disease outbreak occurred once a year in the study area between July – August. While Newcastle disease vaccination schedules recommend vaccinating against Newcastle

disease every 3-4 months throughout the year, further research to determine differences in targeted vaccination prior to the outbreak period and vaccinating all year round is recommended.

Prevention and control of Newcastle disease

The study revealed different precautions taken against Newcastle disease by poultry keepers in the study area with 46% using vaccines, 37% using mixed ingredients locally available from trees and shrubs and 17% using curative/treatment drugs as a preventive measure. Precautions taken disaggregated by ownership of the enterprise were as shown in Figure 4.

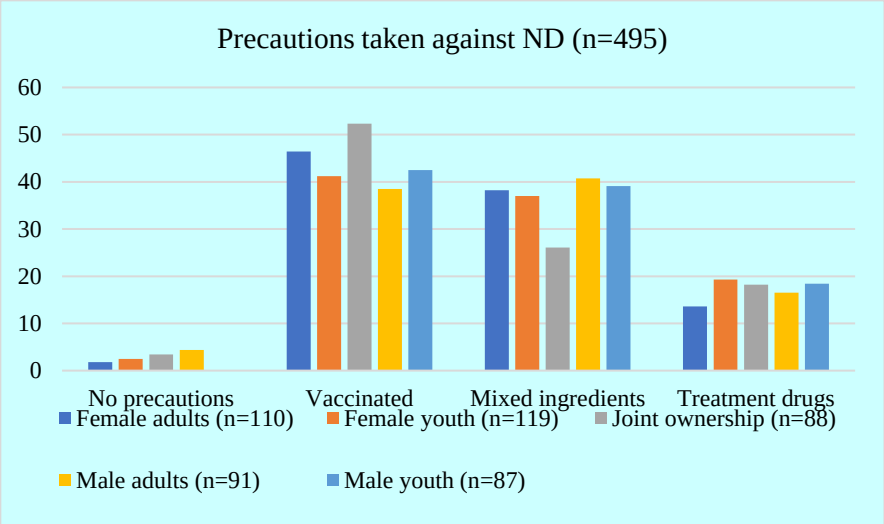

Figure 4. Precautions against Newcastle disease

There was a higher proportion of jointly-owned poultry enterprises vaccinating against Newcastle disease; with the same category comprising the lowest proportion using a mixture of locally available ingredients from shrubs. The lowest proportion of those vaccinating were adult males who also comprised of the highest proportion of those using mixed ingredients.

Precaution dynamics on the poultry enterprise

An analysis of flock sizes and Newcastle disease incidences revealed differences based on precautions taken as shown in Figure 5.

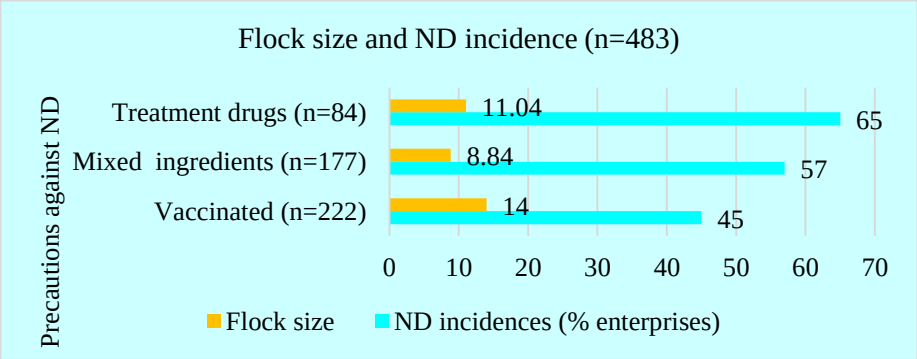

Figure 5. Precaution-based effect on Newcastle disease dynamics

The study revealed largest flock sizes in poultry enterprises where vaccination was used as a precaution against Newcastle disease. Significantly larger flock sizes ($p<0.05$) were found in poultry enterprises

where vaccination against Newcastle disease was conducted compared to enterprises where mixed ingredients of locally available ingredients obtained from shrubs and trees were used. Incidences of Newcastle disease were significantly lower in poultry enterprises where vaccination was carried out compared to enterprises where treatment drugs and mixed ingredients were used as a precaution against Newcastle disease.

The findings of further analysis of Newcastle disease and mortality disaggregated by sex and age of poultry enterprise owners were as shown in Figure 6.

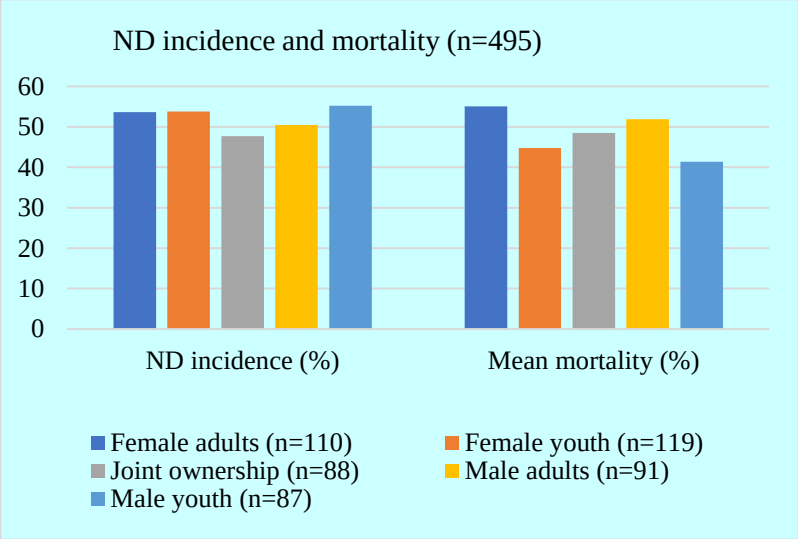

Figure 6. Newcastle disease incidences and mortality rates

The highest mortality rates were observed in poultry enterprises owned by adult females and were significantly higher than mortality rates in enterprises owned by the youth. This may partly explain the smaller flock sizes observed in enterprises owned by female adults. It is therefore imperative that female adults require interventions specifically tailored to meet their needs, constraints and preferences if their empowerment through indigenous poultry is to be realized.

Conclusions and recommendations

Results showed that poultry enterprises were not owned by women only as generally perceived, but by young and old men and women. However, most results showed that female adults were lagging behind in poultry production with smallest flock sizes and highest mortality rates attributed to Newcastle disease. With numerous R andD agencies working towards women empowerment through indigenous poultry production, it paramount to identify gender-specific roles, needs, constraints and preferences in order to design interventions that address the same and lead to the desired outcome (women empowerment) of the target group. Based on the small flock sizes kept in the study areas, indigenous poultry production remains at a subsistence scale and is unlikely to result in empowerment of women at that level of operation. It is therefore paramount to develop and implement innovative strategies geared towards transformation of the enterprise to commercial production.

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EMERGING LIVESTOCK FEEDS

Utility of *Saccharomyces cerevisiae* fermentation product in pig feeding programs: amelioration of deleterious effects of enteric bacterial pathogens

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Abstract
The objective is to evaluate effects of *Saccharomyces cerevisiae* fermentation product **(**SCFP) in mitigating deleterious effects one of the enteric pathogens relevant to pig production. A total of 90 weaned piglets (Yorkshire*Landrace ♀ X Duroc ♂; 21 day old) were assigned to pens (3 pigs/pen) based on weaning body weight in three experiments. Pigs were fed diets without or with SCFA (n=5) and challenged with enterotoxigenic *E. coli* K88 (ETEC), a causative agent for post-weaning colibacillosis. Pigs had free access to water and feed for 14 days. Responses included feed intake, growth, feed efficiency, intestinal histomorphology, incidences of diarrhea, ETEC attachment to mucosa, microbial community, digesta ammonia content and plasma cytokines. Data were presented as percent difference over the control. Pigs fed SCFP grew faster than control pigs indicating some degree of protection linked to increased feed intake, reduced concentration of ETEC numbers adhering to the mucosa, higher digestive and absorptive surface, lower digesta ammonia concentration and lower plasma pro-inflammatory cytokine (IL-6). Overall the data indicated that components in the SCFP could protect piglet against enterotoxigenic *E. coli*.

Keywords: Pigs, enteric diseases, GIT health and function, growth performance, *Saccharomyces cerevisiae* fermentation product.

Introduction

Advances in genetics has certainly produced pigs with greater biological and economic performance in terms of daily gain, feed efficiency and lean yield (Krupa *et al.,* 2017; Merks, 2018). However, performance observed at farm level is sub-optimal relative to genetic potential. Poor performance at the farm is linked to numerous dietary, physiological, environmental, physical and social factors that singly or collectively negatively affect growth and feed efficiency (Patience *et al.*, 2015). Pork production is a continuum of interdependent physiological phases and sub-optimal performance in one phase irreversibly impacts the next phase (Figure 1). For example, poor gut health in nursery pigs impacts duration and feed cost of reaching market weight (Kiarie *et al.*, 2016). Ingestion of optimal level of dietary nutrients is critical for optimal pig performance and overall health. However, the level of feed intake observed in practical farm situations is often lower than the potential feed intake (Nyachoti *et al.,* 2004; Patience *et al.*, 2015). Many studies have concluded that interactions between feed factors (the nutrients, anti-nutrients and toxins) and gastrointestinal ecology (endogenous secretions and microbiome) have the greatest impact on variation in pig performance (Pastorelli *et al.*, 2011; Kiarie *et al.*, 2013; Kiarie *et al.*, 2016). The peculiarity is that being the continuation of the external environment, the functions of the gastrointestinal tract (GIT) includes protection against insults (infectious and non-infectious), digestion and absorption of nutrients, secretion of endogenous materials, hosting of intestinal microbiota, and excretion of undigested portion of the ingested feed and metabolic waste.

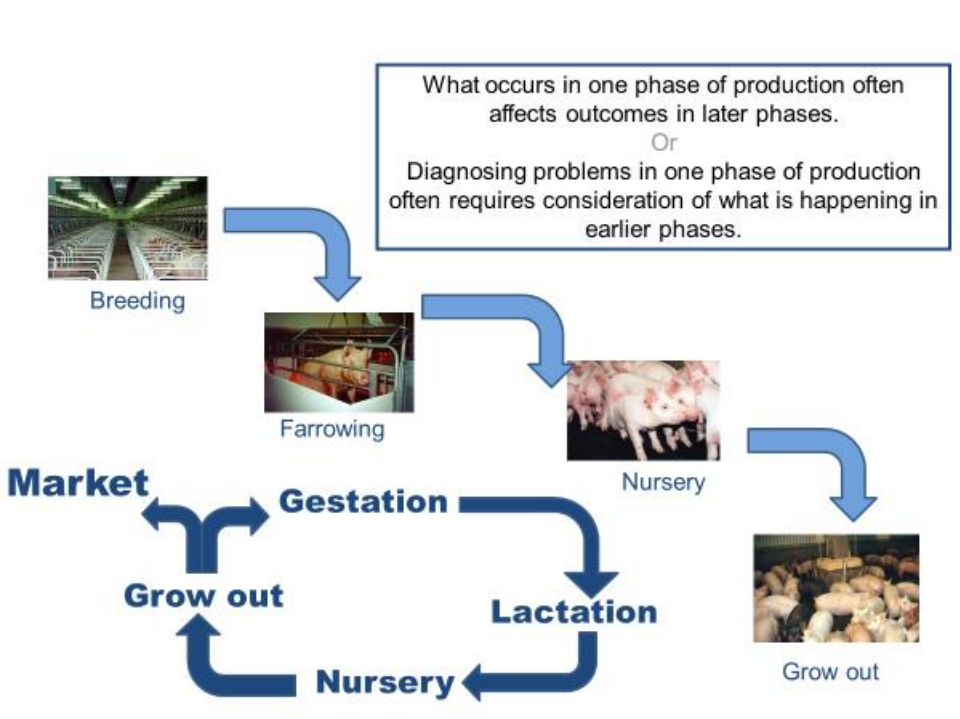

Figure 1. Pork production continuum

Pigs at the farm setting encounters a wide range of enteric pathogens (e. g. *E. coli*) and toxins (e.g. fungal mycotoxins such as aflatoxin, deoxynivalenol, fumonisin and zearalenone). Whether these pathogens and/or toxins produce clinical disease or not, they are associated with the stimulation of the immune system, which triggers a series of responses including reduction in feed intake and increase in energy expenditure and body protein catabolism (Pastorelli *et al.,* 2011). The practical consequences are that nutrient partitioning can be altered away from growth toward metabolic responses in support of immune function (Klasing, 2007; Kyriazakis, 2010). The extent and the duration of the pathophysiological responses depend on the type and the intensity of pathogen and/or toxin exposure and on the host's ability to stimulate its immune response (Kyriazakis, 2010). From a pig industry perspective, feed account for 60 to 70% of variable production cost and optimal feed efficiency is critical for profitability. In this context, management and feeding strategies to minimize negative effects on feed efficiency are of practical importance to pork industry stakeholders. Overcoming today's pig disease and stress challenges requires a healthy and stable Gastro-Intestinal Tract (GIT) environment under all conditions. A functional GIT is a result of the status of many interrelated elements such as villi architecture, GIT-associated immune system and microbiota. Management and dietary strategies ought to support robust digestive health by maintaining immune system and gut microbiota balance.

In cognizant of the fact that optimal GIT health and function translates into better performing pigs that are more capable of reaching their genetic potential there are numerous feed technology solutions for optimizing GIT in the market place (Kiarie *et al.,* 2016; Kiarie and Mills, 2019). One such solution is *Saccharomyces cerevisiae* fermentation product (SCFP) that has been shown in several studies to have positive effects on growth and reproductive performance in pigs (Wang *et al.,* 2009; Patterson *et al.,* 2011; Shen *et al.,* 2011). We examined our three published experiments (Kiarie *et al.,* 2010; Kiarie *et al.,* 2011; Kiarie *et al.,* 2012) that used ETEC challenge model to demonstrate efficacy of SCFP in mitigating ensuing negative effects.

Methodology

The experiments were conducted at the University of Manitoba, Winnipeg, Canada. The animal use protocols were reviewed and approved by the University of Manitoba animal care committee and followed the principles established by the Canadian Council on Animal Care. A total of 90 weaned piglets (Yorkshire*Landrace ♀ x Duroc ♂; 21 day old) were assigned to pens (3 pigs/pen) based on

weaning body weight. The pigs were fed nutritionally balanced diets without or with 0.2% *Saccharomyces cerevisiae* fermentation product (SCFP). The SCFP is from an unmodified strain of *S. cerevisiae*, including the products of fermentation, residual yeast cells, yeast cell wall fragments, and the media used during fermentation (Diamond V Original XPC, Diamond V Mills, Cedar Rapids, Iowa, USA). Piglets had free access to water and feed for 14 days post-weaning. All pigs were orally challenged with ETEC on day 7 post-weaning. The ETEC strain and challenge protocols are extensively validated and well established at Dr. Nyachoti laboratory as recently reviewed (Adewole *et al.,* 2016). Measurements such as feed intake, growth, feed efficiency, intestinal histomorphology, incidences of diarrhea, ETEC attachment to mucosa, microbial community, digesta ammonia content and plasma cytokines were reported. The data were subjected to Proc GLM procedures of SAS for statistical analyses. For the purposes of this paper, the data were presented as percent difference over the control.

Results and discussion

The data showed piglets fed SCFP sustained +67% higher daily gain relative to control fed piglets, this effect on growth was partially due to feed intake stimulation (+14%) during challenge (Figure 2). Anorexia and attendant shift in the partitioning of dietary nutrients away from skeletal muscle accretion toward metabolic responses that support immune system is the hallmark of sub-clinical and clinical infections in animals (Klasing, 2007).

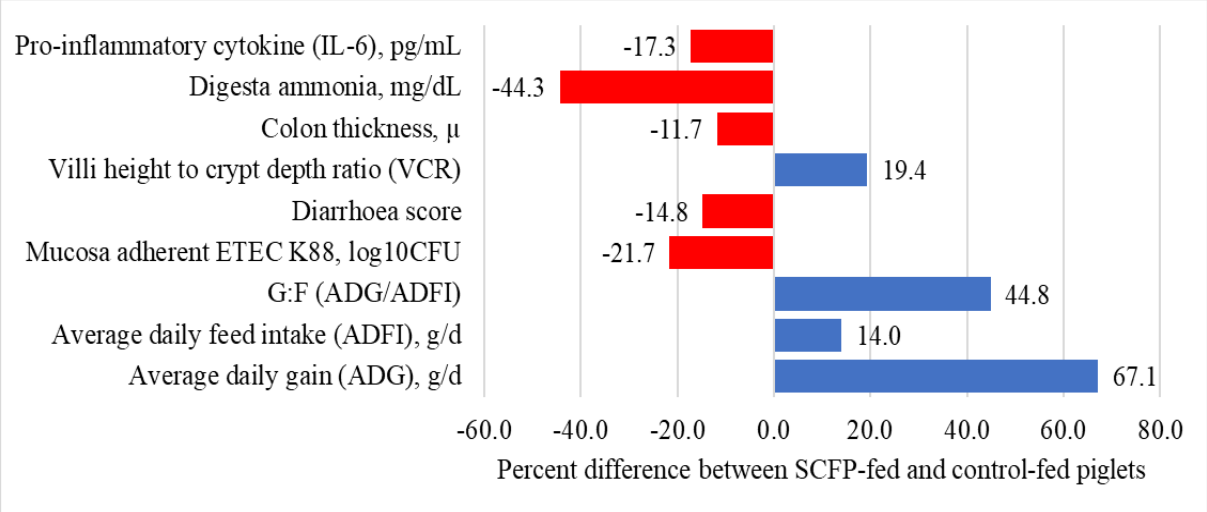

Figure 2. Effects of SCFP on growth performance, indices of intestinal function and health, plasma cytokines and diarrhea in piglets challenged with enterotoxigenic *E. coli* K88 (Kiarie *et al.,* 2010; Kiarie *et al.,* 2011; Kiarie *et al.,* 2012). Measurements taken 7 days post-challenge.

Yeast fermentation products may improve the performance and health of piglets by preventing bacteria such as ETEC from binding to intestinal epithelial cells (Adewole *et al.,* 2016). Indeed, the lower number of ileal adherent ETEC (-21%) and lower incidence of diarrhea (-15%) in pigs fed SCFP relative to the control indicated this additive protected against ETEC colonization. The peculiarity is that the mannan-oligosaccharides derived from the yeast cell walls have been reported to influence intestinal microbial population by preventing bacteria from attaching to mannose residues on intestinal epithelial cell surfaces and thereby preventing colonization of the intestinal tract by harmful bacteria (Muccilli and Restuccia, 2015). This might explain the lower counts of ETEC attached on the mucosal of ileum of pigs receiving SCFP relative to the control.

The renewal of the intestinal epithelium is a consequence of a dynamic equilibrium between production of enterocytes in the crypt and desquamation in the villi (Pluske, 2016). Thus, VCR is a useful criterion for assessing intestinal health and function. Piglets fed SCFP had +19% higher VCR relative to control indicating improved digestive and absorptive capacity linked to improved growth performance. Increased mass of GIT and portal vein drained viscera imply a greater utilization of digestible energy to meet maintenance energy requirements, subsequently resulting in less energy utilized for protein and fat deposition (Just *et al.,* 1983). In this context, it is interesting that SCFP pigs had thinner colonic tissue suggesting lower gut mass. Reduction of growth-depressing microbial metabolites such as ammonia has

been proposed as one of the mechanisms underlying the effects of AGP on animal growth (Visek, 1978). Reduction (-44%) in the concentration of digesta ammonia in pigs receiving SCFA concomitant with higher ileal digesta bacterial richness and diversity, lower prevalence for the order enterobactericeae (Kiarie *et al.*, 2011) and, lower ETEC attachment and lower incidences of diarrhea suggests a healthier GIT environment. Enterotoxigenic *E. coli* (ETEC) strains causing diarrhea are more often detected in neonatal and newly weaned pigs (Fairbrother *et al.*, 2005). Thus, reducing the prevalence and the persistence of ETEC in pig herds may contribute to protecting pigs from contamination between production cycles and to reducing the risk of cross contamination of piglets in the production system. The current study contributes to the understanding of the mechanisms through which SCFP may benefit piglets during a sub-clinical enteric challenge. Sub-clinical diseases cause the largest economic loses to the famer in terms of growth and feed efficiency as the animals do not show overt disease symptoms to elicit veterinarian intervention (Kiarie *et al.*, 2013). Our data extended previous observations by other researchers that demonstrated protective benefits of SCFP in pigs subjected diverse challenges including enteric pathogens such as *salmonella* (Price *et al.*, 2010) and fungal mycotoxins (Weaver *et al.*, 2014).

Conclusions and recommendation

Many diseases and performance-related issues can occur in young age particularly at weaning but have repercussions to the whole herd productivity. The current study contributes to the understanding of the mechanisms through which SCFP may benefit piglets during sub-clinical ETEC infection. The effect of SCFP on growth and appetite in the presence of ETEC suggests that SCFP afforded protection against ETEC and that there is merit in feeding this additive to support performance under farm conditions. The exact mechanism of action of SCFP is not clear, however, maintaining a beneficial intestinal environment through modulation of microbial ecology and improving intestinal immunity have been suggested as potential modes of action of yeast products. It is suggested that healthy and stable GIT environment help pigs resist stress and perform better.

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New frontiers in poultry and pig feeding: optimizing gut function and health first

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Abstract
Diet formulation is a precise science driven by the need to match nutrient supply with requirements. Central to this proposition is an assumption of a functional gastrointestinal tract to digest and absorb nutrients and to excrete waste products. The gut is also living ecosystem hosting billions of microorganisms responsible for plethora of vital functions including nutrient digestion and immune system development. There are, however, many specific bacterial pathogens such as *clostridia, E. coli* that generally cause disease when ecosystem is disturbed in some manner. Moreover, among other gut inhabitants are several taxa such as *Campylobacter* and *Salmonella* capable of causing significant illnesses in humans via contaminated animal products. Traditionally, the industry has relied on prophylactic broad-spectrum antimicrobial growth promoters (AGP) in feed or water to enhance

intestinal development, growth, and control enteric diseases. However, the emergence of microbes that are resistant to antibiotics used to treat human and animal infections along with increasing consumer demand for antibiotic free animal products have collectively restricted or eliminated such production practices across the world. It is prudent to expect that poultry and pigs raised on feeds without AGP will experience higher incidences of intestinal health problems and prolonged period of immunological challenge. The metabolic changes induced by inflammation are homeostatic in nature and thus nutrients that would have been utilized for growth, skeletal muscle accretion and egg production are diverted to support host defense systems. Therefore, availability of dietary strategies for maintaining gut health and function will be imperative for profitability and sustainability of the poultry and pig industries under restricted use of antimicrobials. This paper will present recent work accomplished at the University of Guelph and elsewhere on advances on feed technologies such as natural fermentation metabolites and derivatives that could be strategically used to optimize gut health and function for better feed utilization.

Key words: Gut health, feed additives, feed efficiency, microbiome, digestion.

Introduction

The primary functions of the gastrointestinal tract (GIT) are to digest and absorb nutrients and to excrete waste products (Pluske *et al.*, 1996). A functional gut is a result of the status of many interrelated elements such as villi architecture, gut-associated immune system and microbiome. However, microbial status is very critical to the overall health and functionality of the gut. The GIT microbiome is responsible for a plethora of functions including intestinal development and functionality (as evidenced by differences seen between gnotobiotic and conventional animals), nutrient digestion and absorption, mucus secretion, immune development and cytokine expression (Klasing, 2007). However, there are many specific bacterial pathogens that also inhabit the GIT, and they generally cause disease when the gut ecosystem is disturbed in some manner. Farmers strive to keep chickens and pigs free of infections (bacteria, viruses, parasites) to achieve the best utilization of feed for muscle gain and egg production as possible. However, with at least 400 species of bacteria, with numbers as high as 10^{14} colony forming units/g inhabiting the GIT (Savage, 1977), it is little wonder that perturbations sometimes occur to cause clinical disease and occasionally death (Kiarie *et al.*, 2013). Specific enteric pathogens can cause enormous economic losses to poultry and swine enterprises, hence there is interest in being able to identify, quantify and control the different components of the microbiota (both pathogenic and non-pathogenic) to improve health and production.

Methodology

This paper presents recent work accomplished at the University of Guelph and elsewhere on advances on feed technologies such as natural fermentation metabolites and derivatives that could be strategically used to optimize gut health and function for better feed utilization.

Results and discussion

Dietary strategies for managing metabolic realities of a living gut

I. Stimulating functional gastrointestinal development

There are numerous functional ingredients, factors and /or nutrients that are known to enhance GIT development and could be strategically applied in starter diets for chicks and piglets to enhance digestive capacity and resilience to enteric pathogens (Kiarie, 2016). For example, epidermal growth factors (Kim *et al.*, 2017), yeast metabolites (Kiarie *et al.*, 2010; Kiarie *et al.*, 2011; Kiarie *et al.*, 2012; Leung *et al.*, 2018) and organic acids (Kiarie *et al.*, 2018).

II. Reducing undigested substrates by use of feed enzymes

Although pigs and poultry are highly efficient in converting feed to food products, they still excrete significant amounts of undigested nutrients. For example, broilers lose almost 25-30% of ingested dry matter, 20-25% of gross energy, 30-50% of nitrogen and 45-55% of phosphorus intake in the manure (Ravindran, 2012). Pigs of different breeds and ages were observed to digest 78% of gross energy in typical corn and soybean meal diet (Urriola and Stein, 2012). Addition of 30% corn dried distiller's grains with solubles to this diet resulted in further reduction of digestible gross energy. The undigested

nutrients are excreted in the manure with negative implications on production efficiency, profitability and sustainability of farm operations. The peculiarity is that feedstuffs contains anti-nutritional factors (ANF) such as phytic acid or fractions that are not degraded sufficiently or indeed at all by the conditions and the array of digestive enzymes in the gastrointestinal tract (Kiarie *et al.,* 2013; Kiarie *et al.,* 2016). This inherent digestive inefficiency in monogastric animals is seen as the reason of commercial development and application of exogenous feed enzymes technology. Beneficial effects of feed enzymes are inextricably linked to the amount of the undigested fat, protein and starch in the ileum. Accelerated intestinal digestion and removal of what would otherwise be apparently undigested without feed enzyme must clearly limit the nutrients available for the microbes (Kiarie *et al.,* 2013; Munyaka *et al.,* 2016).

III. Low crude protein synthetic amino acids supplemented diets

In poultry and pig nutrition, protein (amino acids) is the second most expensive component of the feed after energy. The protein supply may have a significant impact on the intestinal microbiota, both qualitatively and quantitatively. High protein diets increase the concentrations of proteolytic bacteria, especially *clostridia* and *E. coli* (Heo *et al.,* 2013). From the viewpoint of animal health, it is interesting that there seems to be a link between enteric pathogens and certain protein sources. With respect to poultry, administration of feed with animal derived proteins led to a sharp increase in the concentrations of *Clostridium perfringens* and necrotic lesions in the intestinal mucosa (Drew *et al.,* 2004). Adjusting protein supply and amino acid profiles can be considered as essential to achieve optimal performance and to control the intestinal formation of metabolites such as ammonia and biogenic amines from protein fermentation, that are generally considered as detrimental (Nyachoti *et al.,* 2006; Heo *et al.,* 2013). The use of supplemental amino acids would offset or minimize the need to use some of expensive animal proteins, which could reduce the cost of feeds. Furthermore, extensive use of supplemental amino acids would allow to more precisely meet the animal dietary requirements while reducing dietary crude protein. This change in formulation can positively impact gut health and the environment by reduction of environmental excretion of nitrogen and reduce metabolic stress of detoxifying N-catabolites.

IV. Nurturing favorable microflora

To optimize performance of pigs and poultry raised with AGP free feeding programs, it is essential to manage the composition of intestinal microbial community to avoid the inherent intestinal health risks of intensive production systems. In a drug free production system, the emphasis shifts from fighting the unfavorable organisms with antibiotics to nurturing the favorable organisms i.e. working with nature to ensure a favorable and stable intestinal ecology (see Figure 1). Collet, (2012) opined that the three most important legs of an effective intestinal management program includes “seeding” the gut with favorable organisms, "feeding" the favorable organisms and "weeding" out the unfavorable organisms.

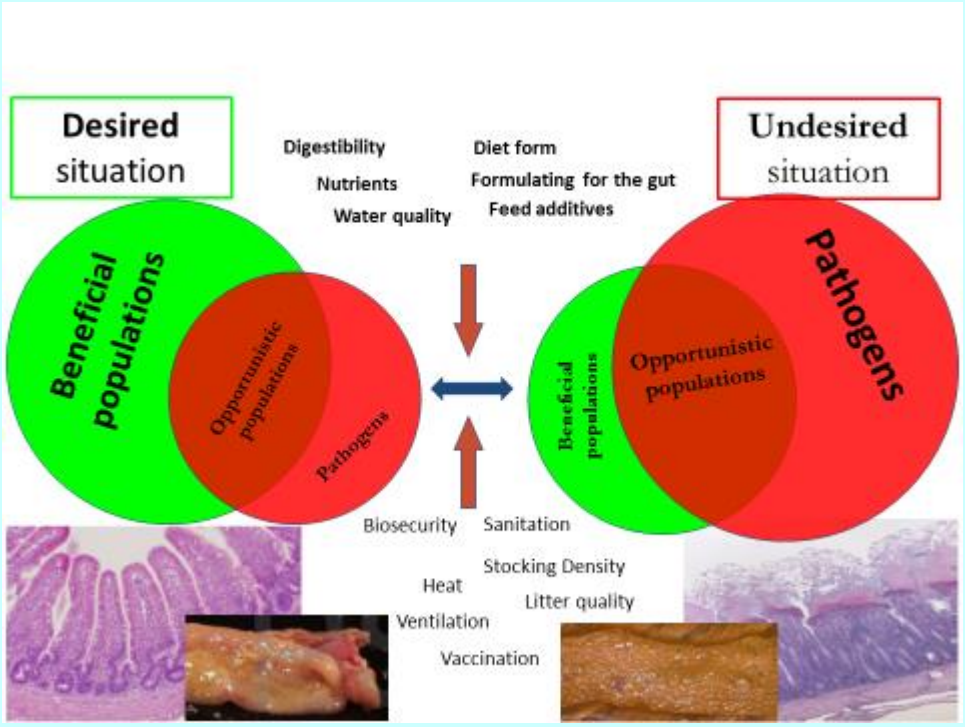

Figure 1. Strategies for maintaing a functional gut in the context of AGP feeding programs

V. Seeding the gut with favorable organisms

The first week after hatch is the most critical period of a chick life. The newly hatched chick is susceptible to environmental and health challenges due to undeveloped digestive, thermoregulatory and immune system. Colonization of mucosal surfaces in newly hatched chickens is therefore dependent on environmental exposure mainly through feeds, litter, water etc. Colonization of the gut with pioneer bacteria species, that are able to modulate expression of genes in the gut epithelia to optimize nutrient assimilation and create favorable conditions for establishment of a stable and beneficial climax flora, should be the starting point of any gut health management program (Collet, 2012). In this context, probiotics or direct fed microbials appear to be most effective during the initial development of the microbiota, or after any dietary change or stress and following antibiotic therapy and thus can be interpreted in the context of the ecological phenomena of primary and secondary succession in which a community is established or re-established following a disturbance (Collet, 2012). As methodological advancements continue, a progress toward development of novel probiotic approaches is plausible particularly in the area of probiotics with immunomodulation capabilities (Waititu *et al.*, 2014).

VI. Feeding the favorable organisms

In addition to seeding the gut with the correct pioneer species, it is crucial to enhance their ability to proliferate, compete and colonize to stall pathogen proliferation. There are many feed additives that could be used to promote proliferation of beneficial microbiome (Patterson and Burkholder, 2003). Some oligosaccharides, such as inulin and oligofructose, yeast metabolites have been proposed as 'prebiotics' because of their potential to selectively stimulate growth of *Bifidobacterium* spp. within the human large intestine, suppress proliferation of potential pathogens and modulate a variety of human enteric conditions and diseases (Gibson and Roberfroid, 1995). Prebiotics are defined as 'non-digestible food ingredients that beneficially affect the host by selectively stimulating the growth and (or) activity of one or a limited number of bacteria in the colon, and hence improve host health' (Gibson and Roberfroid, 1995). The peculiarity with prebiotics is that they promote production of short chain fatty acids which are known to have a microbiota stabilizing effect and butyrate in particular has been shown to stimulate the production of host defense peptides (β-Defensins and Cathelicidins) (Sunkara *et al.*, 2011). By providing a competitive advantage to the acid tolerant organisms such as the *Lactobacilli* and a competitive disadvantage to the acid intolerant organisms like the *Clostridia, Salmonella* and *E. coli* there is tremendous opportunity to maintain a functional and healthy gut. Such manipulation of the microbiota has both short and long term (Collet, 2012).

VII. Weeding out the unfavorable organisms

Nurmi and Rantala introduced the term competitive exclusion (CE) more than 4 decades ago following observation that oral gavage of newly hatched chicks with intestinal contents from *salmonella*-free birds reduced *Salmonella* colonization (Nurmi and Rantala, 1973). Competitive exclusion generally refers to a reduction in colonization by a pathogen due to several possible mechanisms: physical occupation of a site, resource competition in a physical or chemical niche, or direct physical or chemical insult to the potential colonist (Oakley *et al.,* 2014). Although the underlying mechanisms remain poorly understood, pioneering work of Nurmi and Rantala (1973) has inspired development of several commercial products (Oakley *et al.,* 2014). However, practical application remains elusive because undefined cultures are often more effective in controlling *salmonella* than the defined cultures in commercially regulated products (Oakley *et al.,* 2014). Alternative strategies have capitalized on increasing knowledge of the molecular basis that the pathogens use to attach to the mucosal to colonize. Microbe attachment to host cell docking sites on the intestinal epithelium is dependent on surface molecule structure and this is the pivotal first step in the colonization and infection of the gut (Giron *et al.,* 2002). For example, blocking the attachment mechanism of unfavorable organisms with a type-1 fimbria blocker can reduce their capacity to compete with the favorable organisms in the gut (Giron *et al.,* 2002). Products that mimic docking sites for specific gut epithelia glycoproteins may be useful in preventing attachment and colonization by gut pathogens recognizing these sites (Giron *et al.,* 2002). For example, several bacteria exhibit a binding effect specific for the sugar mannose (Mirelman *et al.,* 1980). Mannose in the cell wall may cause the yeast or its residue to act as a decoy for the attachment of bacteria to the intestinal wall and this has been the basis of commercial success of many yeast based products (Kiarie *et al.,* 2010; Kiarie *et al.,* 2011; Kiarie *et al.,* 2012; Corrigan *et al.,* 2015).

Conclusions

Raising poultry and swine successfully without AGP will be challenging and will require several approaches and strategies "*no silver bullet*" for optimizing gut health and performance. Diet composition and formulation strategies will be pivotal for the development and maintenance of a functional and healthy gut and so are other elements such as management and genetics. Innovations of alternative dietary strategies for maintaining healthy gut and productivity will be imperative for profitability and sustainability of the poultry and swine industries under restricted use of antimicrobials.

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The effect of fermentation of mature ground *Prosopis juliflora* pods on crude fibre and crude protein content

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Abstract
Prosopis juliflora pods are non-conventional feed resources that are being explored for use as alternative raw materials in livestock feeds and are readily available in arid and semi-arid lands of Kenya. However, the high crude fibre (CF) and low crude protein content interferes with livestock performance. The objective of the present study was to investigate improvement in CP and reduction in CF when the pods were fermented spontaneously and with probiotics; *Lactobacillus salivarius* (LS) and *Saccharomyces cerevisiae* (SC). Study findings showed that CF reduced by 10.43%, 11.31%, 14.01% and 12.18% for spontaneous, SC, LS and LS/SC respectively while CP increased by 10.07%, 11.96%, 11.49% and 8.72% for spontaneous, SC, LS and LS/SC respectively. Fermented Prosopis pods can therefore be used as an alternative feed resource.

Introduction

Kenyan human population growth is estimated at 2-3 % annually (KNBS, 2009) from an initial population of 40 million in 2009. Food production should therefore be in tandem with this growth to ensure food security. However, 75% of Kenya's land mass is classified as arid and semi-arid (GoK, 2007) and unfit for crop production. There is need for exploration of non-conventional livestock feed resources that are available all year round, cost effective and with no competition with humans. Prosopis pods have been identified as a probable feed resource that fits these characteristics (Odero-Waitituh *et al.*, 2016). Prosopis species are generally fast-growing, drought-resistant, nitrogen-fixing trees or shrubs adapted to poor and saline soils in arid and semi-arid zones (Anderson, 2005). Chemical analysis of Prosopis pods resulted in 18% CP (Koech *et al.*, 2010), 13% and 69% sugars and carbohydrates (Choge *et al.*, 2007). Also, Odero-Waitituh *et al.*, (2015), reported an metabolizable energy (ME) value of 2.8 MJ/Kg. However, the presence of anti-nutrient like crude fibre (17 %) reduced broiler performance (Odero-Waitituh *et al.*, 2016).

Various studies have reported improved nutritional value and reduction in anti-nutritional content when the pods were fermented. For instance, Sukhanandi *et al*., (2014) and Aremu *et al*., (2015) reported reduced anti-nutrient content and improved nutritional value of various parts of the pods on microbial and spontaneous fermentations respectively. Yusuf *et al*., (2008) reported improved broiler growth when spontaneously fermented decorticated Prosopis pods were fed. Therefore, the objective of this study was to investigate the effects of spontaneous and microbial fermentations on Prosopis pod's CP and CF content.

Materials and methods

Study site: The fermentation was carried out at the National Centre for International Research on Animal Gut Nutrition, Nanjing Agricultural University, Peoples Republic of China.

Prosopis harvesting, drying, storage and milling: Mature Prosopis pods were obtained from Marigat Sub County in Baringo County, Kenya Clean pods were dried in the sun until a constant weight was achieved. Grinding of the whole pod was done according to the procedure described by Choge *et al*., (2006) and flour passed through a 5mm sieve.

Microbial cultures: Single culture of LS, SC, mixed culture of SC and LS and, spontaneous fermentation.

Fermentation: Solid state fermentation was done where 66 g of each sample was weighed and put in fermentation bags. 2g of inoculum and 32 g of buffered saline solution was added. They were then mixed thoroughly and incubated at 37^0C for 24, 48 and 72 hours.

Proximate analysis

The proximate composition of the samples were analyzed as per the methods of Association of Official Analytical Chemists (AOAC, 1995) as follows; Moisture by drying at 105°C for 24h, Crude protein (N × 6.25) by Micro Kjeldahl, the ash content by ignition at 550°C in a Muffle furnace to constant weight. Crude fibre was analyzed according to the procedure by Goering and Vansoest (1975). The NDF and ADF determination was done according to the procedure manual by Ankom technology. Fiber analyzer used was ANKOM^{2001}, model A2001 by ANKOM technology (www.ankom.com).

Statistical analysis

Data was subjected to analysis of variance using General linear model (GLM) of Statistical Analysis Systems (SAS, 9.1.3) computer package. An F-test at 5% probability level was used to test for significance and means separation was done by Tukey's HSD.

Results and Discussion

Proximate, NDF and ADF fractions are shown in Table 1. All fermentation methods used affected the proximate fractions positively. Moisture was reduced, which ensures reduction in microbial attack and improvement in dry matter therefore better keeping quality. Ash content improved indicating mineral enrichment during fermentation.

Table 1. As fed Proximate, NDF and ADF composition of GMPP and FGMPP

		Moisture	CP%	CF%	Ash	NDF%	ADF%
GMPP		9.06±0.03	14.79±0.03	22.67±0.1	4.94±0.06	34.44±1.19	22.91±0.99
FGMPP							
SF/C	24 hrs	7.62±0.03	16.28±0.03	20.33±0.1	5.06±0.06	34.45±1.19	22.12±0.99
	48 hrs	7.61±0.03	16.3±0.03	20.32±0.1	5.04±0.06	35.78±1.19	22.68±0.99
	72 hrs	7.63±0.03	16.28±0.03	21.48±0.1	5.03±0.06	34.47±1.19	21.80±0.99
SC	24 hrs	7.3±0.03	16.56±0.03	20.13±0.1	5.02±0.06	34.06±1.68	22.39±0.99
	48 hrs	7.33±0.03	16.44±0.03	20.11±0.1	5.05±0.06	35.06±1.19	22.35±0.99
	72 hrs	7.34±0.03	16.59±0.03	20.14±0.1	5.01±0.06	32.61±1.19	20.53±0.99
LS	24 hrs	7.85±0.03	16.49±0.03	19.49±0.1	5.5±0.06	33.62±1.19	21.83±0.99
	48 hrs	7.8±0.03	16.44±0.03	19.3±0.1	5.06±0.06	36.68±1.19	23.94±0.99
	72 hrs	7.81±0.03	16.57±0.03	19.47±0.1	5.09±0.06	35.20±1.19	23.28±0.99
LS/SC	24 hrs	8.52±0.03	16.08±0.03	19.91±0.1	5.05±0.06	31.76±1.19	19.60±0.99
	48 hrs	8.58±0.03	16.02±0.03	19.79±0.1	5.06±0.06	32.61+1.19	20.06±0.99
	72 hrs	8.53±0.03	16.08±0.03	20.05±0.1	5.02±0.06	34.38+1.19	22.92±0.99

Data are mean values ± SE; GMPP = Ground mature Prosopis pods; FGMPP = Fermented Ground mature Prosopis pods; NDF = Neutral detergent fibre; ADF = Acid detergent fibre; CP = Crude Protein; CF = Crude fibre

Spontaneous fermentation and use of probiotics improved crude protein content of ground Prosopis pods. The crude protein content increased drastically within the first 24 hours by 10.07%, 11.96%, 11.49% and 8.72% for spontaneous, SC, LS and LS/SC respectively. There was no significant increase in CP in 48hr and 72hr fermentations (Figure 1). This was observed for all the fermentation methods, which is in agreement with (Yusuf *et al.*, 2008 and Aremu *et al.*, 2015) for spontaneous and (Sukhanandi *et al.*, 2014 and *Thi Huyen et al.*, 2019) for microbial fermentations. Fermentations with LS and SC gave the highest CP value probably due to immediate microbial activity from the inoculation leading to fast microbial action, synthesis of microbial enzymes for substrates breakdown (Sukhanandi *et al.*, 2014) and microbial protein synthesis. Fermentation with a combination of LS/SC could gave the lowest CP values probably due to competition by the microorganisms for the substrates or antagonism

between the microorganisms (Blandino *et al.*, 2003).

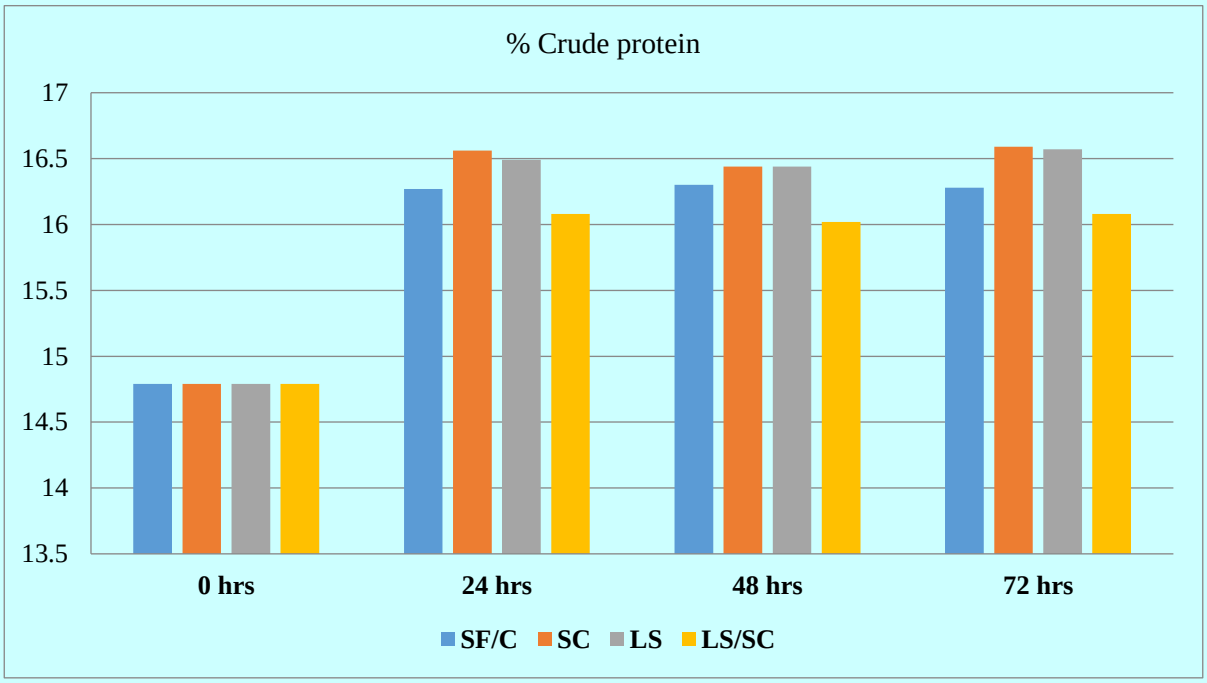

Figure 1. Crude protein of FGMPP and GMPP using different fermentation methods –
Crude fibre content reduced after 24 hours by 10.43%, 11.31%, 14.01% and 12.18% for spontaneous, SC, LS and LS/SC respectively after which increasing fermentation time did not affect the CF value significantly. However, spontaneous fermentation had higher CF values (5.66%) at 72hrs when compared with fermentation at 24 hours. This was also reported by Sukhanandi *et al.*, (2014).

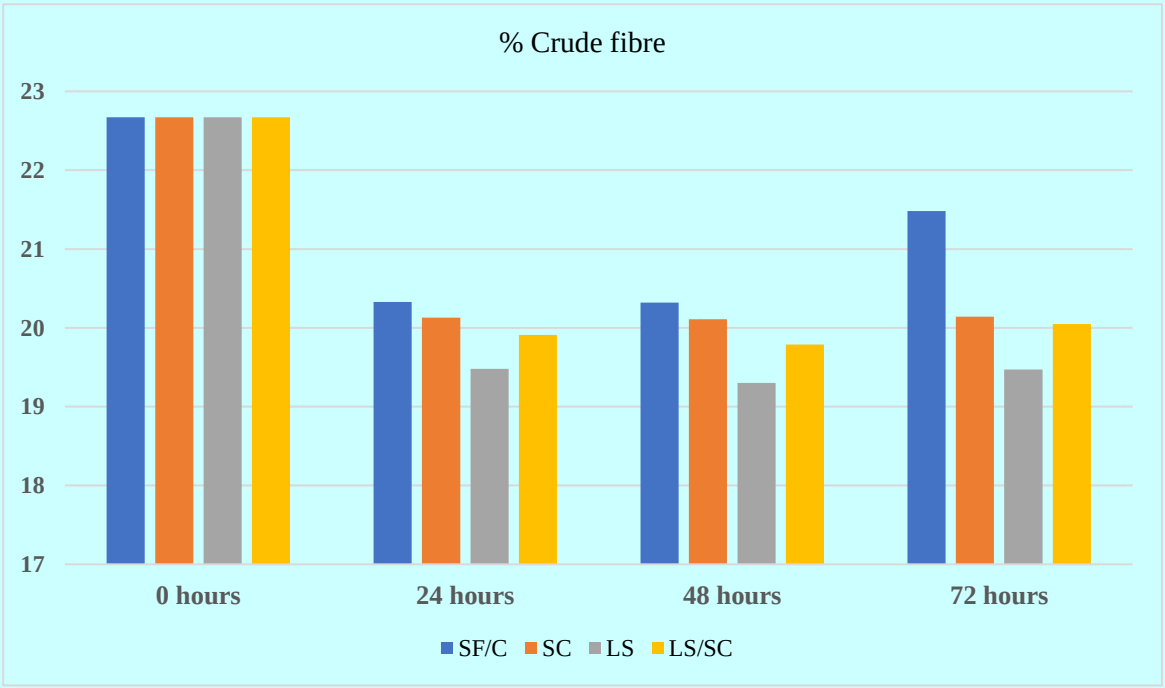

Figure 2. Crude fibre of FGMPP and GMPP using different fermentation methods

Conclusion and Recommendation

Findings of the study showed that spontaneous fermentation or with probiotics (SC, LS or LS/SC) increased the crude protein and reduced crude fibre. The SC and LS were more effective in improving CP content of Prosopis while LS was more effective in reducing CF content of Prosopis. The use of fermented Prosopis pods is recommended in livestock feeds so long as the dietary requirements are formulated as per the feeding standards and nutrient requirements of individual class of livestock. More studies are being conducted to investigate if there is any improvement in amino acid profile during spontaneous, SC and LS fermentations and, which fermentation gives the highest value.

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Utilization of Alternative Feedstuffs for Poultry Production - A Review

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Abstract
The potential for increasing chicken production is through sound management practices, especially improved nutrition. Conventional poultry feed ingredients in developing countries are becoming scarce and very expensive. However, alternative feedstuffs are available for feeding birds under all production systems. The objective of this study was to examine some of the locally available feedstuffs, their role in chicken nutrition and limitations arising from their usage. Birds require all nutrients namely, energy, proteins, fats, minerals and vitamins in balanced proportions. The nutrient requirements of birds vary according to genotype, age and purpose of production (eggs or meat). They require 2400-3200 kcal per day and 14-23 percent energy and crude proteins respectively. Alternative plant feed resources locally available in Kenya include; spent brewers waste, triticale, wheat, sorghum grains, cassava roots, sweet potato tubers, green vegetable materials, sunflower and sesame seed meals. Alternative animal protein feed resource that can support chicken production include; housefly maggots (44.44-63.99% C.P and 2381-4140 kcal metabolizable energy), fish byproducts, termites (37-46.3% C.P), earth worms and soldier fly maggots. A number of challenges that may arise from utilization of alternative feeds include, lack of consistence in nutrient quality, limited information on available nutrients, presence of anti-nutritive factors, seasonal and unreliable supply, cost of processing and competition with humans. Therefore, research, training and development agencies should focus on the need to develop technologies that can reduce the cost of production by promoting and improving on the alternative poultry feed resources available in different ecological zones of Kenya.

Key words: Chicken, nutrients, energy, protein, conventional feeds and alternative feeds

Introduction

Worldwide production of poultry meat and eggs has increased over the years and this is expected to continue. It is predicted that most increase in poultry production will occur in developing countries (FAO, 2002). The growth in poultry production will have a profound effect on the demand for feed and other raw materials. Feed is the most important input for poultry production in terms of cost. Availability of low priced and high quality products is paramount if poultry production is to remain competitive and continue to grow to meet the demand for animal proteins (Long, 1996). Poultry feeds contribute 60-70% of the total production costs and therefore most farmers pay close attention not only to availability but also to quality and proper usage of poultry feed (Nyaga, 2007). Wastage of feed resources leads to loss in revenue. Poor quality feedstuffs lead to low growth performance in birds and unsatisfactory egg production in layers, leading to marked loss in revenue.

Poultry species are omnivores with simple stomach like man. They possess short digestive systems. In fast growing chicken, it takes less than 3 hours for feeds to pass from the mouth to the cloaca. To compensate for relatively short digestive tract and rapid transit time, high performing birds need easily digestible, high nutrient density diets (Sonaiya, 1995). Any change in nutrition of chicken diets is reflected in birds' performance almost immediately. There is need to balance the nutrients in the chicken diet to avoid malnutrition that may affect their performance.

Conventional poultry feed ingredients in Kenya and other developing countries are becoming scare and very expensive (Okitoi *et al.*, 2003). There is need therefore to develop or search for possible alternative

nutrient sources without compromising on nutritional value (Sonaiya, 1995 and FAO, 2006). Alternative feedstuffs are often referred to as non-traditional feedstuffs because they have not traditionally been used in animal feeding or are normally not used in animal diets. However, it is difficult to draw a clear distinction between traditional and non- traditional feedstuffs. Feed classified as traditional in one region may be untraditional in another area (FAO, 2002). The greatest potential for efficient utilization of the feedstuffs is traditional family (Scavenging or backyard) and semi-intensive system (FAO, 2006). Most of these alternative feedstuffs have obvious potential; their use has been negligible owing to constraints imposed by low usage at farm level. The gap between local supply and demand traditional of poultry feed ingredients is expected to widen over the coming years. The scenario provides a compelling reason to explore the usefulness of locally available alternative feedstuffs.

Chicken nutrient requirement

The potential for increasing chicken production is through sound management especially improved nutrition (King'ori, *et al.*, 2010). For growth, production and good health, chicken need a balanced array of nutrient in their diets (Sonaiya, 1995). Nutrient requirement in birds vary according to genotype, age and purpose of production (eggs or meat). Like other non-ruminant, birds require all nutrients namely, energy, proteins, water, fats, minerals and vitamins in balanced proportion.

Energy requirement

Chickens can derive energy from simple carbohydrates, fat and proteins. However, they cannot digest or utilize complex carbohydrates such as cellulose and hemicelluloses. So feed formulation uses a system based on available energy. Energy level in the diet is therefore the major determinant of chickens feed intake. When the dietary energy level changes, feed intake will change and specification for other nutrients must be modified to maintain the required intake (Kingo'ri, 2010). Different classes of birds need different amounts of energy for metabolic purposes and deficiency will affect production performance (Table 1).

Table 1. Energy requirement of leghorn chicken

Nutrient	Unit	0-3wk	3-6wk	6-8	Laying hens
Metabolic able Energy	Kcal/kg	3200	3200	3200	2900

(Adapted from Firman, 1984)

However, King'ori *et al.*, 2010, reported that energy requirements for growing chickens are 2600 and 2400Kcal/Kg Metabolizable energy (ME) for heavy birds (1.66-2.14Kg) and light birds (1.0-1.65kg) respectively during 5-8, 8-14 and 14-21 weeks growing period.

Fat and fatty acids are also sources of energy. They have greater energy density compared with carbohydrates and proteins. Hence, fats are included in poultry feeds to achieve the necessary dietary concentration. They account for about 5% of most practical diets. They also assist in control of dust in poultry diets. Previous studies have shown that Linoleic acid is the only essential fatty acid needed in poultry diet and its deficiency has been observed in birds.

Protein and amino acids

The function of dietary protein is to supply amino acid for maintenance, growth and production. The synthesis of muscle and egg proteins requires a supply of 20 amino acids. Chicken require at least 10 essential amino acids in the diet namely lysine, methionine, threonine, typtophan, isoleusine, leusine,histidine, valine, phenylalamine and arginine. Of the essential amino acids, lysine, methionine and threonine are the most limiting in many practical diets. Adequate dietary supply of nitrogen from protein is essential to synthesize non-essential amino acids. This ensures that essential amino acids are not used to supply nitrogen for synthesis of non-essential amino acids. Satisfying the recommended requirement for both proteins and essential amino acids therefore ensures the provision of all. Generally, protein supplementation is lacking in free range system of chicken production thereby limiting egg and meat production (Okitoi, *et al.*, 2003).

Crude protein requirement for growing indigenous chicken was estimated by Chemjor, 1998, as 20.16 and 14% for heavy birds and light birds respectively during the three growing periods.

Table 2. Percent Protein and amino acids requirement of leghorn chicken

Nutrient	Growing 0-6 wks	Growing 6-14wks	Growing 14-20wks	Laying	Laying daily mg intake/ hen	Breeding
Proteins	18	15	12	14.5	1600mg	14
Arginine	1.00	0.83	0.67	0.68	750mg	0.68
Glycine	0.70	0.58	0.45	0.50	550mg	0.50
Histidine	0.26	0.22	0.17	0.16	680mg	0.16
Isoleusine	0.60	0.50	0.40	0.50.	550mg	0.50
Leusine	1.00	0.85	0.67	0.73	800mg	0.75
Lysine	0.85	0.60	0.45	0.64	700mg	0.64
Methionine	0.60	0.50	0.40	0.55	600mg	0.55
Phenylalamine	1.00	0.83	0.67	0.80	880mg	0.80
Throenine	0.68	0.57	0.37	0.45	500mg	0.45
Tryptophan	0.17	0.14	0.14	0.14	150mg	0.14
Valine	0.62	0.52	0.41	0.55	600mg	0.55

(Adapted from FAO, 2006)

Mineral requirements

Minerals are needed for the formation of skeletal muscles, metabolic activities and acid-base balance in the body of birds. Calcium and phosphorus are the abundant mineral elements. Calcium and P are essential in eggshell formation. Under normal conditions, P occurs in form of phytate which is poorly utilized by poultry due to lack of endogenous phytase enzyme in the digestive system. A ratio of 2:1 must be maintained between Ca and non-phytate P in growing birds' diet, to optimize the absorption of the two minerals.

Alternative plant feeds

The rising cost of conventional feed ingredients is a compelling factor to seek for alternative feed resources not directly used by humans as food. Protein feed resources though not required in large quantities as energy sources, are higher in cost per unit than the latter. Any effort towards reducing reliance on conventional protein sources will highly reduce the cost of poultry products.

Energy supplements such as Maize, Sorghum and millets are offered by smallholder farmers to the birds in the morning and late in the evening. These are grains of choice for supplementing the diet of scavenging poultry in Kenya (Okitoi, *et al.,* 2003). Using the estimate of 35g of grain supplement per bird per day for the 40 million birds in Kenya, in the smallholder production system, the annual requirement would be 511,000 tons. This has led to attention being paid to other alternative feedstuffs.

Spent Brewers Waste

Beer is one of the most consumed products in the world. In the manufacture of beer, various residues and by-products are generated (Mussatto, 2009). The commonest and most abundant is brewers spent grains which constitute 85% of the total by-product (Tang, *et al.,* 2009). Brewers Spent Grain (BSG) is readily available, high volume, low cost by-product for livestock production (Robertson, *et al.,* 2010). Increase endogenous metabolism as well as proteolytic activity in BSG affects composition within a short time (Kunor, 1995). The BSG are of high nutritive value (Tang, *et al.,* 2009) and contain cellulose and high protein content as shown in Table 3. It is quite common and cheap and produced all the year round in towns and rural areas. Results of research in Vietnum (Long, 1996) demonstrated that utilization of BSG as animal feed can reduce feed costs. Dong and Ogle B. (2000) used BSG to replace different levels of commercial concentrates in growing ducks. They discovered that cheaply available BSG can be used to replace concentrates to make more profits on ducks rearing. BSG has excellent chemical composition suitable for poultry production (Table 3 and 4). Essential amino acids concentration in BSG was found to be as good as those of ideal proteins reported by Rose (1997).

Table 3. Chemical composition of concentrate and BSG (as % DM)

Nutrient	Concentrate	BSG
DM%	88	25
CP%	18.8	23.6
EE%	6.41	10.6
CF%	3.33	14.5
NFE	64.8	47.9.
NDF	-	50.9
ADF	-	17.5
Ash%	6.46	3.46
Ca%	1.51	0.29
P%	1.41	0.48
Fe mg/Kg	470	330
ME /Kg	12.9	7.3

Adapted from Dong and Ogle 2000

Table 4. Essential amino acids composition in ideal, concentrate and BSG

Amino acid	Ideal**	Concentrate	BSG
Lysine	100	100	100
Isoleusine	79	103	83
Leusine	151	212	141
Methionine	73	92	123
Valine	106	150	11o

Adapted from Dong and Ogle 2000

The high level of Crude fibre has been considered to be a hindrance to utilization of BSG in chickens. However, several studies have demonstrated that some levels of inclusion of BSG can improve fed intake and growth rate in chickens. For instance, Caria and Millan (1996) examined the replacement of Soy by solid fraction coming from brewer's liquid waste and brewer's yeast mixture (50:50) to feed growing chickens. In the study the replacement of 20% Soy protein by brewer's waste protein to the diet showed no significant difference in growth and feed intake of chicken when compared with Soy protein fed chicken. These studies indicate that BSG can be used as a complementary protein source for chickens.

Triticale (Triticum durum)

Triticale is a hybrid between Wheat and Rye grass. Triticale has digestible energy (DE) and protein composition superior to barley. Experimental trials show that Triticale has a great feed potential for broiler chicken. Triticale contain between 10.3 to 15.6 per cent crude protein, however, researchers have reported considerable variation in protein content for different cultivars. Many live weight performance and production trials suggest that it could replace wheat based diet at cost reduction of 5 per cent (Hermes and Johnson, 2004). Partial replacement of more Maize with triticale in layers diet has been shown to have no effect on egg production and feed efficiency. Broiler diet may contain up to 30% or more Triticale.

Sorghum

Sorghum is a cereal that can grow in marginal areas where Maize cannot perform well. It contains tannins that lower protein and energy digestibility. Low tannin sorghum can be used to completely replace maize.

Cassava root and potato tuber meals

When proper nutritional adjustments are made in the diet that contain cassava products (chips, pellets or flour), the performance is comparable to with performance obtained in animal feeding programmes based on Cereals. Cassava requires lower inputs as compared to cereals. Most research that has been conducted in the world indicates that Cassava flour inclusion range from 20 to 40% in the diet for poultry and swine. However, a study by Brum, *et al.*, 1990, showed that 66.7% of Maize in broiler diet can be replaced by cassava without compromising on their growth performance. Cassava contains very low protein content (2.2%) and limiting amino acid especially lysine (0.077%) and tryptophan (0.075%).

The principal characteristics of cassava are high starch content that gives an energy level slightly lower than Maize and Sorghum. Due to this limitation the price of cassava is generally around 70-75%in relation to the price of Maize. The difference in price allows poultry producers to supplement the diet with sources of proteins and fat such as Soybeans. A moderate amount of amount of Soybeans can supplement all nutritional deficiencies of cassava when used in poultry feeding programmes. Another aspect that explain the preference for cassava is that some consumers desire chicken with less yellow skin. The option has been to develop feeding programme in which Maize only 5%feeding programme and ration based on cassava (Table 5).

Table 5. Nutritional composition of cassava flour (82%) with integral soybean (18%) as compared to Maize

Content	Cassava flour+ Integral Soybean	Commercial maize
ME Mcal/kg	3.25	3.34
Crude proteins (%)	9	8.5
Methionine (%)	0,12	0.35
Lysine (%)	0.46	0.26
Threonine (%)	0.28	0.29
Methionine + Cysteine (%)	0.24	0.35
Tryptophan (%)	0.10	0.07
Arginine (%)	0.51	0.4
Fat	3.5	3.6
Calcium	0.29	0.04
Available Phosphorus	0.09	0.04

Source: Burtrago and Luckett, 1999

The use of cassava in animal feeding programs require elimination of anti-nutritional factors such as linamarine in cassava roots. The compound is a precursor of hydrogen cyanic acid. Adequate processing can eliminate the problem. In general, 100 ppm of hydrogen cyanic acid in the final product is considered safe in diets. Detoxification methods to remove cyanide include ensiling, sun-drying, air-drying, roasting, soaking and molting as reported by various studies on Cassava feeding trials.

Sweet potatoes are good sources of energy but low protein content. They can be used up to 40-50 per cent in the diet. Sweet potato meal contains low levels of trypsin inhibitor. Whereas Irish potatoes are a good source of energy they contain solanine, a toxic substance. Solanine concentration increases when the tubers are exposed to fluorescent light. The exposure to light turns the flesh of the tuber green in colour. The tubers also become toxic with solanine when they sprout. To avoid solanine toxicity, sprouted and green tubers should not be fed to chickens.

Green materials

Green plants are the cheapest sources of nutrients particularly proteins and vitamins for scavenging chickens. Many garden vegetable produce are suitable for feeding chickens and farmers can be encouraged to create additional foraging for their birds. Farmers can grow vegetables such as Kales, Rape, and food beans that provide supplementation for the chickens (FAO, 2006).

Cotton seed meal

Cotton seed meal contains 36.5 per cent crude protein. High level crude fibre and gossypol limit its use in poultry diet. Low gossypol meal can be used at 10-15 per cent in broiler diet.

Sunflower and sesame meals

Sunflower and sesame meals contain 46.4 and 41.2 per cent respectively. The inclusion level in poultry diets range between 15 and 30 per cent.

Alternative Animal protein feed resources

Animal protein sources are limited in poultry as a result of competition with human. It is therefore imperative that other sources come into play to bridge the gap. Insect such as earth worms, termites and Maggots can play a significant role.

House-fly maggots

Various studies have suggested the utilization of maggots as feed for enhancement of chicken performance (Ukah and Onwujiariri, 2012). They can also play an important role in recycling any form of waste and other accumulated nutrients in the environment (Bushy, 1991). The resultant maggots offer high proteins for poultry and fish (Zuidhof, *et al.*,2003 and Oguni, *et al.*, 2007). As early as 1969, Calvert suggested that dried housefly growing in poultry waste had high protein levels (63%) and fats (15.5%) content were better source of quality feed as Soy bean meal in chicks fed during the first two weeks after hatching. In 1999, Inaoka and others successfully fed house fly maggots on growing chicken with excellent results. They reported that dried maggots and pupae contain 56.9% and 60.7% Crude proteins and 20.9% and 19.2% crude fat respectively. They have protein and amino acid similar to fish when fed to broiler chicken (Hwangbo, *et al.*, 2009).

The nutrient content of maggots is comparable to most animal proteins; as demonstrated by various authors as shown in Tables 6 and 7. The amino acid profile of housefly larvae has been found to be superior to Soybean meal and blood meal (Odesanya, *et al.*, 2011). In addition housefly larvae contain better essential amino acid profile than fish meal except Threonine, Tryptophan and Cysteine (Oniebo *et al.*, 2008).

Table 6. Nutrient content of maggot as reported by Hwungbo, *et al.*, 2009, Odesanya, *et al.*, 2011 Okah and Onwwujiariri, 2012

Item	Author Hwungbo, *et al.*, 2009	Author Odesanya, *et al.*, 2011	Author Okah and Onwwujiariri, 2012
Crude proteins	63.99	48+0.52	44.44
Ether Extract	13.1	-	9.76
Energy (ME)	4140	3755+190	2381
Ash	5.16	10.03+0.44	14.29
Ca	2.01	0.344	0.03
P	1.326	0.970	0.05

Table 7. Amino acid profile (% composition) of housefly larvae and other protein feed stuffs

Amino Acid Meal	HFLM	Fish meal	Soybeab meal	Blood meal
Lysine	6.04	4.55	2.62	5.99
Histidine	3.09	1.36	1.02	3.96
Threonine	2.03	2.60	1.66	3.47
Arginine	5.80	3.99	2.90	3.19
Valine	3.61	3.09	2.06	6.41
Methionine	2.20	1.68	0.52	0.91
Iso-leusine	3.06	2.97	2.07	0.90
Leusine	6.35	4.45	3.29	1.01
Phenylalamine	3.96	2.35	2.12	5.47
Tryptophan	-	0.69	0.65	1.02
Cysteine	0.52	0.92	0.74	1.31
Tyrosine	2.71	1	1.27	1.73

Adapted from Aniebo et al., 2008

Another advantage of using maggots as chicken feed is their short life cycle and their production in large biomass (quantity) from materials regarded as waste make the a viable option to explore.

Fish byproducts

In areas where fishing is operation, there is potential for using offal and other byproducts for feeding poultry. For example, the edible flesh of most fish represents only 40% of their total weight leaving 60%

for use as protein feed resource (FAO, 2006). Scrap fish and fish waste or residue heads and offal can be dried and processed into meat for feeding poultry.

Termites

Termite are social insects that swarm seasonally especially at the onset of rains. They are edible and highly sought for as a delicacy. During the swarming period, a lot of termites are wasted and could be utilized for poultry production. Even during the dry season. The workers can easily be trapped and fed to birds. In ackyard poultry production, farmers include termites in the diet of their birds (Okitoi, 2003). It is believed that feeding termites improves the nutrition of birds. The eggs and larvae are particularly relished by chicks while adult birds also feed on adult insect (Sogbesan, 2008). The nutrient composition of termites has been shown to be quite good. The crude protein accounts for 46.3% (Sogbesa, 2008) when fed to fish. Aduku, 1993 reported that the crude protein ranges between 37-44.12%. However, termites are understood to be carriers of some worms (*Railletina galli, Heteraki s gallinae* etc). It is imperative that farmer should deworm their poultry routinely if they feed them with termites (Alenyorege and Ugwumba, 2011). A simple method has been used in Africa to rear and harvest termites. To trap the termites, fill a mud pot with old sisal sacks, straw, hay, Maize husks or any dried crop residue and cow dung. This has to be moistened with water and the pot placed upside down in the field. If the inverted pot is opened the next day it will be full of termites and can be fed to the birds.

Earthworms

They are natural food for scavenging birds. They can be fed live or dried and are highly palatable to poultry. Earthworms can also easily be produced and harvested for feeding poultry. Successful culture of earthworms requires favourable condition for growth and development. The chicken can be used to harvest the earthworm or they fed in dried form.

Challenges in using alternative feeds

Whereas alternative feedstuffs can fully incorporated in poultry diet, there are challenges that will be encountered; namely nutritional, technical and socio-economic aspects (Table 6).

Table 8. Factors affecting utilization alternative feeds

Nutritional aspect	Technical aspect	Socio-economic aspect
1. Variability or lack of consistence in nutrient quality	1. Seasonal and unreliable supply	1. Competition with use as human food
2. Limited information on availability of nutrients	2. Need for processing or detoxification	2. Poor prices relative to other feeds
3. High fibre content	3. Limited research and development facilities for determining nutrient composition and inclusion level in poultry	3. Cost per unit energy or amino acid, relative to of other traditional feeds
4. Presence of anti-nutritive factors		4. Cost of processing
5. Need for nutrient supplements (added cost)		
6. Mass production, processing and preservation		

(Adopted from FAO, 2004)

Conclusion and recommendation

Non-conventional feed resources are available for feeding poultry at all levels of production. Smallholder poultry keepers who wish to make their own feeds must adopt simple rations based on feed resources they produce or those readily available and affordable in their local environment. Free-range poultry keepers should make efforts to provide sufficient supplementation to their birds' as opposed to throwing Kitchen leftovers. Training, research and development agencies should focus on the needs of smallholder poultry producers who are mostly women. Such effort would improve the quantity of eggs

and chicken meat available for consumption and sale by rural communities and thus enhance the food and nutrition security and income at household level.

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Effect of Gamma Irradiation of Local *Brachiaria Ruziziensis* (Germain and Evrard ecotypes) Seeds on the Grass Performance and Quality

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Abstract

Appropriate methods of mutation induction are of high importance in pastures for increased genetic variability and improved performance. The objective of this study was to investigate agronomic and nutritive performance of mutant lines through induced mutagenesis to seeds of a local landrace of *Brachiaria*. The seeds were irradiated with 0, 10, 20, 30, 40 and 600Gy doses of gamma radiation from Cobalt 60 (^{60}Co). Treatments were; KE 0Gy, KE 10Gy, KE 20Gy, KE 30Gy, KE 40Gy and KE 600Gy resulting into M1 seeds. The mutant (M1) seeds were planted in the greenhouse in germination pots for one month and the seedlings transplanted to the field. Seeds of M6 plants (M7 seeds) were used to establish field experiment in a completely randomized block design, with three replications. Parameters measured included; tillering, leaf-stem ratio, dry matter weight, in-vitro digestibility, crude protein, amino acids and fatty acids. Data collected was analyzed using Genstat version 18 software. Mutant lines exhibited better agronomic and nutritive values, in-vitro digestibility coefficients and essential amino acids compared to the wild type. Performance increased with increased gamma ray exposure with 600Gy treatment out performing all other treatments whereas the control performed dismally. There was significant difference ($P<0.05$) in the amino acid contents with 600Gy treatment having the highest values of dry matter yields, essential amino acids whereas control had the highest values of fatty acids. Application of nuclear technology to other grasses would lead to increased biomass and improved nutrition for increased animal productivity leading to food and nutrition security.

Key words: Gamma rays, Dry matter, Digestibility, Amino acids, *Brachiaria* grass

Introduction

Seed irradiation before sowing is one of the most effective methods that can be used to improve plant performance. The effect of gamma radiation in improving plant performance has been shown to be highly related to the level of doses used (Respati *et al*., 2018). However, information is scanty on the effect of gamma radiation dose on the local Brachiaria species in Kenya. The objective of this study was therefore to determine effect of gamma irradiation of local *Brachiaria ruziziensis* **(**Germain and Evrard ecotypes) seeds on the grass performance and quality.

Materials and methods

Total of 1,000 landrace (KE) seeds were put in each of 6 pre-labeled petri dishes (KE 0, KE 10, KE 20, KE 30, KE 40 and KE 600). Each petri dish represented one treatment. The seeds were irradiated with 0, 10, 20, 30, 40 and 600 Grey (Gy) doses of gamma radiation from Cobalt 60 (^{60}Co). Treatments were; (i) KE 0 (Control), (ii) KE 10 (exposed to 10Gy), (iii) KE 20 (exposed to 20Gy) (iv) KE 30 (exposed to 30Gy) (v) KE 40 (exposed to (40Gy) and KE 600(exposed to 600Gy). The control seeds were not irradiated (0 Grey).

Field trials

Field trials were conducted at KALRO - Lanet (0° 27' 09' S and 390 38’ 45’ E at an elevation of 1600 meters above sea level. The site is located in Nakuru County, Kenya. The area has a bimodal rainfall

pattern with an annual mean rainfall of 800mm ranging from 534 to 1,049mm and 83% relative humidity. Temperatures range between 8 to 30^{o}C (Pratt and Gwyne, 1977).

Green house

Mutant seeds (M1 seeds) were grown in germination trays in the green house for one month during which time germination rate was recorded.

Field experimental design

The land for setting M1 Brachiaria seedlings was ploughed and harrowed using a tractor. At the time of planting, single superphosphate (0:18:0) at a rate of 250 kg/ha was used. The experiment was laid out as a complete randomized block design (RCBD) with three replications. The seeds were planted into holes at a depth of 3.0cm at a spacing of 60 cm x 30cm. The Brachiaria grass was top dressed using CAN (27% N) at 250 kg/ha when the crop was 60 cm. Agronomic performance was recorded at booting (Rana and Suresh, 2014). The grass was cut at 2.0 cm above ground at booting stage by throwing a 1.0^2 m quadrant three times at each treatment and sward within the square was harvested using a sickle, homogenized and used to determine leaf to stem ratio, nutritive values, and herbage yield (kg/ha). In-vitro digestibility was performed using method described by Tilley and Terry (1963).

Nutritive and mineral, amino acid and fatty acid analysis

Dry matter (DM, g/kg) contents were determined according to AOAC (1990) method while organic matter (OM) and ash were determined according to AOAC (2006) method. Crude protein (CP) content (g/kg DM) was calculated as 6.25 x N (Kjeldahl nitrogen) content in the feed. The N content was determined according to AOAC (2006b) method. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to Van Soest *et al.,* (1991).

Minerals were analyzed using a technique described by Okalebo *et al.,* (2002). Amino acids and fatty acids were analyzed using a technique described by Tie-xin and Wu Hong (2008).

Data analysis

Analysis of variance was carried out for the data collected. Mean separation was done using Tukey's whenever there was significant treatment effect. Genstat version 18 software was used for the analysis.

Results

Germination

In the greenhouse, there was significant ($P<0.05$) difference in percent germination three weeks after sowing. Percent germination significantly ($P<0.05$) decreased with increased gamma ray exposure. The 600 Gy dose had the least while the control had the highest percent germination (Figure 1).

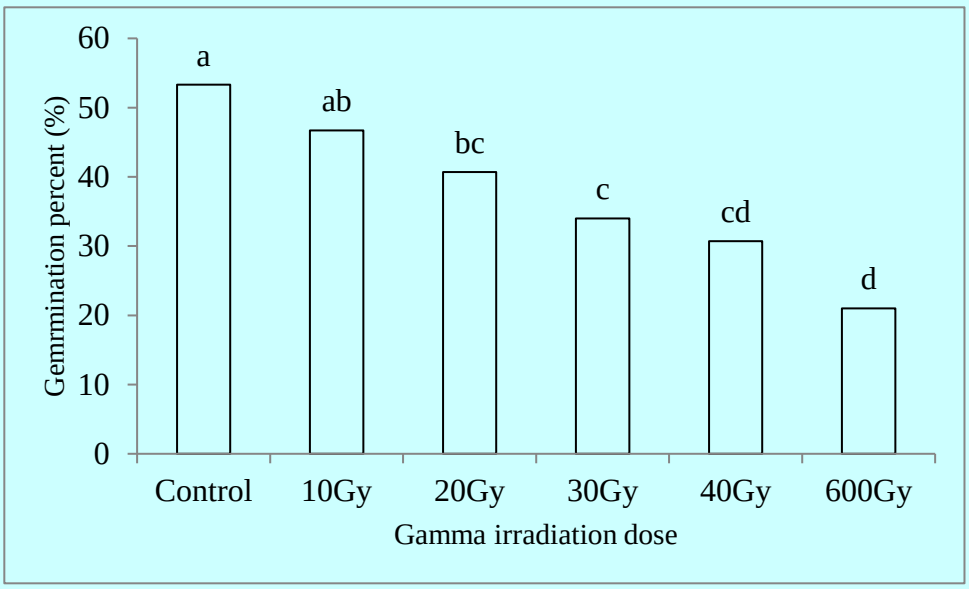

Figure 1. Effect of gamma irradiation dose on Brachiaria germination in the greenhouse at 3 weeks after sowing

Field establishment

The field establishment was significantly lowest in the treatment receiving the highest dose (600Gy). Tillering increased with increase in gamma ray exposure. The 600 Gy dose recorded the highest number of tillers (37) compared to the other doses and the control (Table 1). For the days to 50% flowering, the 600 Gy irradiation dose took significantly the longest to flower (197 days), followed by the control (179 days). The 40Gy treatment took the least number of days though not significantly different from the 10, 20 and 30 Gy doses respectively (Table 1). For the shoot elongation rate, the 30Gy dose recorded the highest shoot elongation rate though not significantly different from the 10, 20 and 40 Gy doses respectively. The 600Gy dose had the least stem elongation rate. Similarly, the 600Gy dose recorded the least internode length, though not statistically different from the other treatments. The 30Gy dose had the highest leaf elongation rate then the other gamma radiation doses and the control (Table 1). The 20Gy recorded the highest leaf length (31.7 cm). Gamma radiation at the low doses had the leaf length significantly different from the control. However, there was no significant difference between the control and the high dosage (600 Gy) (Table 1).

The leaf shoot ratio increased with increase in the gamma radiation dose. Conversely, the chlorophy ll content decreased with increase gamma ray dosage. The plant height was significantly highest when the seeds were treated with 10 Gy radiation dose, while the 600 Gy dose had the shortest plants (Table 1).

Table 1. Effect of gamma irradiation on agronomic performance of *Brachiaria ruziziensis*

Treatment	Establishment	Tillers	Day_50	SER	IL	LER	LL	LSR	Chlorophyll	PH
Control	100a	15.7e	179b	0.25bc	6.5	0.15b	17.8c	0.25c	46.4a	127.3ab
10Gy	100a	21.0e	160c	0.32ab	6.6	0.18b	28.3ab	0.27bc	41.8ab	138.7a
20Gy	100a	24.0d	154c	0.37a	5.7	0.17b	31.3a	0.30abc	40.0bc	121.7abc
30Gy	100a	26.7c	154c	0.40a	5.6	0.5a	30.3ab	0.31abc	38.0bc	94.3bcd
40Gy	100a	34.0b	150c	0.35a	6.2	0.2b	30.7a	0.36ab	35.9c	80.7cd
600Gy	97.3b	37.0a	197a	0.21bc	5.3	0.1b	24.0bc	0.37a	27.1d	75.0d
Tukey MSD (α=0.05)	2.41	2.2	12.7	0.09	NS	0.3	6.5	0.1	5.3	43.7

Means followed by different letters within a column are significantly different from each other at α=0.05. MSD- Tukey's mean significant difference.

Mineral and sugar content of Brachiaria ruziziensis

Percent protein increased with increase in gamma ray exposure with treatment exposed to 600Gy, having the highest protein content and the control the least. The iron concentration was highest in treatment exposed to 30Gy and the least in the control treatment. The highest zinc concentration was observed in the 10Gy exposure (78.7 mg kg^{-1}) followed by 20Gy exposure (73.0 mg kg^{-1}) while the 600Gy recorded the least zinc concentration levels. Similarly, the 600Gy exposure had the lowest sucrose level (7.2) while the 20Gy exposure had significantly highest sucrose content (Table 2).

Table 2, Effect of gamma irradiation dose on the mineral and sugar content of *Brachiaria ruziziensis*

Treatment	Crude protein (%)	Zinc (mg kg^{-1})	Sucrose (µg g^{-1})	Iron (ppm)
Control	8.2e	65.4c	7.2d	175.0e
10Gy	8.9d	78.7a	12.2b	185.4d
20Gy	10.6c	73.0b	13.6a	209.8b
30Gy	12.3b	64.6c	9.2c	260.5a
40Gy	12.6b	62.9c	7.6d	193.9c
600Gy	14.0a	58.4d	7.2d	187.4cd
Tukey MSD (α=0.05)	0.65	3.5	0.43	8.4

Means followed by different letters within a column are significantly different from each other at α=0.05. MSD- Tukey's mean significant difference

Proximate analysis and digestibility coefficients of Brachiaria ruziziensis mutant lines

There was significant (P<0.05) difference in proximate analysis results with the control having higher levels of percent nutrient detergent fiber (NDF) fractions and total fats but significantly (P<0.05) lower percent crude protein (CP) than the treatment. The CP increased with increasing ^{60}Cobalt exposure where treatment exposed to 600Gy had the highest amount of CP (13%). The digestibility coefficients increased significantly (P<0.05) with increased ^{60}Cobalt exposure with treatment exposed to 600Gy having significantly (P<0.05) high values of organic matter digestibility (OMD), dry matter digestibility (DMD), and dry and organic matter digestibility (DOMD) (Table 3).

Table 3. Effect of gamma irradiation dose on the proximate analysis and digestibility coefficients of *Brachiaria ruziziensis*

Treatment	NDF	ADF	CP	ADL	OMD	DOMD	DMD
Control	56.5bc	37.2c	7.7bc	5.6a	32.7ab	281.8ab	36.7
10Gy	61.7a	44.4a	6.7d	5.7a	21.8d	184.7d	24.2
20Gy	59.8ab	42.9ab	7.5cd	5.3a	26.9bcd	225.5bcd	27.6
30Gy	56.0bc	36.3c	8.4b	4.2b	30.1bc	255.0bc	35.4
40Gy	59.8ab	42.0b	8.2bc	5.2a	23.4cd	196.8cd	27.7
600Gy	52.8c	33.0d	13.2a	3.4c	37.6a	318.1a	40.1
MSD (α=0.05)	4.1	2.2	0.8	0.6	7.4	62.5	NS

Means followed by different letters within a column are significantly different from each other at α=0.05. MSD- Tukey's mean significant difference

NDF- Nutrient detergent fiber, ADF- acid detergent fiber, OMD- organic matter digestibility, CP- Crude protein, DMD- dry matter digestibility, DOMD- dry and organic matter digestibility.

Correlation of the nutrient contents to digestibility coefficients and agronomic variables

There was significant (P<0.05) negative correlation between NDF, acid detergent fibre (ADF) and acid detergent lignin (ADL) with the leaf length (LL), leaf shoot ratio (LSR), and total seed weight (TSW) but significantly (P<0.05) positively correlation with the plant height. The OMD and DOMD had a significant (P<0.05) positive correlation with stem elongation (SE) but no significant (P>0.05) correlation with the other agronomic variables. Percent crude protein showed a significant (P<0.05) negative correlation to percent fats, days to 50% flowering and plant height, but a significant (P<0.05) positive correlation with organic matter digestibility, shoot elongation, leaf-to-shoot ratio, leaf length and total seed weight. The fats showed significant (P<0.05) positive correlation with days to 50%

flowering and height but a significant (P<0.05) negative correlation with the shoot elongation, leaf length, leaf-shoot ratio and total seed weight (Table 4).

Table 4. Correlation of the nutrient contents to digestibility coefficients and agronomic variables

	NDF	ADL	CP	OMD	FATS	DAY_50	SE	LL	LSR	Height	TSW
NDF	1	0.99**	-0.98*	-0.84^{ns}	0.98*	0.95^{ns}	-0.92^{ns}	-0.99**	-0.96*	0.99*	-0.97*
ADL		1	-0.98*	-0.83^{ns}	0.97*	0.94^{ns}	-0.91^{ns}	-0.99*	-0.96*	-0.99*	-0.97*
CP			1	0.93^{ns}	-0.99**	-0.97*	0.97*	0.99**	0.96*	-0.98**	0.99**
OMD				1	-0.94^{ns}	-0.94^{ns}	0.98*	0.90^{ns}	0.90^{ns}	-0.89^{ns}	0.93^{ns}
FATS					1	0.97*	-0.97*	-0.99*	-0.96*	0.99**	-0.99**
DAY_50						1	-0.99**	-0.98*	-0.99**	0.95*	0.95*
SE							1	0.96**	0.97**	-0.95^{ns}	0.95*
LL								1	0.982*	-0.99**	0.98*
LSR									1	-0.95^{ns}	0.94^{ns}
Height										1	-0.99**
TSW											1

*, **- significant at p<0.05 and p< 0.01 respectively; ns- not significant
NDF-Neutral detergent fiber, ADF- Acid detergent fiber, CP- Crude protein, OMD- Organic matter digestibility, DAY_50- Days to 50% flowering, SE- Shoot elongation, LL- Leaf length, LSR- Leaf-shoot ratio, TSW- Total seed weight

Discussions

The present results show that seed treatment with ^{60}Co gamma radiation, plant germination and establishment in the field. The restriction in germination may have been caused by the high amount of irradiation that resulted in the cell cycle arrest at the G2/M phase during somatic cell division or genome damages, changes in protein synthesis and reduced amount of endogenous growth regulators (Kiong *et al*., 2008). Additionally, Shah *et al*., (2008) stated that processes such as destruction of auxin, ascorbic acid content changes, biochemical and physiological disturbances could induce the inhibition of plant germination. These results are in agreement with other findings that reported decreased germination potential and survival rates of different crops due to increased irradiation dose (Warid *et al*., 2017).

The other plant growth parameters that were negatively affected by the higher radiation dose included the shoot and leaf elongation rate, leaf length and seed weight. However, the low radiation doses performed better than the control. This may be as a result of the modification or damage of important component of plant cells caused by the free radicals. These radicals usually affect the anatomy, morphology, physiology and biochemistry of the plants depending on the dose of the radiation (Ashraf *et al*., 2003). Toker *et al*., (2005) showed that the growth of chickpea seeds had significant increase in plant growth parameters but at 400Gy, a depression in the plant shoot length was observed. Low doses of gamma irradiation stimulates the cell proliferation, cell growth and enzyme activity (Moussa, 2010) but the high doses of gamma rays disturbs the protein synthesis, enzyme activity and water exchange (Aly and El-Beltagi, 2010). This will also explain the observation on the amount of sucrose, iron and zinc content results from this study.

The proximate analysis showed that the radiation increased the crude protein content, organic matter digestibility and, dry and organic matter digestibility. The increase in protein content is possible due to de novo synthesis of stress proteins triggered by metal exposure (Mishra *et al*., 2006). Borzouei *et al*., (2010) explained that the irradiation of seeds with high doses of gamma ray modifies the synthesis of protein. These results agreed with the finding of Meire *et al*., (2014) who reported that gamma irradiation influenced the chemical composition of the mushrooms, especially the dose of 500 Gy, which provided the highest averages crude protein and fiber in the mushrooms on day one of storage. This finding differed with the finding of Sahng-Wook *et al.*, 2013 who reported no significant differences was found in proximate analysis of nutrients between raw whole cotton seed and gamma irradiated one.

Correlation analysis from this study showed some positive correlation between the dry matter and seed yield and the morphological characteristics of the plant. These findings are in agreement with the finding

of Tudsri *et al*., (2002) who reported morphological characteristics were correlated with DM yield and nutritional quality. This implies that manipulation of these morphological traits through mutagenesis could be used to improve the overall performance of the grasses in terms of the herbage yield for enhanced cattle productivity.

Conclusions

Results from agronomic performance**,** mineral and sugar levels, nutrient profile**s** indicated that the mutant lines differed from their parents, and therefore, these mutant lines could be used as a donor parents in forage breeding program and some of them can be recommended as new Brachiaria ecotypes suitable for Kenya. The mutant lines could be selected, multiplied (especially lines exposed to 600Gy mutation) and used in feeding trials to determine reproductive performance of dairy cattle fed on the mutant lines. Future studies should focus on total mixed ration formulation using the mutant lines, designed feeding trials, fractionation of amino and fatty acids from the lines for incorporation in poor forages and national performance trials of mutant lines with an aim of forage variety release.

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Current Status of Dairy Production Systems and Management Practices in Taita-Taveta and Makueni Counties of Kenya

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Abstract
A situational analysis survey was conducted to establish the current status of dairy production systems and management practices in Makueni and Taita Taveta Counties in Kenya. Data were collected by enumerators using a questionnaire uploaded in ODK using tablets and smart phones. Descriptive data analysis was performed based on the key variables in the data set. Primary data was collected from 79 dairy farmers who were selected using purposive and simple random sampling techniques. The study aimed to characterize dairy production and prioritize constraints and opportunities for development. The study revealed that the leading dairy production constraints were feed shortage, pests and diseases and limited access to finances for investment, cited by 86, 83 and 44% of respondents respectively. Poor access to extension services, poor quality of feeds and poor access to AI services also ranked high (37, 33 and 32% respectively) as the main constraint hindering dairy productivity in the study counties. The study further revealed that the main feed resources were the grasses (100%), crop residues (80% and fodder legumes (45%). Dairy meal was the most commonly used supplementary feed in the farms, and its high costs would limit its use as dairy supplements in the farms. A large percentage of the respondents (49 %), practice livestock rearing as their main source of incomes. Zero grazing was the main type of production system practiced in the study regions (80%) followed by semi-zero grazing (40%) which was dominant in Makueni county. Average milk production recorded in the households was 9.5 kg per cow per day. Taita Taveta County recorded higher milk production (12%) than Makueni (7%). Alleviation of the identified constraints would improve dairy cattle productivity in the area.

Introduction

Growth in agricultural production and productivity is vital to raising rural incomes and to meet the food and raw material needs of the fast growing population. Livestock have an important part to play, as they provide high-quality protein to consumers and regular income to producers. For sustainably, livestock must be managed with efficiency (FAO, 2011). The profitability of the dairy enterprise requires both the production units (cows) and the most appropriate inputs. Kenya's dairy sub-sector accounts for about 3.8 % of the National gross domestic product (GDP) and directly contributes to the livelihoods of about four million Kenyans through food, income and employment (FAO, 2011).

Empirical findings are that the country's milk is expensively produced, making it unaffordable to a large proportion of the population. Despite the many recommendations on how to increase yields, it has remained low and it's per unit cost of production relatively high. Use of commercial feed supplements is expensive and unaffordable by many smallholder dairy farmers. Additionally, whenever pasture grasses and cereal straws forms a high proportion of animals' diets, the primary consideration is to overcome the effect of the resulting nutrient limitation by diet supplementation (Abbator, 1990). Thus, the poor quality of pastures fed to ruminant animals inhibits their performance (Mshelizah *et al.*, 2015). The crude protein content of the grasses drops below 4% during the dry season, and are very low in phosphorus and energy.

There is a need therefore to adopt low-cost supplementary feeds to reduce the cost of dairy production. Multi-nutrient mineral blocks are such alternatives that can solve this problem of dairy profitability. Multi-nutrient mineral blocks are a balanced feed supplement containing protein, energy, mineral and vitamins for ruminants. Multi-nutrient mineral blocks are generally used to augment the rumen energy and ammonia level of ruminants when the energy and protein needs for maintenance and production are low especially during the dry seasons. Therefore, the feeding of the blocks is a convenient and inexpensive method of providing a range of nutrients required by the rumen microbes and the animal,

which may be deficient in the diet. The current baseline study was designed to obtain bench mark information on current smallholder dairy production systems and management practices prior to an on-farm technology validation on MUMBs feeding trials in Taita Taveta and Makueni Counties.

Methodology

Study sites

The study was carried out in Mwatate and Wundanyi sub-counties in Taita Taveta and Makueni and Mbooni sub-counties in Makueni County.

Sampling techniques

Field visits were undertaken to study locations and farms that were purposively selected from USAID Feed the Future project counties between October and November 2018. Sub counties were purposefully selected in collaboration with the extension and County representative staff. At each study location, the farmers were randomly selected based on the intensity of dairy practices as informed by previous stakeholder meetings. Purposive and simple random sampling techniques were used to select a sample of 79 dairy cattle farmers in the two Counties. Data was collected using questionnaires uploaded in the ODK in tablets and smartphones.

Survey data processing and analysis

Descriptive statistics; means, proportions, ranges, and cross-tabulations were used to make summary tables and charts for various variables using Statistical Package for the Social Sciences (SPSS) version 20 (SPSS, 2014) and Excel software.

Results and discussion

Household characteristics

Socio-economic characteristics of households in the study area are shown in Table 1. Most of the farmers interviewed were the households' heads (62%). However, where the household was not interviewed, a good representation by the spouses was observed with a mention of 73% households. Overall, men respondents dominated in the interviews (62%), as compared to women respondents (38%). Male-headed household types dominated the study (72%). However, Taita Taveta County had larger number of female-headed households. This factor could be attributed by cultural beliefs in some communities in Kenya that a 'woman's' place is the 'kitchen', where men go to cities to look for employment.

Table 1. Household characteristics and socioeconomic profile of the respondents

		Makueni n=37	Taita Taveta N=42	Total n=79
Household head	Yes	48.6	75	61.6
	No	51.4	25	38.4
Relationship to HH head (If No above)	Son/daughter	21.1	28.6	23.1
	Spouse	73.7	71.4	73.1
Gender of the respondent	Male	45.9	80	62.5
	Female	54.1	20	37.5
Household type	Male headed	86.5	58.3	72.6
	Female headed	13.5	19.4	16.4
	Male headed-female managed	0.0	19.4	9.6
	Others	0.0	2.8	1.4
Age group of HH head	18-35 years	2.7	0.0	1.4
	36 -55 years	51.4	38.9	45.2
	56-65 years	29.7	47.2	38.4
	Above 66 years	16.2	13.9	15.1
Education level of HH head	Never attended school	0.0	5.6	2.8
	Secondary	18.9	41.7	30.1
	University/College	70.3	19.4	45.2
	Upper Primary	10.8	33.3	21.9

A larger component of respondents (34%) were between the ages 36-55 years old, while 15 % were 66 years old and above. The youth's population in the two study counties seemed to shy away from farming (1%). The project (USAID FtF, feed block commercialization project) is a potential employer for those jobless generation of youths. The project aims at capacity building on feed block production and marketing once the adoption of the blocks increases. Supporting of digital agriculture should also be encouraged in the policy in order to attract these youths to farming, a factor that will contribute to the countries' Big Four of food security and industrialization for employment.

The study revealed that 45% of the respondents had acquired levels of university/college education, 30% had a secondary school qualification, 22% had primary school education and 3% had never been to school. However, greater percentage of illiteracy was recorded in Taita Taveta County. Formal of education of respondents is vital for research technology adoption as it is easier for educated farmers to try new agricultural technologies.

Main sources of income

Figure 1 illustrates the main sources of income of households. A large percentage of the respondents (49 %) practice livestock rearing as their main source of incomes, while others had other sources of income. This illustrates the importance of dairy farming in the study area.

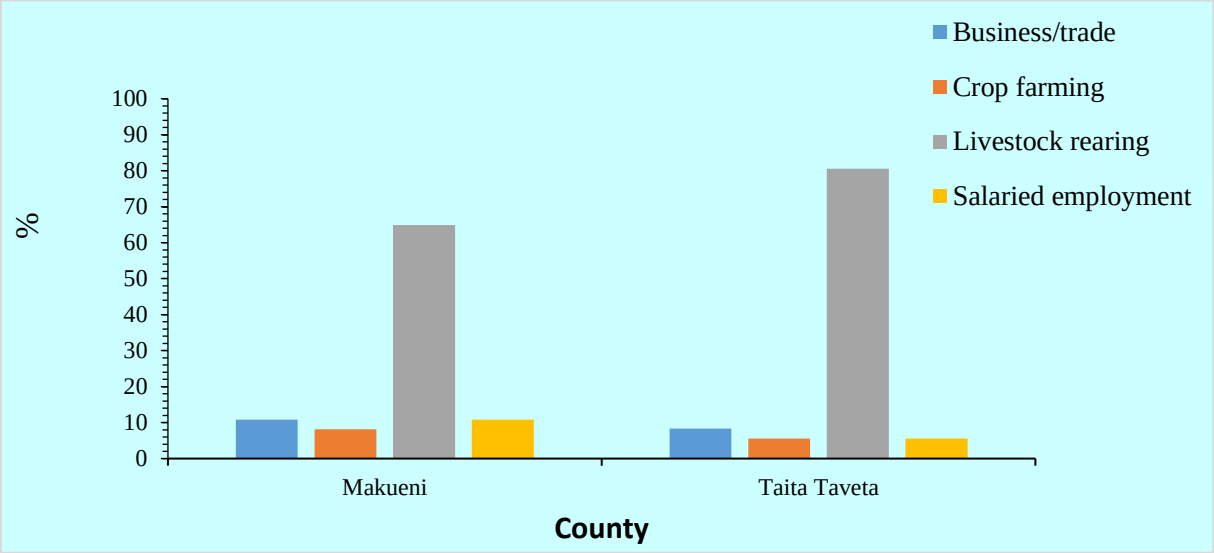

Figure 1. Main sources of income

Dairy cattle breeds

Figure 2 shows the dairy cattle breeds kept in the study areas. Friesians were the most preferred in the two counties (Makueni (78%) and Taita Taveta (83%). This could be due to its high milk production potential. Cross breeds and Ayrshires were the second and third most preferred breeds in the two Counties. Local zebus were only kept in Makueni County (10%).

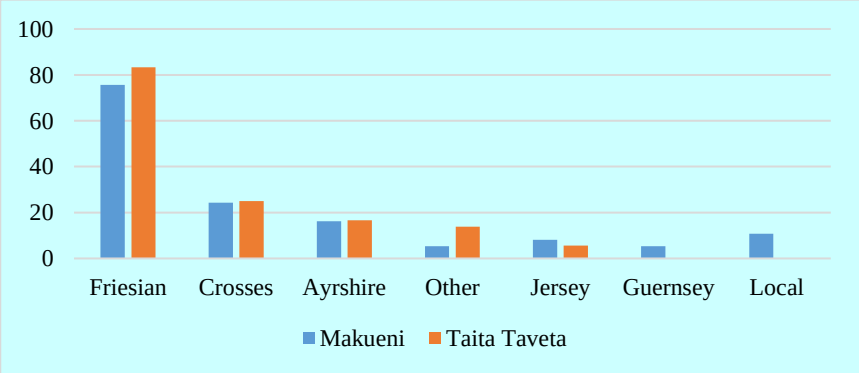

Figure 2. Dairy cattle breeds

Farm sizes and land allocation

The results showed that Makueni had larger land holdings (average of 7 acres) than Taita Taveta with 4 acres on average (Figure 3). Land allocated for dairy farming was also larger in Makueni than in Taita Taveta (3 and 2 acres respectively). Land holding has implications in dairy productivity as it dictates forage availability in the households. Excessive off-farm purchase of forages increases the cost of milk production, thus reduce profits.

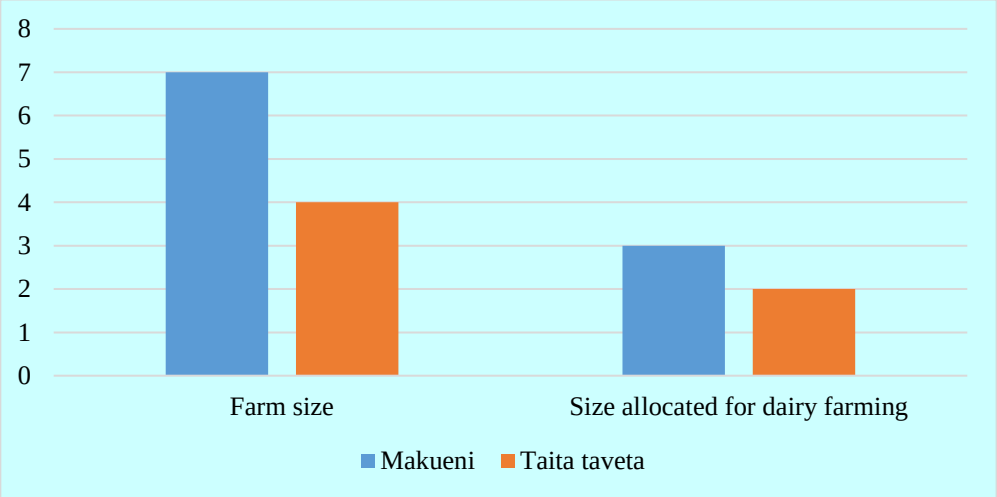

Figure 3. Farm sizes and land allocated for dairy farming (acres)

Dairy production systems

Zero grazing was most preferred in the two study regions (Figure 4). However, Taita taveta recorded the highest percentage of households with zero grazing than Makueni County (78%). This could be attributed to the small land holdings shown above. Semi-zero grazing system was practiced in Makueni County.

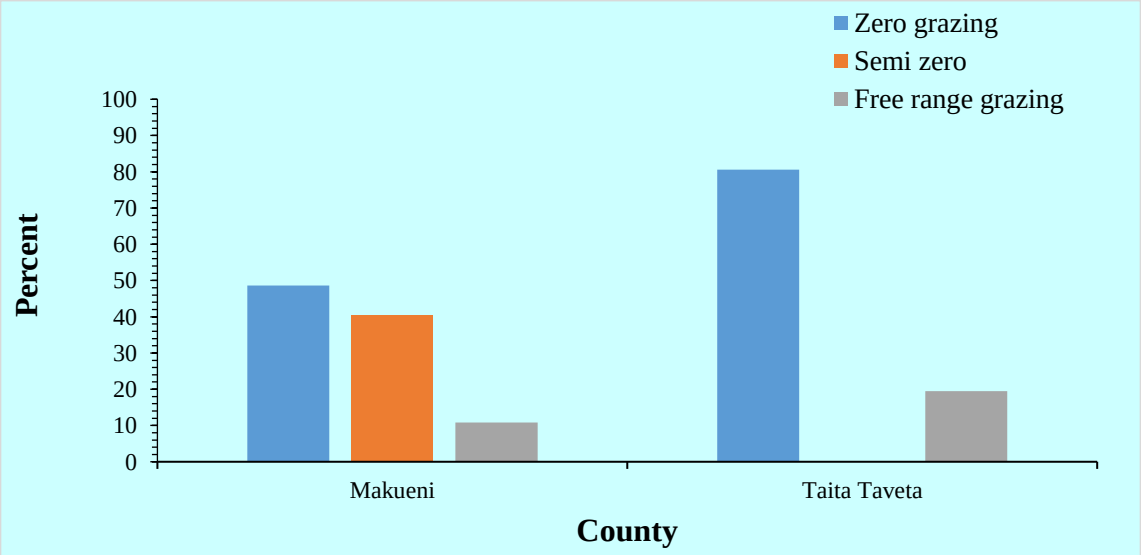

Figure 4. Type of production system

Feed availability

Figure 5 shows the availability of various feed and feed supplements in the study area. Forage grasses were most common in both Makueni and Taita Taveta counties (100%). Crop residues as livestock feed were more common in Makueni County (81%) than in Taita Taveta county (20%). Fodder legumes were most available in Taita Taveta County (58%). Supplementary feeding was poorlypracticed in both

counties, with as low as 10% responds in Taita Taveta County. Utilization of crop residues is usually associated with inherent constraints of low digestibility, protein, energy and mineral contents that often result in poor intake and palatability. Feeding crop residues with the supplements of protein, energy and minerals as well as chemical treatment can overcome these constraints. The study showed that supplementation was practiced by 58% of the respondents. Molasses Urea Mineral blocks, if well adopted will solve this problem of lack of feed supplementation.

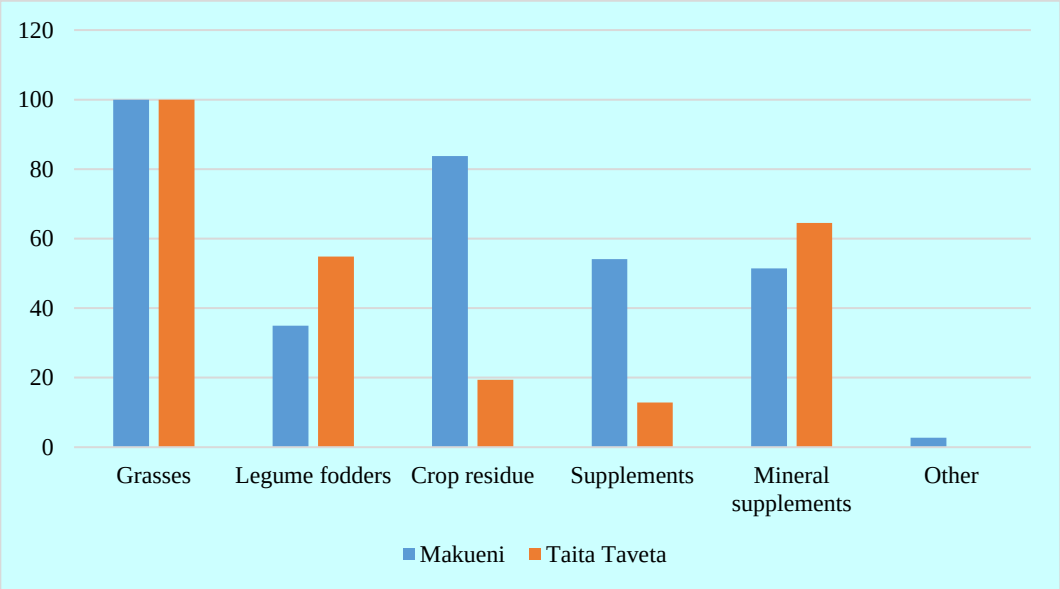

Figure 5. Availability (%) of different types of feeds and supplements

Feed resources

The farmers had different preferences for the types of feeds (Table 2). Most of the households obtained their feeds from their own farms (Table 2). Dependence on commercial feed supplements would reduce farm profits from milk sales due to their high cost. There is a need to train farmers on formulating home-made feed supplements such as MUMBs and mineral salts to reduce the cost of feeding and improve milk production.

Table 2. Main sources of basal feeds and supplements (% respondents)

Forage source	Makueni		Taita Taveta	
	On-farm	Purchased	On-farm	Purchased
Grasses	89.2	10.8	87.1	12.9
Legumes	100	0	82.4	17.6
Crop residue	100	0	100	0
Supplements	5	95	0	100
Mineral supplements	5.3	94.7	0	100

Available feed supplements (%)

Commercial dairy meal was the most preferred feed supplement in the study area (51%) followed by maize germ (13%). However, maize germ alone cannot meet the CP requirement of dairy animals. A medium yielding dairy animal requires crude protein (CP) ranging between 14 to 16%, while high yielding have protein requirement of up to 18%. The reasons for high preference of commercial dairy meal as supplement could be due to lack of other alternatives, expertise and technological know-how on home-made rations.

Table 3. Common supplements used in the farms

	Makueni	Taita Taveta	Mean total
Dairy meal	55.1	47.2	51.2
Maize germ	8.2	16.7	12.5
Salt blocks	22.4	0.0	11.2
Mineral blocks	6.1	0.0	3.0
Diamond-V	0.0	5.6	2.8

Milk production, processing and marketing

Average milk production recorded in the households was 9.5 kg per cow per day (Figure 6). Taita Taveta County had higher milk production (12kg) compared to Makueni (7kg). Home consumption of milk was limited (1%) in the Counties as farmers sold most of the milk to earn cash at the expense of their families. This is critical as it can lead to children and pregnant mothers' malnutrition.

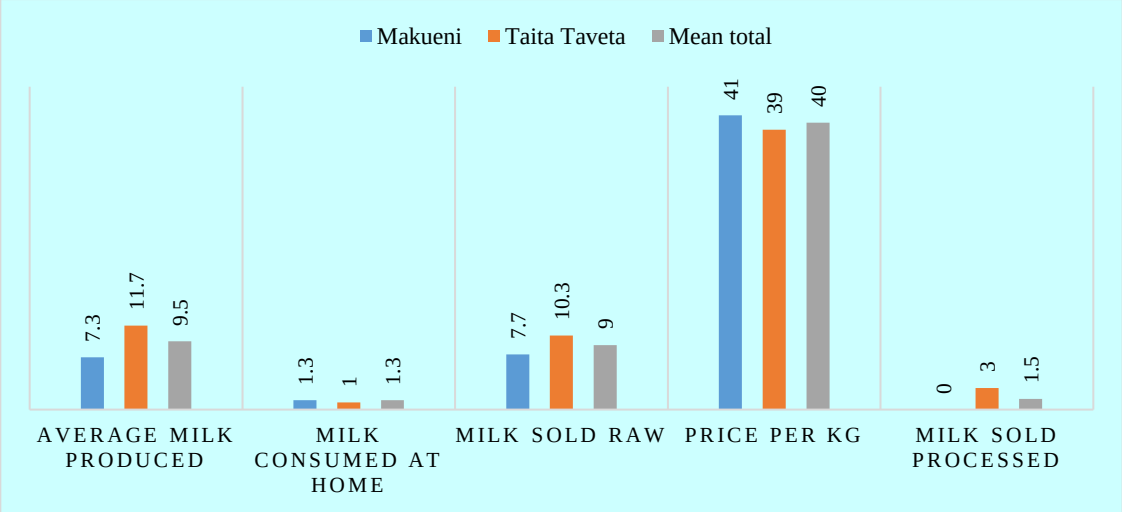

Figure 6. Milk production, processing and marketing

Average price per kg of milk was Kes 40. However, Makueni had better prices for their milk (Kes 41) than Taita Taveta County (Kes 39). This could be attributed to milk middlemen in Taita Taveta who buy the milk at low farm gate prices and sell expensively in Mombasa which offers a good market for the commodity. Installation of milk coolers and milk processing plants by the County Governments may solve this problem. Cottage milk processing was minimal in the study areas.

Constraints limiting dairy production

Identification and ranking of different production constraints is basic prior to beginning any livestock improvement program. The ranking of cattle production constraints are presented in Table 4. Feed shortage, pests and diseases and limited access to finances for investment (86, 83 and 44% respectively) were considered as the major problems. Poor access to extension services, poor quality of feeds and poor access to AI services also ranked high (37, 33 and 32% respectively) as main constraint hindering dairy production.

Table 4. Main Constraints in dairy production

Constraint	Makueni	Taita Taveta	Mean
Inadequate feeds	100	72.2	86.1
Pests/parasites and diseases	97.3	69.4	83.4
Limited access to finances for investment	64.9	22.2	43.6
Poor access to extension services	48.6	25	36.8
Poor quality feed	54	11.1	32.6
Poor access to AI services	16.2	47.2	31.7
Poor quality breeds/animals	29.7	5.6	17.7

Factors affecting forage production in farms

Multiple response analysis (%) of important forage production constraints are tabulated in Table 5. Low forage yield and low rainfall were cited as the most important constraint in the study Counties (73 and 55% respectively). Other constraints that were hindering forage production were high cost of fodder establishment (47%), lack of planting materials (40%), poor viability of seeds (25%) and pests and diseases (16%). Rain water harvesting for fodder production can be an option for increasing fodder yields in smallholder farms.

Table 7. Response analysis (%) of forage production constraints

Constraint	Makueni	Taita Taveta	Mean
Low yields/production	100	45	72.5
Low rainfall	100	9.7	55
High cost of establishment	39	55	47
Lack of planting materials	44	36	40
Poor viability of seeds	31	19	25
Pests and diseases	8	23	15.5
Other	0	6.5	3

Conclusions and Recommendations

Livestock play an important role in the economy of different communities by supporting the livelihoods of farmers, consumers, and traders through provision of food, income, employment and resources for industrialization. Increasing the productivity and competitiveness of the dairy cattle through reduction of identified constraints will spur the dairy production chain. Based on the results of the study, the following recommendations should be considered for improving the dairy industry in the counties of Makueni and Taita Taveta:

- The shortage of feed could be addressed through improvement of feed production and use of low-cost supplementary feeding systems for sustainable dairy production.
- Improvement of farmers' knowledge base and skills on dairy cattle feeds and feeding should be done through training and/or capacity building for improved productivity
- Exposure of dairy producers to alternative feeds resources.

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Screening of Napier Grass (*Pennisetum Purpureum* Schumac) Clones for Stunt Disease Incidences and Severity in Western Kenya

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Abstract
Napier stunt disease (NSD) is a threat to Napier grass farming in the smallholder dairy industry in east and central Africa. In Kenya, NSD it is caused by *Candidatus* Phytoplasma oryzae (Ns-phytoplasma) belonging to the 16SrXI group; vectored by a leaf hopper *Maiestas banda*. The study objective was to determine the incidence and severity of stunt disease in 18 Napier clones through screening in three Counties in Western Kenya. The Napier grass clones were from the germplasm collections maintained at KALRO Kitale nursery and a few collected from KALRO Muguga and farmers' fields in western Kenya. The eighteen Napier clones per replicate were planted in twenty farmers' open fields. In Bungoma the average disease severity in all the clones evaluated for a total of five cuts was 0.001611 representing 0.16% attributed on the few clones observed with high severity. In Kakamega county, the average disease incidence was 0.007656 which translated to 0.7656% and disease severity was 0.084211 which represents 8.4% of the total poulation. This showed that there were few new infections for the five cut backs done in all the farmers' sites. There was positive correlation between disease severity and incidence. In Busia county there was a high disease incidence with an average of 0.100713 which translated to 10.07% of the total clonal population in the County. This indicates that new infections in the county are high. This could be attributed to a high exchange rate of the planting materials within the County and cross border exchange. The average severity index was 0.407778 which translated to 40.78% of the total population evaluated in Busia County. There was positive correlation between disease severity and incidence for all clones except clones, 6, 7, 11, 12, 13 and 14 had high level of disease incidence and low disease severity for the number of five cuts done.

Key Words Napier grass Clones, Stunt disease severity and Incidence

Introduction

Napier grass (*Pennisetum purpureum* Schumach) (Poaceae) is an important fodder crop grown in Kenya and other countries within East and Central Africa (Muyekho *et. al*., 2003). The grass is one of the major fodder grasses adapted by Kenyan small scale dairy farmers for cut-and-carry system (Humphreys 1994). The main attributes to its adaptability are because of high herbage yield, easy establishment, rapid regeneration, relatively high quality for utilization, and tolerance to drought. Dairy cows feeding on Napier grass alone can produce 7-10 litres of milk on average compared to less than 6 liters per cow per day on natural pastures (Potter and Anindo, 1986). Napier grass is associated with intensive and semi-intensive livestock production systems for milk and beef production (Kabirizi *et al*., 2007). It is also used by farmers in eastern Africa as a protection of soil erosion and trap plant for the management of cereal stem borers through the Push-Pull technology (Midega *et al.*, 2012). Napier grass has advantages over other fodder grasses because of its high yielding capacity and ease of propagation and management within a wide ecological range (0 < 2,000m ASL) (Orodho 2006).

In recent years, a disease associated with stunting, overall loss in biomass and death of Napier grass has been reported in Kenya, Uganda, Tanzania and Ethiopia (Jones *et al*., 2004, 2007). The disease known as Napier Stunt Disease (NSD) is caused by the phytoplasma *Candidatus phytoplasma oryzae* belonging to the 16SrXI group, which is transmitted through infected planting materials (Jones *et al.*, 2004, Wamalwa *et al.*, 2016). Symptoms expressed by phytoplasma-infected plants include small chlorotic leaves, proliferation of tillers, and shortening of internodes to the extent that clumps appear very stunted, ultimately resulting in death of the plant (Ajanga, 2005). The dairy sector in eastern and central Africa is now under threat of this disease that may wipe out Napier grass clones with a narrow genetic base (Farrell et. al. 2004, Jones et. al. 2004 and Nielsen *et al*., 2007). A significant reduction in milk output has been reported in areas ravaged by the disease, and has led to decline in household incomes (Khan *et*

al., 2012). The current mitigation strategies that include use of fertilizer, rouging and careful visual selection of planting material have not been effective in controlling this disease. The objective of this study was to determine the incidence and severity of Napier Stunt Disease in 18 clones of Napier grass in Western Kenya where the disease is prevalent.

Methodology

The experimental plots planted in 2013 were located in three counties namely, Bungoma, Kakamega and Busia. Experimental plots were planted by 20 farmers groups six in Bungoma, seven in Kakamega and seven in Busia Counties. Farmer groups were selected across the counties with the help of the County Agriculture extension officers. The lead farmer in the group planted eighteen Napier clones in their farms assisted by other members of the group. The plot size was 6m x 3m each with 28 plants. Fertilizer (Triple super phosphate –T.S.P) at 60kg $P_20_5ha^{-1}$ was applied at planting and 80kg N ha^{-1} of Calcium Ammonium Nitrate – C.A.N) was applied at top-dressing the first six weeks after planting and after every cut. Harvesting (cut back) was done at an interval of 8 weeks. Based on the number of plants affected within a plot and the total number of clones within a replicate, the disease incidence was recorded using a scale of 1-5 while the disease severity was based on visual observation and recorded using a scale of 0-100% (Ajanga, 2005). The incidence is the number of new individual plants affected by a disease in a specified population. This is the extent of manifestation or spread of a disease in a population. In this study, severity was based on visual scoring on the magnitude of the spread of the disease within the affected stools based on percentage spread. Data was analyzed using Genstat Discovery edition 4 for summary statistics and interaction between incidence and severity. Graphical presentation was done using Excel.

Results

The data used calculate the relationship between incidence and severity of Napier Stunt Disease in Bungoma, Kakamega and Busia Counties is shown in Table 1.

Table 1. Disease incidence and severity in the 3 counties

Cultivar	Disease incidence			Disease serverity		
	Bungoma	Kakamega	Busia	Bungoma	Kakamega	Busia
South Africa	0	0	0.0056	0	0	2
Farmer	0.0119	0.0466	0.0819	12.833	48.3333	40.333
Okame	0.0027	0.0586	0.0408	11	27.5833	21.667
T 112	0.0025	0.03529	0.0216	7	22.3333	14
ILRI 16815	0	0.01222	0	5	1	0
T 20	0	0.0058	0.0511	0	0.13333	19
KK 1	0	0.03218	0.0213	0	19.3333	19.167
Bana	0	0.06576	0.0436	0	35.0833	12.667
T 60	0	0.03863	0.0133	0	29.3333	8.3333
T 41	0.0028	0.02623	0.0189	5	10.9167	29.333
ILRI 16805	0.0035	0.00435	0.02	0	7.5	36.333
KK 3	0.0067	0.04247	0.0933	8.3333	6.66667	30.333
ILRI 16802	0	0.03898	0.0403	11.667	22.3333	49.667
KK 2	0.0629	0.021	0.0886	0	22.8333	49.833
Songor	0.0176	0.24868	0.2493	27.833	79	39.333
T 105	0	0.0058	0.0143	21.667	0	28.667
T 89	0.0033	0.01745	0.0376	0	19.6667	31
Alupe Napier	0	0.02973	0.0178	2.5	32.5	9.3333
L 14	0	0	0.0018	0	0	3.25
South Africa L13	0	0.0071	0	1.5	0	0

Each observation is the mean of the Incidence and Severity for the replicates per County

Bungoma County

Disease severity within the county is shown in Fig 1 while disease incidence is shown in Figure 2. The correlation between incidence and severity are shown in Figure 3.

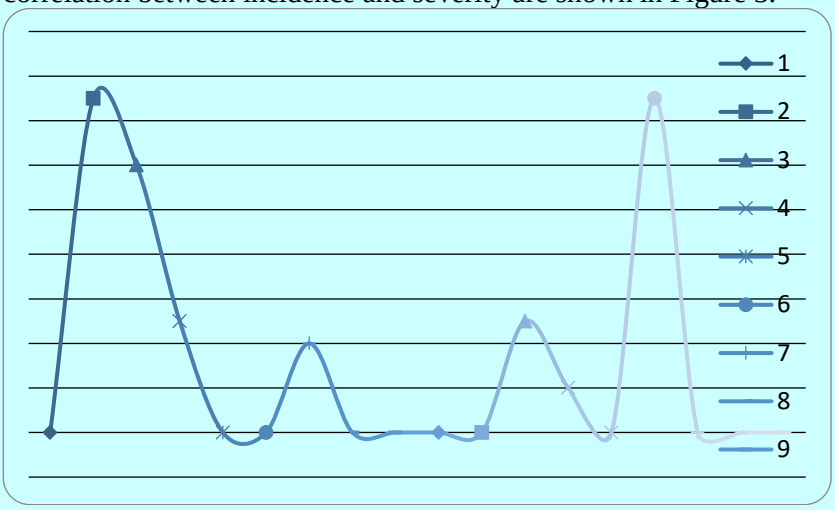

Figure 1. Disease severity graph for the 18 clones evaluated in Bungoma County in each selected farm
Legend: The Y axis represents the severity indices converted from percentiles while the X axis represents the clones that were used in the study. Clones and their respective names: 1. South Africa 2. Farmers clones. 3. Okame 4. T112 5. ILRI 16815 6. T20 7. KK1 8. Bana 9. T 60 10. T41 11. ILRI 16805 12. KK3 13. ILRI 16802 14. KK2 15. Songor 16. T 105 17. T 89 18. Alupe.

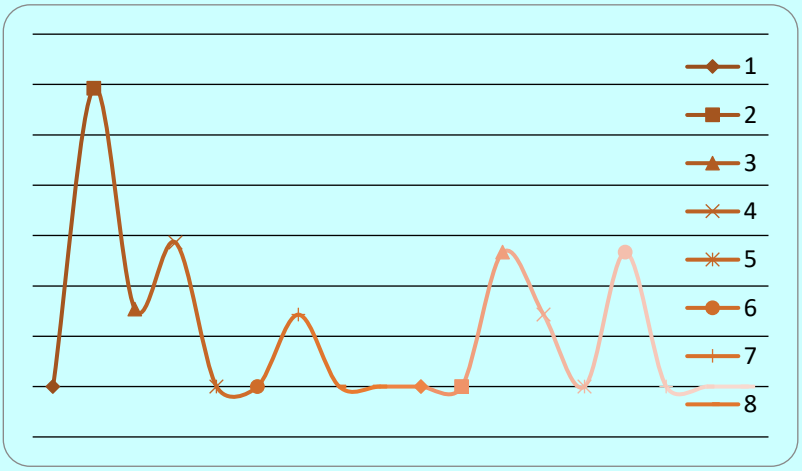

Figure 2. Disease incidence graph for the 18 clones evaluated in Bungoma County in each selected farm

Legend: The Y axis represents the severity indices converted from percentiles while the X axis represents the clones that were used in the study.
Clones and their respective names: 1. South Africa 2. Farmers clones. 3. Okame 4. T112 5. ILRI 16815 6. T20 7. KK1 8. Bana 9. T 60 10. T41 11. ILRI 16805 12. KK3 13. ILRI 16802 14. KK2 15. Songor 16. T 105 17. T 89 18. Alupe.

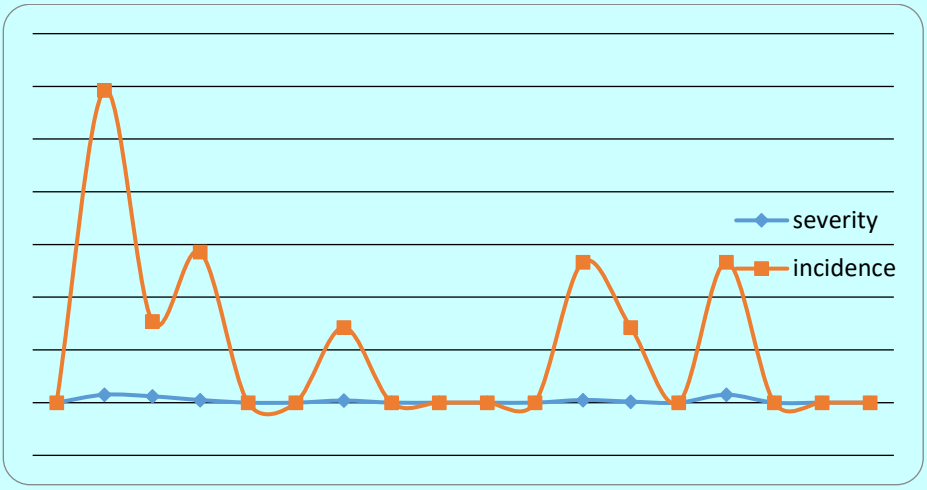

Figure 3. Correlation between disease incidence and severity in Bungoma County.
Legend: The Y axis represents the severity indices converted from percentiles while the X axis represents the clones that were used in the study.
Clones and their respective names: 1. South Africa 2. Farmers clones. 3. Okame 4. T112 5. ILRI 16815 6. T20 7. KK1 8. Bana 9. T 60 10. T41 11. ILRI 16805 12. KK3 13. ILRI 16802 14. KK2 15. Songor 16. T 105 17. T 89 18. Alupe.

In Bungoma the results indicate that, clone 2 (farmers' variety) and clone 15 (Songor) had the highest severity. The average disease severity in all the clones evaluated for a total of five cuts was 0.001611 representing 0.16%. This could be attributed on the few clones observed with high severity while clones 1,5,6,8,9,10,11,14,16,17 and 18 had the lowest severity after the 5th cut at intervals of every 8 weeks. The farmers' clones had the highest incidence at 30 % (Figure 2) compared to clones in the plots evaluated and also had the highest severity score. Similarly, clones with low incidence also had a low disease severity after the 5th cut at an interval of 8 weeks. This shows that farmers can opt to use these clones up to 5th cut because of their low incidence and severity of the disease. Comparison of the disease severity and incidence was done to show the interaction of these two factors. In (Figure 3) above clones 1, 5, 6, 8, 9, 10, 11, 14, 16, 17 and 18 had minimal level of both disease incidence and severity for the number of five cuts done. These could be used as preliminary candidates to create breeding populations and thereafter selection.

Kakamega County
The data (Figure 4) below shows that ILRI 16802 had the highest disease incidence followed by T 60. This translated to 10.53% of the total clones in the total clonal population. The average disease incidence was 0.007656 which translated to 0.7656% of the total poulation. This implies that in Kakamega county, there were few new infections for the five cut backs d in all the sites. This could also be attributed to a low number of dairy farmers who practice cut and carry system and hence less exchange of planting materials.

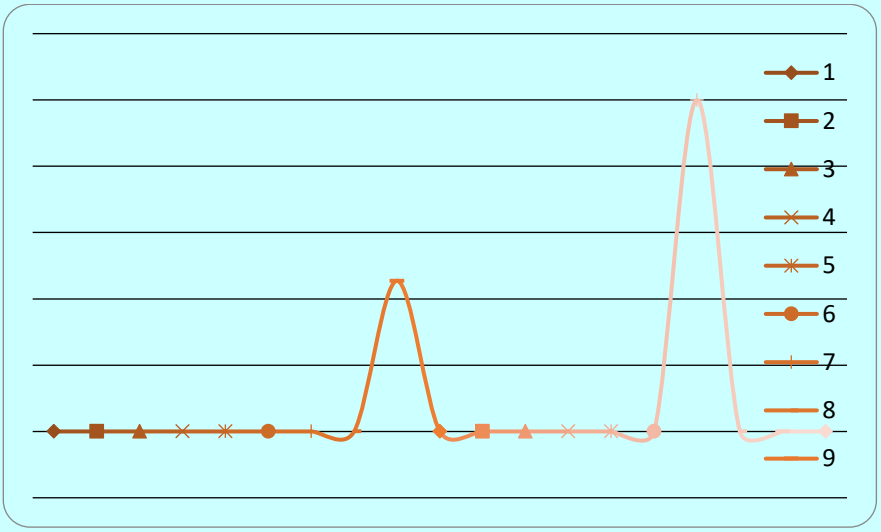

Figure 4. Disease incidence graph for the 18 clones evaluated in Kakamega County in each selected farm

Legend: The Y axis represents the severity indices converted from percentiles while the X axis represents the clones that were used in the study.

Clones and their respective names: 1. South Africa 2. Farmers clones. 3. Okame 4. T112 5. ILRI 16815 6. T20 7. KK1 8. Bana 9. T 60 10. T41 11. ILRI 16805 12. KK3 13. ILRI 16802 14. KK2 15. Songor 16. T 105 17. T 89 18. Alupe.

The same trend was observed with the disease severity (Figure 5). The average disease severity was 0.084211 which represents 8.4% of the total population evaluated in Kakamega county. From the data, there was positive correlation between disease severity and incidence for clones 9 and 16.

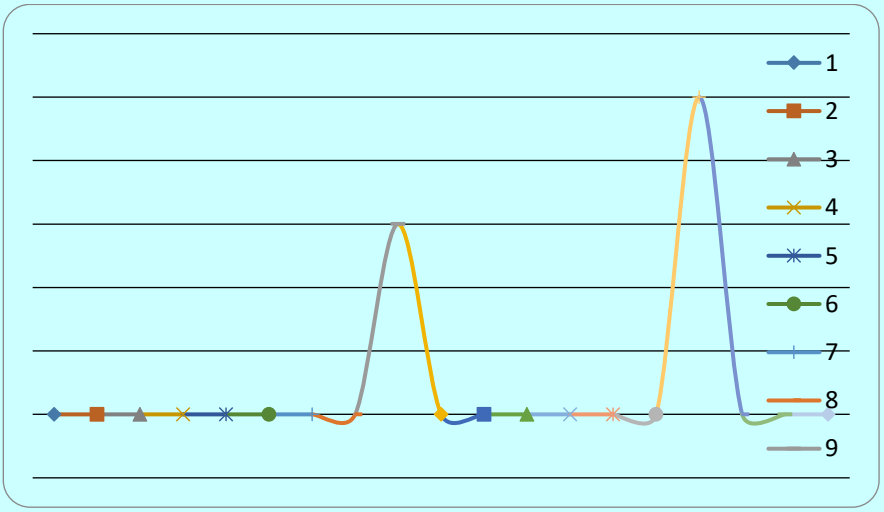

Figure 5. Disease severity graph for the 18 clones evaluated in Kakamega county in each selected farm

Legend: The Y axis represents the severity indices converted from percentiles while the X axis represents the clones that were used in the study.

Clones and their respective names: 1. South Africa 2. Farmers clones. 3. Okame 4. T112 5. ILRI 16815 6. T20 7. KK1 8. Bana 9. T 60 10. T41 11. ILRI 16805 12. KK3 13. ILRI 16802 14. KK2 15. Songor 16. T 105 17. T 89 18. Alupe.

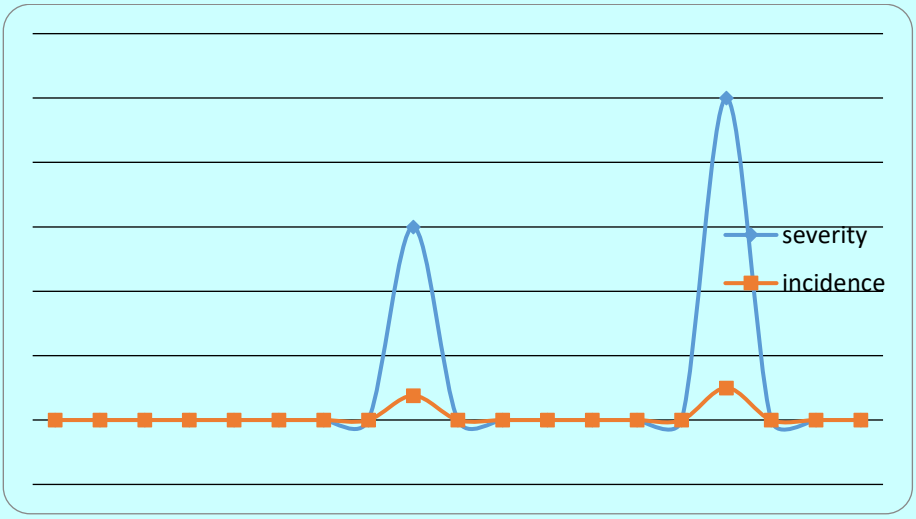

Figure 6. Correlation between disease incidence and severity in Kakamega county

Legend: The Y axis represents the severity indices converted from percentiles while the X axis represents the clones that were used in the study.
Clones and their respective names: 1. South Africa 2. Farmers clones. 3. Okame 4. T112 5. ILRI 16815 6. T20 7. KK1 8. Bana 9. T 60 10. T41 11. ILRI 16805 12. KK3 13. ILRI 16802 14. KK2 15. Songor 16. T 105 17. T 89 18. Alupe.
Legend: 1.SA 1 2. Famers clones 3. Okame 4. T112 5. Bana 6. KK1 7. T20. 8. ILRI 16815 9. T 60 10. T41 11. ILRI 16805 12. KK3 13. T105 14. Songor 15. KK2 16. ILRI 16802 17. T 89 18. Aupe 19. SA 2

Busia County

In Busia county there was a high disease incidence (Figure 7) with an average of 0.100713 which translated to 10.07% of the total clonal population in the County. This indicates that new infections in the county were high. This could be attributed to a high exchange rate of the planting materials within the County and cross border exchange.

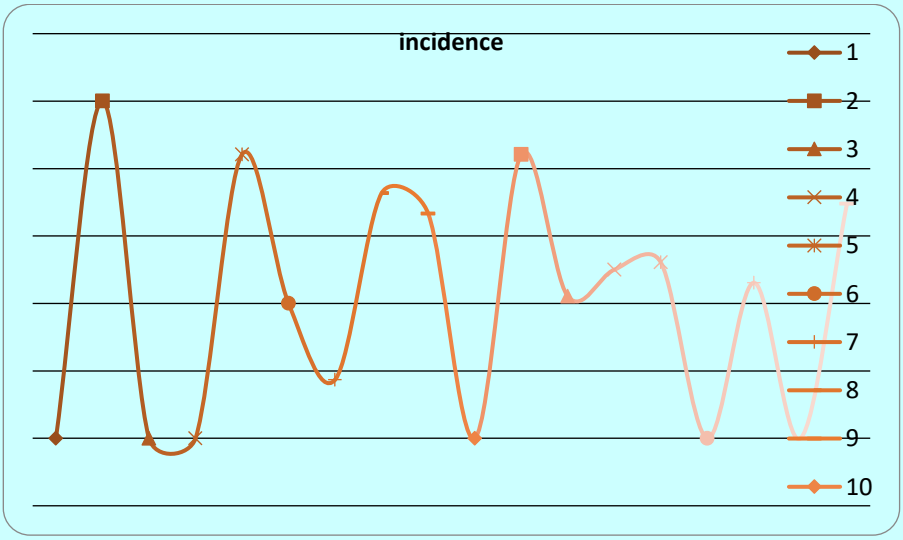

Figure 7. Disease incidence graph for the 18 clones evaluated in Busia County in each selected farm
Legend: The Y axis represents the severity indices converted from percentiles while the X axis represents the clones that were used in the study.

Clones and their respective names: 1. South Africa 2. Farmers clones. 3. Okame 4. T112 5. ILRI 16815 6. T20 7. KK1 8. Bana 9. T 60 10. T41 11. ILRI 16805 12. KK3 13. ILRI 16802 14. KK2 15. Songor 16. T 105 17. T 89 18. Alupe

The same trend was observed for severity (Figure 8). The average severity index was 0.407778 which translated to 40.78% of the total population evaluated in Busia County.

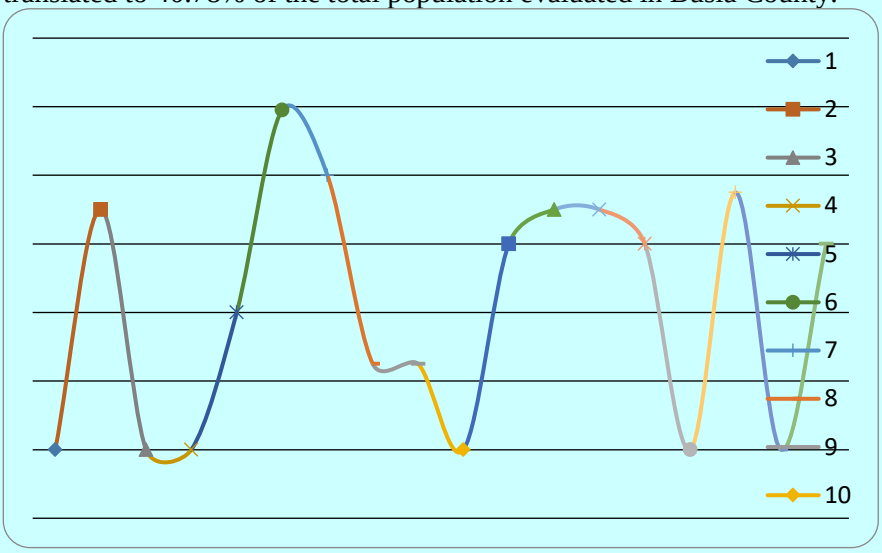

Figure 8. Disease severity graph for the 18 clones evaluated in Busia County in each selected farm
Legend: The Y axis represents the severity indices converted from percentiles while the X axis represents the clones that were used in the study.

Clones and their respective names: 1. South Africa 2. Farmers clones. 3. Okame 4. T112 5. ILRI 16815 6. T20 7. KK1 8. Bana 9. T 60 10. T41 11. ILRI 16805 12. KK3 13. ILRI 16802 14. KK2 15. Songor 16. T 105 17. T 89 18. Alupe.

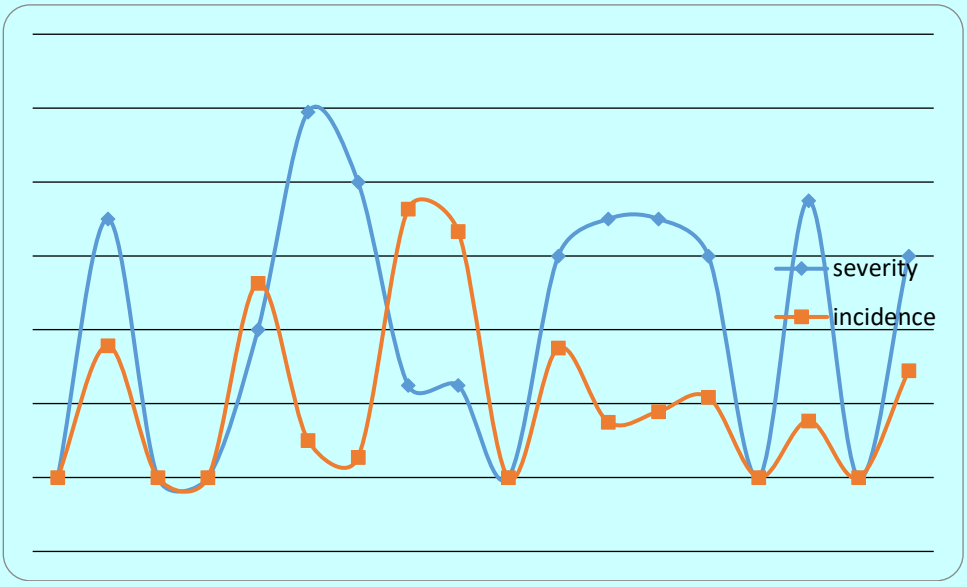

Figure 9. Correlation between disease incidence and severity in Busia county
Legend: The Y axis represents the severity indices converted from percentiles while the X axis represents the clones that were used in the study.
Clones and their respective names: 1. South Africa 2. Farmers clones. 3. Okame 4. T112 5. ILRI 16815 6. T20 7. KK1 8. Bana 9. T 60 10. T41 11. ILRI 16805 12. KK3 13. ILRI 16802 14. KK2 15. Songor 16. T 105 17. T 89 18. Alupe.

In (Figure 9) above shows, there was positive correlation between disease severity and incidence in all clones except clones 6, 7, 11, 12, 13 and 14 which had high level of disease incidence and low disease severity for the five cuts done.

Preliminary conclusion and recommendations

Clones, South Africa, T- 41, Kakamega-2 (KK 2), and T89 had low incidence and less severity to NSD across the Counties. Busia County showed a high disease incidence and severity for most clones. This could be attributed to either a high border exchange of planting materials which may not be diverse hence narrowing the genetic base which in turn translates to a higher manifestation of the disease. Busia County could have a conducive environment for the vector that transmits the phytoplasma leading to a high disease incidences than in the other counties. The clones with the lowest incidences and severity indices could be used as short term solution and be multiplied using either clonal or micro propagation methods. The clones that had the lowest incidences and severity after the five cuts among the counties could be used to develop a breeding population that can be used as a reservoir for NSD tolerant gene pool. Since it was noted that exchange of planting materials could be a source of disease spread, it is important that policies be put in place to regulate movement of planting materials from one region to another.

Acknowledgment

The authors thank Director General, Kenya Agricultural and Livestock Research Organisation, Institute and Centre Directors, Kenya Agricultural and Livestock Research Organisation Kitale for providing an enabling environment and ASARECA for funding the project. The co-operation by the Agricultural and Livestock Extension Officers and farmers in the different Counties who participated is highly acknowledged. This study was made possible through financial support of East Africa Agricultural Productivity Project (EAAPP).

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Black Soldier Fly Larvae Meal as a Cheap Alternative to Conventional Protein Sources in Poultry Feeds

Osuga, I.M[1,2]., Nyingi, D.W[1,3]., Onsongo, V.O[4]., Munga, L[3], Subramanian, S.[1], Gachuiri, C.K[4], Wachira, A.M[5]., Mwangi, D.M[5]., Tanga, C.M[1]., Ekesi, S[1]., Nankibugwe, D[6]., Van Loon, J. J. A[7]., Dicke, M[7]. and.Fiaboe, K.K.M[1,8]

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Abstract

In the recent past, high costs of poultry feeds are driving many vulnerable communities involved in poultry production out of business. The high cost is mainly driven by the protein source, which represents the most expensive component in not only poultry feeds but generally, in animal feed. The main conventional protein sources in poultry feed are soybean meal and fishmeal. Exploring potential cheap alternative sources of proteins in poultry feeds is therefore paramount to the sustainability of the industry and profitability of the business. The present study explored potential of partially replacing the conventional protein sources with black soldier fly larvae (BSFL) meal in broiler and layer chicken diets. A conventional diet (C) containing Soybean and Fishmeal was compared to three experimental diets formulated by inclusion of BSFL meal at 5 (B1), 10 (B2), and 15% (B3) for broiler diets and 5 (L1), 10 (L2), 15 (L3) and 20% (L4) for layer diets. Dietary effects on average daily feed intake, average daily body weight gain, egg production and the economic implication of their use in broiler and layer chicken production were evaluated. The results indicated that replacement of Soybean meal and fishmeal with BSFL in the diets did not affect daily feed intake and daily body weight gain. However, egg production increased significantly ($p<0.05$) with the inclusion of BSFL meal in layer chicken diets. For both broiler and layer chicken, inclusion of BSFL in the diets resulted in increase in the Cost Benefit Ratio (CBR) and Return on Investment (RoI). The higher the inclusion of BSFL meal in the broiler and layer diets,

the higher the CBR and RoI. The results of the study imply there is need for the promotion of insect mass production enterprises for animal feed protein as well as for income generation and job creation particularly in the developing countries such as Kenya.

Key words: black soldier fly, alternative feeds, conventional protein.

Performance of the African Catfish (*Clarias gariepinus)* Fed on Diets Containing Black Soldier Fly (*Hermetia illucens*) Larvae Meal

Maina, A.N[1,3]., Osuga, I.M[1,2]., Munga, L.K[3]., Munguti, J.M[4]., Subramanian, S[1]., Fiaboe, K. K. M[1,5]., Van Loon, J. J. A[6]., Dicke, M[6]., Ekesi, S[1] and Tanga, C.M[1]

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Abstract

This study aimed at evaluating the growth rate, survivability and economic performance of the African catfish (*Clarias gariepinus*) when fed on diets containing Black Soldier Fly larvae (BSFL) meal as a replacement for fishmeal (FM). Treatment diets were formulated to contain BSFL meal at the rate of 0% (C), 25% (D1), 50% (D2), 75% (D3) and 100% (D4. The diets were formulated to meet the nutrient requirements of catfish. The experimental catfish were housed in harper nets each measuring 2 by 2 by 2 meters and the net had one millimeter perforations to allow proper circulation of water and also prevent escape of the catfish. Each harper net held 20 pieces of catfish. The experiment was laid out in a completely randomized design with each treatment being replicated three times. The performance of the catfish was determined by recording the weights, lengths and mortality in each cage. Data collection was done twice monthly for six months. Analysis of variance was carried to determine the different effects of the treatment diets. Water quality parameters measured were within the optimum levels. Catfish consuming D2 and D3 diets had the highest weight gain and length gain. The performance of the catfish consuming the control diet (C) and diets D1 and D4 was comparable and with no significant ($P>0.05$) differences. A 5% mortality was only noted in the catfish consuming diets C and D1. There was no mortality for the other treatment groups. These findings suggest that BSFL meal can be utilized or used to replace FM in diet formulations for rearing African catfish for improved growth and production. Our findings revealed that the combination of fishmeal and BSFL meal significantly enhanced the growth performance and carcass nutrient status of the African catfish. The implications for human nutrition are discussed.

Key Words: Diet, Catfish, Carcass, Mortality, Fishmeal, Weight gain

Effects of Substituting Fishmeal with Black Soldier Fly Larvae (*Hermetia illucens*) Meal on Growth Performance and Carcass Quality of Exotic Layer Chicks and Grower Pullets

Sumbule, E. K[1, 2]., Ambula, M. K[2]., Osuga I.M[1, 3]., Miano D.M[4]., Alaru, P.A.O[4]., Subramanian, S[1], Fiaboe, K. K. M[1,5]., A. van Loon[6]., J J., Dicke M[6], Ekesi S[1] and Tanga, C M[1]

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Abstract

The increasing demand for fishmeal (FM) and soybean meal for use in formulating animal feeds has led to increase in their prices and low certainty in their availability in future. Insect rearing could be a part of the solution as they take a short period to mature, require small space and fewer resources to start. A study was designed to evaluate the effect of substituting FM with black soldier fly larvae (BSFL) meal at different inclusion levels as protein source in chick and grower diets on weight gain, feed intake, feed conversion efficiency (FCE) and carcass characteristics. A total of 250 day old Isa Brown chicks were used for this experiment that ran for a period of 20 weeks. The chicks were randomly distributed into five treatments each with five birds per replicate and nine replications. Diets were formulated based on five different inclusion levels of BSFL (0%, 25%, 50%, 75% and 100%). Data on weight gain, feed intake, carcass characteristics and FCE was analysed using one way analysis of variance (ANOVA). The results showed that most parameters were significantly different during the chick stage while there was no significant difference observed for the grower stage parameters and carcass characteristics. For the chick stage, growth rate was higher for the lower inclusion levels of BSFL meal but was generally depressed at high levels of substitution of FM with BSFL meal. The depressed growth rate was attributed to a reduced feed intake of the chicks for the diets with higher inclusion levels of BSFL meal. However, at the grower stage, the feed intake was not affected and therefore the birds performed comparatively well across the treatment. The results show that BSFL meal can replace FM in poultry diets. For chicks, high performance can be achieved at lower inclusion levels of BSFL up to 50% while in grower birds, the replacement can be up to 100%.

Key words: black soldier fly, fish meal, layers, diets

Growth Performance of Indigenous Chicken at Chick Stage Fed on Diets Containing Black Soldier Fly Larvae Meal in Kenya

Waithaka, K[1,3]., Osuga, I[1,2]., Kabuage, L[3]., Wachira, A[4]., Mwangi, D[4]., Tanga, V[1]., Ekesi, S[1]., Nankibugwe, D[5]., Subramanian, S[1]., Van Loon, J[7]., Dicke, M[7] and Fiaboe, K[1,6]

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Ab-stract

Previous studies have revealed that feed constitutes about 70% of total poultry production costs. This is mainly due to the high cost of feed ingredients especially protein concentrates and their limited availability which continue to discourage the uptake of commercial indigenous chicken (IC) production as a source of livelihood in Kenya. Studies elsewhere have identified Black soldier fly (*Hermetia illucens*) larvae (BSFL) meal as an alternative protein source. This study aimed to provide information on the nutritive value of locally prepared BSFL meal and to determine the growth performance of improved indigenous chicken fed on diets containing graded levels of the meal. The study was conducted at the Kenya Agricultural and Livestock Research Organisation (KALRO), Naivasha station. A total of 320 KALRO improved indigenous chicken day old chicks were used for the feeding trial during the chick phase. Five diets were formulated to NRC (1994) requirements (at least 2800 Kcal/ Kg ME content and 18% CP) with BSFL meal included at the rate of 0% (C0), 5% (C1), 10% (C2), 15% (C3) and 20% (C4) to replace the conventional protein sources (fishmeal and soybean meal) in the diets are the rate of 0, 25, 50, 75 and 100% respectively. The five dietary treatments were randomly allocated to the experimental units in a completely randomized design and the birds were fed on the diets from week 2 to week 8. The results showed significant influence of the dietary treatments on the average final body weight of the chicks, the average daily weight gain, and average daily feed intake. The chicks receiving the control diet (C0) gained the highest weight per day (13.66±0.37 g/day) followed by those receiving 10% BSFL inclusion level (12.08±0.37 g/day). There was a significant difference in food conversion ratio (FCR) with diets containing BSFL meal having the highest FCR. However, there was no significant difference in FCR of chicks receiving the control diet and 10% BSFL inclusion level. These results show that BSFL meal can replace the conventional protein sources in poultry diets without detrimental effects on the survival and productivity of the chicks with 10% BSFL inclusion level giving better growth and feed efficiency than other BSFL meal inclusion levels.

Key words: black soldier fly, fish meal, indigenous chicken, diets

INOVATIONS IN ANIMAL BREEDING

Consensus Parameter Estimates for Traits of Economic Importance in Indigenous Chicken Breeding Program

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Abstract
The objective of the current study was to estimate pooled genetic and phenotypic parameters of traits of economic importance in indigenous chicken (IC) breeding program. This was realised through meta-analysis of published estimates on heritability, phenotypic and genetic correlations collected from different studies in the tropics. The traits of economic importance considered were egg number (EN), egg weight (EW), body weight at 12 weeks (BW), average daily gain (ADG), age at first egg (AFE), fertility (FERT), hatchability (HA) and immune antibody response (Ab). The findings indicate that, the collected parameter estimates from different studies were heterogeneous and therefore the weighted parameters were computed. The weighted heritability estimates ranged from low for EN at 0.12 to moderate 0.43 for EW. The growth traits ADG and BW realized heritability estimates of 0.20 and 0.24, respectively. Fertility traits such as AFE, FERT and HA had corresponding weighted heritability estimates of 0.25, 0.30 and 0.40. The Ab on the other hand, realised a heritability of 0.27. The genetic correlation between the egg traits (EN and EW) was negative at -0.24. The growth traits (ADG and BW) had positive genetic and phenotypic correlations at 0.23 and 0.42, respectively. The genetic correlation between fertility traits (AFE and FERT) was high and positive at 0.59. The findings demonstrated that parameters from different studies were heterogeneous and therefore computation of pooled estimates is necessary for development of IC breeding program.

The current study has demonstrated that there is heterogeneity in genetic and phenotypic parameter estimates in the literature for IC. The weighted heritability, genetic and phenotypic parameters presented in the current study therefore provide consensus estimates that could be used in breeding programs. This is because they account for variations attributed to data size, time and estimation methods adopted in different studies used to estimate genetic parameters in IC.

Key words: Genetic and phenotypic parameters, growth traits, indigenous chicken, meta-analysis.

Introduction

Genetic and phenotypic parameters are important inputs in development of breeding programs (Dana *et al.*, 2011). They should be population specific in ideal conditions (Koots and Gibson, 1996). Most breeding programs, especially those in developing countries are however faced with a critical challenge of inconsistent and limited pedigree and performance recording (Wasike *et al.*, 2011). Use of estimates from other populations has been recommended where parameters for some traits of interest are lacking (Koots and Gibson, 1996).

There are, however, several parameter estimates in the literature obtained under different management and environmental conditions. This implies that, these parameters could be heterogeneous as they have varied levels of accuracy as measured by the sampling variance and therefore could lead to varying results (Huedo-medina *et al.*, 2006). This poses a challenge to breeders on which parameters to adopt in development of sustainable breeding programs. In Kenya, the chicken breeding program was developed using parameters from different studies without pooling (Okeno *et al.*, 2013). This could lead to under or over estimation of response to selection because of three reasons. First, the populations used are reared under different production systems. Second, the methods of estimation differ and third, different sample sizes with different selection history are usually used. There is therefore need to estimate the pooled parameters for chicken breeding program in Kenya since data for estimation of population specific estimates are still lacking. The current study used meta-analysis to estimate pooled genetic and phenotypic parameters for IC breeding program.

Methodology

Data source

Data was obtained from published articles on indigenous chicken in refereed journals. The identified articles were published from 1987 to 2018. A total of forty nine (49) articles with heritabilities, genetic and phenotypic correlations for traits of economic importance for IC breeding program were used. The traits of economic importance considered included egg number (EN), egg weight (EW), body weight at 12 weeks (BW), average daily gain (ADG), age at first egg (AFE), fertility (FERT), hatchability (HA) and immune antibody response (Ab) (Okeno *et al.*, 2013). The data collected on these traits included direct additive heritability, genetic and phenotypic correlations, standard errors, number of sires and number of records used to obtain them.

Data analysis

Heterogeneity test

A heterogeneity test was done to test whether all the estimations from all the studies were homogenous with only random variations. An alternative hypothesis that at least one estimate differed from the others was tested. The test was based on Cochran's, (1954) Q statistic;

$$Q = \sum_{i=1}^{k} w_i \left(\hat{h}_i^2 - \hat{h}_+^2\right)^2$$

where $w_i = 1/s_i^2$ and $\hat{h}_+^2 = \sum_{i=1}^{k} w_i \hat{h}_i^2 / \sum_{i=1}^{k} w_i$, (Hedges and Olkin, 1985) and $\hat{h}_i^2$ and s_i^2 is the value of the ith heritability of given trait and the sampling variance respectively. Heterogeneity was observed and therefore a random effect model was adopted to obtain the weighted estimates.

Weighted heritabilities

The weighted means for the heritabilities were obtained using the inverse of the sampling variance as the weighting factor. A random effect model in Statistical Analysis System software was used (SAS 2002). The random effect model accounts for variation between and within studies. It also allows the estimates to represent random sub-populations with differing underlying true parameters drawn from the overall population (Sheu and Suzuki, 2001). The random effect model used was;

$$\theta_i = \mu + s_i + e_i$$

where θ_i is the estimate of a parameter in the i^{th} study, μ is the population mean, s_i is the between study component of the deviation from the mean, e_i is the within study component due to sampling error in the i^{th} estimate.

Weighted genetic and phenotypic correlations

The genetic and phenotypic correlations were first transformed to Fishers normal scale using the following equation (Safari*et al.*, 2005);

$$Z = 0.5 \log\left[\frac{1+r}{1-r}\right]$$

where r is the correlation value for a given trait. The standard errors were used as the weighting factor were calculated as;

$$se_z = (n-3)^{-0.5}$$

where n is the number of records for phenotypic correlations and number of sires for the genetic correlations. The weighted means of the transformed correlations were calculated and transformed back to correlations.

Results

The heterogeneity test on all the estimates from different studies was found to be positive and therefore the heritabilities, genetic and phenotypic correlations were weighted. The weighted heritability, genetic

and phenotypic parameter estimates for traits of economic importance (EN, EW, ADG, BW, AFE, FERT, HA and Ab) are presented in Table 1.

Table 1. Weighted heritabilities (along diagonal), genetic (above diagonal), and phenotypic correlations (below diagonal)

Traits	EN	EW	ADG	BW	AFE	FERT	HA	Ab
EN	**0.12**	-0.24	0.00	-0.12	-0.30	0.23	0.20	-0.04
EW	0.03	**0.43**	0.00	0.45	0.35	-0.14	0.11	-0.01
ADG	0.00	0.00	**0.20**	0.23	0.00	0.00	0.00	0.00
BW	0.08	0.31	0.42	**0.24**	0.05	-0.33	0.00	-0.07
AFE	-0.36	0.34	0.00	-0.10	**0.25**	0.59	0.00	-0.04
FERT	0.23	0.07	0.00	0.00	0.10	**0.30**	0.43	0.05
HA	0.20	-0.49	0.00	0.00	0.00	0.02	**0.40**	0.00
Ab	-0.02	-0.00	0.00	-0.05	0.00	0.05	0.00	**0.27**

EN; Egg number, EW; Egg weight, ADG; Average daily gain, BW; Body weight,
AFE; Age at first egg, FERT; Fertility, HA; Hatchability, Ab; Immune antibody response

The heritability of egg production traits ranged from low to high with EN having low heritability estimate of 0.12 and EW with high heritability of 0.43. Growth traits exhibited low heritabilities of 0.14 and 0.24 for ADG and BW, respectively. Fertility traits, AFE, FERT and HA, on the other hand, had low, moderate and high heritabilities, respectively. The disease resistance trait (Ab) had moderate heritability at 0.27. The EN had low-to-moderate and negative genetic and phenotypic correlations with EW, BW, AFE and Ab. Egg weight on the other hand, had medium to high genetic correlations of 0.35 and 0.45 with AFE and BW, respectively. The corresponding phenotypic correlations were 0.34 and 0.31. The genetic and phenotypic correlations between the growth traits ADG and BW were 0.23 and 0.42, respectively. They, however, had low correlations with EN, fertility (AFE, FERT and HA) and disease resistance (Ab) traits. Among the fertility traits, AFE had high genetic correlation with FERT of 0.59, while FERT had 0.43 with HA. They generally had low phenotypic correlations. The disease resistant trait Ab had low and negative genetic and phenotypic correlation with all the traits in the breeding goal.

Discussion

The findings of the current study support the premise that, genetic and phenotypic parameters in the literature are heterogeneous and therefore using estimates from different studies in breeding programs may under-or–over estimate response to selection. The weighted heritabilities estimated for egg, growth, fertility and disease resistance traits in the current study deviated from those existing in the consulted literature (Table 1). The deviations could be explained by data size, time and model used for estimation (Wolc *et al.*, 2007). The low heritability realised in EN indicate that this traits could be improved by improved management strategies than selection. On the other hand, the moderate heritability estimates for ADG, EW, FERT, HA, BW, AFE and Ab is an indication that most of the observed variation is due to genotype (Visscher *et al.*, 2008). This means that they can be genetically improved through selection (Agbenyegah, 2017; Muasya *et al.*, 2015). The negative genetic correlations between EN and EW, BW and AFE indicate a negative relationship between these traits. It shows that these traits are dominated by disparate and non-linked loci (Shann-Ren *et al.*, 2018). Selection aimed at increasing either of the traits, therefore, would lead to a correlated deterioration in the other trait. Contrary to the results of the current study, Okeno *et al*., (2013) and Jaturasitha *et al*., (2002) indicated that it would be possible to improve both EN and BW at the same time although with low response. Okeno *et al.*, (2013) showed that increased EN would reduce AFE by 2.46 days, which is supported by the correlation between the traits of -0.30 reported in the current study.

The high and positive genetic correlation between EW and BW shows that selection of either of the traits would result in a joint genetic progress in the other trait (Rosa *et al.*, 2018). This implies that only either EW or BW could be included in the breeding goal. Inclusion of EW would be more convenient as EW would always be available before BW. The highly positive genetic correlation between FERT and HA shows that they can be improved simultaneously (Savegnago *et al.*, 2011). The highly negative phenotypic correlation between EN and AFE implies as EN increases the days to first egg reduces and

therefore increased productive life time (Shad *et al.*, 2007). The moderate and negative phenotypic correlations between EW and HA shows that, their levels of genetic correlations restrict the expression of these traits (Shann-Ren *et al.*, 2018). The high and positive phenotypic relationship between EW, BW and AFE shows that the environmental effect on the expression of the trait is high (Rashid *et al.*, 2018).

Conclusion

The current study has demonstrated that there is heterogeneity in genetic and phenotypic parameter estimates in the literature for IC. The weighted heritabilities, genetic and phenotypic parameters presented in the current study therefore provide consensus estimates that could be used in breeding programs. This is because they account for variations attributed to data size, time and estimation methods adopted in different studies used to estimate genetic parameters in IC.

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Comparison between use of acaricide and vaccination in the control of *Theileria parva* infections in smallholder dairy herds in Kenya

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Abstract

The use of vaccine to control East Coast Fever (ECF) is relatively new in Kenya and is regarded as safer, cheaper and effective. It can be used together with other control strategies but its adoption remains low. The study compared ECF prevalence rates under three prophylactic strategies, namely acaricide, vaccine and a combination of acaricide and vaccine. A cross-sectional survey was conducted in Nandi and Uasin Gishu counties to obtain the study sample using stratified random sampling. Data of 1038 cows affected by ECF infection in 164 farms was subjected to *Chi* square test statistic to estimate ECF prevalence rates in the control strategies. The estimated prevalence rates of ECF infection in acaricide, vaccine and both (acaricide and vaccine) control strategies was 14.64%, 3.18% and 0.87% respectively. No statistically significant association (p=0.374) was found between the control strategies and ECF prevalence rates. A logistic regression model was used to predict outcome (ECF infections) from independent variables of control strategy, production systems and agro ecological zones. The OR =0.811 in vaccine as control strategy indicated that it had a likelihood of ECF infection than acaricide with OR = 0.779, whereas free range production system had a higher risk of ECF infection compared to mostly grazing and zero grazing. Risk of ECF infection was highest in upper highland with OR=0.916 than lower highland (OR=0.756). It was concluded that any of the three ECF control strategies can be applied by farmers in managing ECF infections in dairy herds.

Keywords: Vaccination, acaricide, dairy cattle, East Coast.

Introduction

East Coast fever (ECF) is a cattle disease caused by a parasitic protozoan, Theileria parva, and transmitted by the brown ear tick, Rhipicephalus appendiculatus. It is the most economically important disease of cattle in East and Central Africa including Kenya (Lawrence *et al.*, 2004). East Coast fever is a major hindrance to the introduction of improved exotic cattle breeds due to their high susceptibility to the disease (Minjauw *et al.*, 2003). The disease has been reported to be responsible for annual mortality rates of 40– 80 % among unvaccinated Zebu (*Bos indicus*) calves kept under pastoral management (Homewood *et al.*, 2006).

Control strategies for ECF are based on the use of acaricides to control the vector ticks, chemotherapy of sick animals as well as immunization of cattle by the infection and treatment method (ITM) (Musoke *et al.*, 2004; Oura *et al.*, 2004). Acaricide use and chemotherapy are often limited by high costs, development of resistance by the vector ticks, and the parasites as well as environmental impacts (Mugisha *et al.*, 2005; Kivaria 2006; George *et al.*, 2004). On the other hand, vaccination offers a valuable alternative for ECF control (Oura *et al.*, 2004); however, its widespread application has faced many challenges. These include the requirement of cold chain mode of delivery to remote areas and high cost of the vaccine (up to US$10 per animal), which is unaffordable to most smallholder herders (Di Giulio *et al.*, 2009). Furthermore, vaccination does not completely eliminate the need for acaricide application due to the potential existence of other tick-borne diseases (Laisser *et al.*, 2016). The production environment influences tick vector dynamics too (Gachohi *et al.*, 2010), with the agro-ecological zone (AEZ), livestock production system (LPS), control strategies and animal breed considered important in the epidemiology of ECF. In addition, changes in the biological systems shaped by socio-demographic and environmental factors influence epidemiology of the disease (Gachohi *et al.*, 2012). This study was carried out to estimate ECF prevalence rates in acaricide, vaccine and both acaricide and vaccine control strategies as applied by smallholder farmers stratified by agro-ecological zones and production systems.

Materials and Methods

Study site

Nandi and Uasin Gishu Counties in the North Rift region of Kenya were the study sites. Mixed crop-livestock farming with tea plantation and maize integration is practiced in Uasin Gishu and Nandi Counties respectively. Smallholder dairy farming is a main economic activity in these two counties and uptake of ECF vaccine is relatively high compared to other counties in Kenya.

Study design, data collection and analysis

The minimum sample size (n) was determined using the formula by Anderson *et al.*, (2003) Sample size=Z2*p*q/e2. Where z is desired confidence interval level set at 1.96 for 95% confidence interval; p is the proportion of a characteristic of the population to be sampled, which was set at 0.70, prevalence of ECF in the Kenya highlands (Okuthe *et al.*, 2006); q = (1- p), and e is the error margin allowable for detecting a difference in the sample and was set at 0.05. From this formula, a sample size, (n), of 162 farms was computed.

A multi-stage stratified random sampling procedure was used to select representative villages in which farms are located in each county stratified by agro ecological zones and production systems (pasture, semi zero, zero-grazing). The local extension officers assisted in identification of the farms together with the Agro-vet dealers selling the acaricides and ECF vaccine. A list of farms was developed with guidance from extension officers and agro-vet dealers to which simple sampling procedure was performed to select the farms to visit for data collection. A cross-sectional survey was conducted, where 164 farms were sampled. Seventy three (73) farms were drawn from Uasin Gishu County and 91 from Nandi county. Data on ECF infection prevalence from smallholder farms practicing different prophylactic strategies was collected by interviewing household heads using a comprehensive and pre-tested questionnaire. The data collected was based on farmers' recall of a 12-months reference period prior to the date of data collection. The specific diseases were identified by the standard symptoms with the help of a veterinarian/vet assistants as elicited by the livestock owner. Data collected included herd structure, ECF control strategy, AEZ, production systems, TBDs symptoms, frequency of ECF infections, number affected, recovered or died.

Data were analyzed using SAS statistical package (version 9). Data of 1038 cows affected by ECF infection in 164 farms was subjected to Chi square test statistic to estimate ECF prevalence rates under different control strategies. Additional farm characteristics were analyzed using SPSS software and comprised of cross tabulation. A statistical model to test the influence of independent variables on a binary dependent variable was predicted using logistic regression model.

$$Y(1, 0) = P + Syt + A$$

where ***Y*** = ECF infection (1, 0), ***P*** = prophylactic strategies ***Syt*** = Production system ***A*** = Agro ecological zones

Results

A total of 1038 cows sampled from 164 farms sampled from the two counties were subjected to *chi* square statistical test. Of these 14.64% in acaricide, 0.87% in vaccine and 3.18% both acaricide and vaccine control strategies tested positive for ECF. This gave an estimate of ECF infection prevalence rates in the focused control strategies. There was no association between ECF control strategies and the prevalence rates as p>0.05 (Table 1).

Table 1. ECF infection prevalence rates between different control strategies

ECF Control strategy	n	ECF		χ^2	*p* value
		Positive (%)	Negative (%)		
Acaricide	845	14.64	66.76	1.9701	0.3734
Vaccine	49	0.87	3.85		
Both (Acaricide and vaccine)	144	3.18	10.69		
Total	1038	18.69	81.31		

The influence of the risk factors/predictors such as control strategy, production system and agro-ecological zones on the prevalence of ECF infection prevalence was also tested. There was no significant association between predictors and ECF infection (*p*=0.55; 0.68; and 0.50 for control strategies, production systems and agro-ecological zones respectively). Vaccine as a control strategy had a likelihood of ECF infection with OR=0.811 than acaricide and both. Free-range production system (OR = 0.823) had higher risk of ECF than mostly grazing (OR = 0.741) and zero grazing (OR=0.775). Risk of ECF was highest in upper highland with OR 0.916. (Table 2).

Table 2. Influence of independent predictors on ECF infections

Variable	O.R.	Lower C.I.	Upper C.I.	P value
Control strategies				
Acaricide	0.779	0.498	1.218	0.5488
Vaccine	0.811	0.353	1.864	
Both (Acaricide and vaccine)	Ref			
Production systems				
Only grazing (free range or tethering)	0.823	0.492	1.378	0.6894
Mostly grazing with some stall feeding	0.741	0.450	1.219	
Zero grazing	0.775	0.281	2.133	
Stall feeding with some grazing	Ref			
Agro-ecological zones				
Lower highland	0.756	0.137	3.646	0.5028
Upper highland	0.916	0.188	4.453	
Upper mid zone	Ref			

Discussion

When comparing the control strategies, this study revealed that prevalence of ECF was higher for acaricide treated cows (14.64%) than both vaccine and acaricide (3.18%) and vaccine (0.87%). This finding corroborates with the findings of Homewood *et al.,* (2006) who reported an overwhelming vaccine impact on survivability through protection against fatal ECF and reduction of calf mortality from 20% to 2%. Subsequently, Tatjana *et al.,* (2015), indicated that ECF vaccine (cattle-derived *T. parva*) protected cattle against development of ECF. The high prevalence of ECF in acaricide treated animals (14.64%) compared to vaccine treated ones (0.87%) could be because most production systems (with exotic and cross breeds, mixed stall and open grazing systems) are found in (humid to sub-humid) agro-ecological zones that are conducive to tick vectors (Gachohi *et al.,* 2012).This gives rise to ECF epidemiological states and endemic stability that are expected to occur in tick suitable areas (Norval *et al.,* 1992). This is demonstrated in this study by the fact that all sampled farms are located in ECF endemic regions with grazing production systems in lower (43%) and upper (56%) zones. Therefore, giving rise to high ECF prevalence in acaricide treated animals due to interaction with tick vectors.

Homewood *et al.*, (2006) reported an overwhelming vaccine impact on survivability through protection against fatal ECF and reduction of calf mortality from 20% to 2%. Consequently, Tatjana *et al.*, (2015), indicated that ECF vaccine (cattle-derived *T. parva*) protected cattle against development of ECF but does not protect against *T. parva* causing corridor disease isolated from buffalo. A high proportion (40%) of smallholder farmers practicing zero-grazing used acaricides only, both acaricide and vaccine (40%) while 20% used vaccine only as the ECF control strategies. Free range production system (OR = 0.823) had higher risk of ECF than zero grazing (OR=0.775) and mostly grazing (OR = 0.741) this is attributed to presence of tick vectors in the field where animals are grazed compared to zero grazing where animals are confined and fed in stalls with less contact with tick vectors (Gachohi *et al.*, 2012). This finding contradicted the findings of Gitau *et al.*, (2006), who reported higher prevalence in zero-grazing farms (3%) than in free grazing. Acaricide treatment is compulsory and at stated intervals to achieve more effective and widespread control of ECF in herds. The application is majorly through public dips which is done on weekly basis (Mukhebi *et al.*, 1992).

However, on the prediction of ECF infection using logistic regression model, vaccination as control strategy against ECF had a higher likelihood risk of ECF infection (OR = 0.811) than acaricide and/or vaccine, this is because vaccination procedure results in a mild and controlled reaction that leads to development of immunity to subsequent infections and if an animal is challenged by ticks hence triggers antibody reaction against infection (Di Giulio *et al.*, 2009).

The risk of ECF was highest in upper highland agro-ecological zone with OR 0.916 because of ECF vector tick suitability and farm management practices in this zone (Okuthe *et al.*, 2006). The $p > 0.05$ for ECF infection predictors; [p =0.55 control strategy, p=0.68 production systems and p=0.50 agro-ecological zones] were not found to be significant This is in agreement with Kerario *et al.*, (2018) who reported a lower ECF prevalence of 14.2% on three agro ecological zones in Mbeya, Mara and Singida in Tanzania estimated. The study concludes that both acaricide and vaccine; vaccine treatment applied to dairy animals are not significantly different (p=0.374) as ECF control strategies.

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Estimates of population genetic parameters and admixture population structure in indigenous chicken in Kenya using LEI0258 microsatellite marker

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Abstract
In this study, microsatellite locus LEI0258 coded within the MHC region, was used to genotype 412 chickens representing three populations for genetic architecture determination. A total of 38 and 33 different alleles ranging from 204 to 552 bp were detected in all the populations using genotyped and

sequenced data respectively. The locus attributes showed high genetic diversity as revealed by the polymorphism information content (PIC=0.932), Shannon information and expected heterozygosity (He=0.915). Several indels and SNPs were observed upstream and downstream of R13 and R12 repeat motifs, respectively, of sequenced alleles. The highest effective number of migrants was between coastal and western populations (25). The most probable structure clustering of the populations was at k = 4 with admixed mosaic cluster. The information resulting from this study may be used as a guide to design further investigations for development of sustainable genetic improvement programs.

Keywords: immune competency, indigenous chicken, genetic diversity, LEI0258 marker, Kenya.

Introduction

Indigenous chicken (IC) are the most common in Kenya representing about 80 percent of the total chicken populations (Khobondo *et al.,* 2014). The free range production system is the most predominant type (Okeno *et al.,* 2012). Among the genetic markers microsatellites have been used for several studies. Microsatellites are present both in coding and noncoding regions and are co-dominant markers (Chazara *et al.,* 2013). The tandem repeat LEI0258 marker is of interest because it is highly polymorphic. It is located within the core area of the B region of the chicken MHC and the genotype correlate with serology. The same marker has been used in genetic diversity studies using more than 1,600 chicken from more than 80 different populations to provide a picture of worldwide diversity and to categorize chicken MHC hyplotypes (Chazara *et al.,* 2013). The marker is characterized by the repetition of two tandem and conserved short sequences of 12 and 13 bp and several sequence polymorphisms (indels and SNPs) in the flanking regions (Fulton *et al.,* 2006a). It is the combination of SNPs and indels that determines the allele size and polymorphs. This study therefore sought to decipher population genetic parameters and attributes of this marker in three large population of IC in Kenya. The study further investigated if there are additional gene pools circulating within chicken population in Kenya. The results could be used for future planning of breeding design and conservation for the IC ecotypes.

Materials and Methods

Samples

A total of 412 blood samples were obtained from 3 genetic groups of Kenyan IC, including western group (n=169), central group (n=123) and coastal group (n=120).

DNA extraction and DNA quantification and quality check

Total genomic DNA from the blood samples was extracted using Qiagen Kit (DNeasy Blood and Tissue extraction kit, Cat#69506) following the manufacture's recommendation. The total DNA was quantified and purity assessed as determined via spectrophotometry (Nanodrop 1000 Spectrophotometer, Thermo Fisher Scientific, Waltham, MA). DNA quality and integrity was checked on 0.8% agorose gel at 5v/cm. Samples were stored at -20°C until PCR amplification.

Genotyping and Sequencing of selected Samples

The LEI0258 primer sequences was used for amplification (Fulton *et al.,* 2006a) to yield the amplicons. A cocktail mixture of 12 µl GeneScan 500 LIZ Size Standard and 1000 µl of HIDI formamide were added to PCR products at 9:1 ratio respectively. The mixture was subsequently denatured at 95℃ for 3 minutes and snap-chilled on ice for 5 minutes before capillary electrophoresis. The fragment (allele) sizes were calculated based on the internal size standards of electropherogram using the GeneMapper version 4.1 (Applied Biosystems, USA).

One hundred and thirteen representative alleles of LEI0258 fragments were sequenced by the Sanger method (Bioneer Corp, South Korea). The primers used to amplify the MHC LEI0258 region were LEI0258 forward tagged with T7 and LEI0258 reverse tagged with SP6. The PCR products were fragment analysed in a 1.5% agarose gel stained with 0.025X GelRed (Biotium, USA) run at 7V/cm for 45 minutes. Visualization was done using UV light on the GeneSyst software (InGenus, Syngene, USA). PCR products were purified and then sent for direct Sanger sequencing at Bioneer sequencing center (Korea).

Data analysis

Genotyping data analysis

Allele sizes from the raw data generated on the ABI PRISM 3730 was done using the GeneMapper v4.1.software. Power Marker version 3.25 (Liu and Muse, 2005) was used to calculate Polymorphic Information Content (PIC) to estimate the power of the marker in explaining variation among the populations as well as to generate summary statistics and attributes of LEI 0258 marker at the population level. Population structure was analysed using STRUCTURE software and a Bayesian clustering approach (Pritchard *et al.*, 2000). The optimal number of populations was established using the ad hoc statistic DK based on the rate of change in the log probability of data between successive K values (Evanno *et al.*, 2005).

Sequence polymorphisms and Phylogenetic analysis

Complete sequences of LEI0258 marker with SNP and INDEL sites were trimmed and assembled using CLC Main Workbench software version 7.7 (Qiagen, Bioinformatics). Sequence alignment was done using the Clustal W function on MEGA 6 software (Tamura *et al.*, 2013). Summary tables were adopted to indicate the polymorphisms of all sequenced and aligned alleles (Han *et al.*, 2013). Phylogeny or evolutionary analyses were conducted in MEGA 6 software.

Results and Discussion

Attributes of LEI0258 Marker

Table 1 summarises the attributes of the LEI 0258 locus. The marker revealed 38 alleles defined by their sizes using genotyping/allele scoring method. In particular, central, coast and western populations revealed a total of 21, 28, and 33 alleles, respectively. In comparison, Chazara *et al.*, (2013) identified 50 different alleles in 80 populations while 46 different alleles were identified in Kenyan populations (Ngeno *et al.*, 2014). In this study, many of the identified alleles were shared among different chicken populations suggestive of common ancestry and population admixture as revealed further in cluster and structure analyses. However, diverse alleles in the studied population could be a result of hybridized origin of Asian and European (Ngeno *et al.*, 2015). There was high diversity for LEI0258 marker as observed in the number of alleles. The observed polymorphism of marker LEI0258 locus might explain the plasticity of the chicken in coping with diseases challenges (Farmers personal communications; Ngeno *et al.*, 2014) conferring the highest selective advantage of B-heterozygosity for survival and immune competency.

There were fewer number of effective alleles (8.2) in central population as compared to coastal (14.7) and western (15.4) populations. Average number of effective alleles was 12.8 for the combined populations. Variation in the numbers of private alleles between the populations may be due to different origins of the populations, selection history and immune pressure exerted by different environment on these populations.

The Shannon's information Index was highest in western population (2.972) and lowest (2.386) in central population. The mean overall observed heterozygosity and Polymorphic information Content (PIC) was 0.844 and 0.932 respectively for the total population sampled. However, the central population had the highest observed heterozygosity (0.878) while coastal had the lowest (0.792). The PIC was highest in the coastal population (0.936) and lowest in the central population (0.867). The western population had observed heterozygosity and PIC of 0.864 and 0.932 respectively (Table 1). It is worth noting that western population had the highest number of alleles and effective allele numbers. The western chicken population consists of indigenous chickens (IC) with minimal exotic chicken gene pool, this might imply that IC are more robust in combating diseases compared to the other populations. Several LEI0258 alleles were shared among the populations suggesting that they have been subjected to similar directional selection or due to recombination effect. Alternatively, this sharing of alleles might suggest identity by decent or shared binding site to antigenic determinants. There was high heterozygous genotypes of the 38 LEI0258 alleles observed.

Table 1. Polymorphism of LEI0258 marker in 412 samples of three populations from Kenya.

Pop	Locus	N	Na	Ne	I	Ho	He	PIC	IP
Central	LEI0258	123	21	8.1778	2.386	0.878	0.877	0.867	1
Coastal		120	28	14.769	2.946	0.792	0.932	0.936	20
Western		169	33	15.489	2.972	0.864	0.935	0.932	9
All	Mean	137.33	27.3	12.812	2.768	0.844	0.915	0.932	-
	SE	15.857	3.48	2.3263	0.191	0.027	0.019	0.019	-

Note: Na = No. of Different Alleles, Ne = No. of Effective Alleles, I = Shannon's Information Index, Ho = Observed Heterozygosity, He = Expected Heterozygosity, PIC = Polymorphism Information Content, IP = Individual with Private allele, F = Fixation Index

Polymorphism and diversity of sequenced alleles representatives

The LEI0258 locus was PCR-amplified from all the representative samples analysed from allele scoring data. However, we were able to determine the full LEI0258 sequence from 83 PCR amplicons only, which corresponded to 33 size-polymorphic alleles, ranging from 204 to 552 bp**.** The frequency of the alleles ranged from 1 to 17. However, most alleles were present only once (19 out of 33).

Furthermore, sequence information, repeat regions, and two flanking regions from a subset of alleles per population were analysed. The sequences revealed the repetition of two tandem and conserved short motifs of 12 bp (R12: TTCCTTCTTTCT) and 13 bp (R13: ATGTCTTCTTTCT) plus several sequence polymorphisms in the flanking regions (INDELs and SNPs). The repeat of the R13 motif ranged from 1 to 28. All the sequence samples had the R12 motif with repeats ranging from 3 to 27. Additionally, sequence data revealed the presence of SNPs and INDELs in the flanking regions of LEI0258 locus containing the repeat region R13 and R12. The upstream region was from −81 to −1, and the downstream region was from 1 to 73, excluding the R13 and R12 motifs. The upstream and upstream of the R13 and R12 motifs exhibited several SNPs. There was a 8 bp deletion of ATTTTGAG found at position 22 to 29 bp including the last R12 repeat (Table 2). As witnessed in the results, the polymorphism or allelic variation evidenced in this locus was created by the presence of different number of R13 and R12 motifs, indels and SNPs in the sequenced alleles. The two main VNTR of the R13 and R12 were consistent with previous reports (Fulton *et al.*, 2006b). The variability of R12 ranged from 3 to 27 depicting different polymorphs in allele sizes. The upper limit of 27 repeat motifs were reported in Chinese indigenous chickens (Han *et al.*, 2013). The R13 motif was found with frequency of only one time in most of the samples, this is similar to study by Wang *et al.*, (2014). The largest deletion of 8 bp (ATTTGAG) was found in the downstream sequence of R12 motif. This deletion agreed with previous findings (Wang *et al.*, 2014) but did not conform to the sequence ATTTGAGG detected by Fulton et al., (2006).

Table 2. Polymorphisms identified by the LEI0258 alleles in Kenyan indigenous chicken population.

Chicken population	Fragment length (bp, by genotyping)	Consensus size (bp, by sequencing)	Position (upstream)				Position (downstream)		GenBank number
			-22-23	-2			5	22-29	
			TT	C	R13	R12	T	ATTTTGAG/△	
Ref	-	552	-	-	14	6	-	-	DQ239521.1
Lm29	242	238	-	-	1	7	-	△	
Lm79	264	205	-	-	1	4	-	△	
Lm99	218	204	-	-	1	5	-	△	
Lm111	308	204	-	-	1	13	-	△	
Lm80	325	321	-	-	0	13	-	-	
W45	264	431	-	-	16	5	-	-	
W20	264	263	-	-	1	8	-	-	
W94	450	423	-	-	1	19	-	-	
W117	266	431	-	-	16	6	-	-	
Kal2	450	261	-	-	1	8	-	-	
Kal41	250	309	-	-	1	12	-	-	
Kal173	301	552	-	-	28	3	-	-	
Kal51	250	309	-	-	1	16	-	-	

Note: Δ Defined deletion compared with the reference sequence; - Consistent with the reference sequence.

Cluster analysis

The samples were clustered into four distinct clusters with admixture of the populations (Figure 2a). The phylogenetic relationship constructed using selected sequenced alleles is represented in Figure 2b. The sequences were clustered into five main clusters with observed admixture (every population representative was found in each cluster). The tree in similarity to allele tree (Figure 2a) showed the existing relationships among the chicken population with admixture sequences.

The structure analysis revealed an optimum of four gene pools with evidenced population admixture as well (Figure 3). In previous study, cluster analysis based on combination of LEI0258 and MCW0371 and LEI0258 separately, indicated chicken subdivision into two genetically distinct groups; Lamu (one cluster) and others (cluster two) (Ngeno *et al.*, 2015). The same number of clusters (two gene pools) reported elsewhere (Mwacharo *et al.*, 2007). The two additional gene cluster observed in this study may be attributed to introduction of new gene pool from central populations and cross breeding.

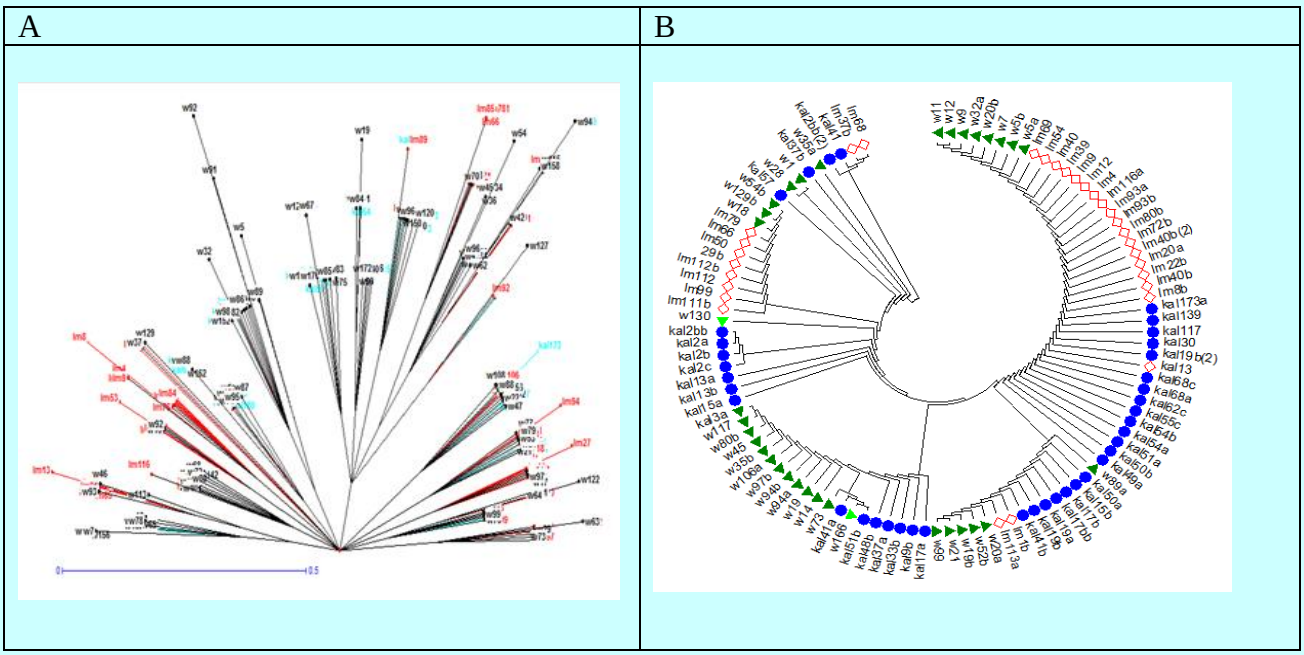

Figure 5. Phylogenetic relationship between Kenyan indigenous chickens. (a) A radiation neighbor-joining dendrogram constructed from allele-sharing distances among 412 individual chickens from three Kenyan chicken populations. (b) Phylogenetic tree showing genetic relationships of selected samples of chicken from 101 sequenced alleles.

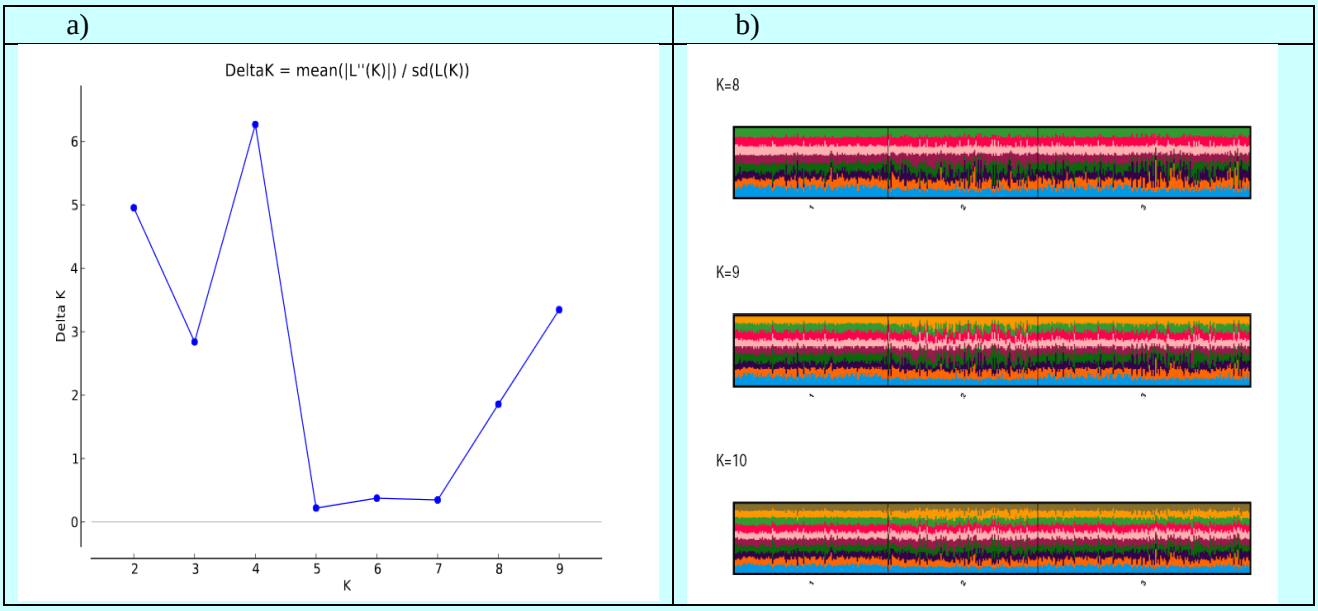

Figure 6. Population structure analysis. Structure clustering of the three chicken populations obtained for a) k = 4 as the best Delta K and b) gene pools with admixture

Conclusions

The LEI0258 is highly polymorphic and diverse in its repertoire. The locus showed four gene pools in Kenyan populations of chicken, a deviation from two observed in other studies. This is suggestive of an additional gene pools introduced.

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Camel and cattle mastitis in Kenya: Prevalence and antibiotic sensitivity of its bacterial causes

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Abstract

Mastitis, a highly infectious disease of dairy animals caused mainly by bacteria and accounts for high economic losses globally. Control of mastitis is normally through good hygiene and treatment with antibiotics. However, effective control is hindered by increasing resistance to antibiotics necessitating routine in-vitro sensitivity testing to avoid indiscriminate antibiotic use and accumulation of residues in milk. This study investigated antibiotic sensitivity profiles of mastitis-causing bacteria in cattle and camels in Kajiado and Laikipia Counties of Kenya. Staphylococcus and Streptococcus isolates from milk samples that tested positive on California Mastitis Test (CMT) were tested for sensitivity to antibiotics commonly used in Kenya. The findings provide evidence of high resistance particularly with sulphonamides in camels and cattle in both counties. Both strains of bacteria were sensitive to chloramphenicol, aminoglycosides and and tetracylines.

Key words: antibiotics, sensitivity, camel, cattle, Kenya, mastitis.

Introduction

The dairy industry is the largest subsector in agriculture in Kenya contributing an estimated 3.2 billion litres of milk per year (Muriuki *et al.*, 2004). This represents 14% national agricultural GDP and 3.5% of the total GDP (GoK, 2008). Challenges facing the dairy sector include poor animal genetics, poor feed quality, unreliable forage and diseases. Key among the diseases is mastitis, an inflammation of mammary glands, which results in heavy economic losses globally (Iyer *et al.*, 2014) due to reduced quantity and quality of milk. Prevalence rates of as high as 64% in dairy cattle have been reported in Kenya. In both cattle and camels, control of clinical and subclinical mastitis can greatly improve production (Atif *et al.*, .,, 2014). The main aetiological agents of mastitis are bacteria, and those frequently reported in Kenya include *Staphylococcus aureus*, *Streptococcus* species and coliforms (Odongo *et al.*, 2012). Some studies have also reported fungal causes such as *Candida albicans* and *Cryptococcus neoformans* (Odongo *et al.*, 2012). Coliforms and environmental Streptococci that are

commonly found in the cows' environment are linked to environmental mastitis. Diagnosis of mastitis employs clinical signs and OIE recommended tests, namely California Mastitis Test (CMT) and Somatic cell count (SCC) (Radostits *et al.*, 2000). Control of mastitis is through administration of antimicrobials and improvement of hygiene. Successful mastitis control is a function of: clinical presentation, correct diagnosis, stage at which treatment is initiated, prudent drug use and bacterial susceptibility to available antibiotics (du Preez, 2000). In Kenya, the most commonly used antibiotics in the treatment of mastitis are penicillin, streptomycin, tetracycline, gentamycin, ampicillin and sulphonamides (Ndirangu *et al.*, 2013). The development of bacterial resistance to antibiotics is among the main reasons for poor control of mastitis (Gitao *et al.*, 2014). This study was conducted to investigate the bacterial causes of mastitis in cattle and camels under a pastoral production system, establish their antibiotic sensitivity and recommend those that are effective for treatment. This information will feed into the national action plan on prevention and containment of AMR (GoK, 2017) strategic objective number 2 that aims to strengthen knowledge and evidence base through surveillance and research.

Materials and methods

Study area and animal sampling

The study was carried out in four camel keeping counties namely, Isiolo, Laikipia, Taita Taveta and Kajiado (Fig 1 and Table 1). Cross sectional surveys on mastitis were conducted on varied dates in 2015 (Isiolo and Laikipia) and 2018 (Isiolo, Laikipia, Taita Taveta and Kajiado) to bring out the dynamism in mastitis prevalence.

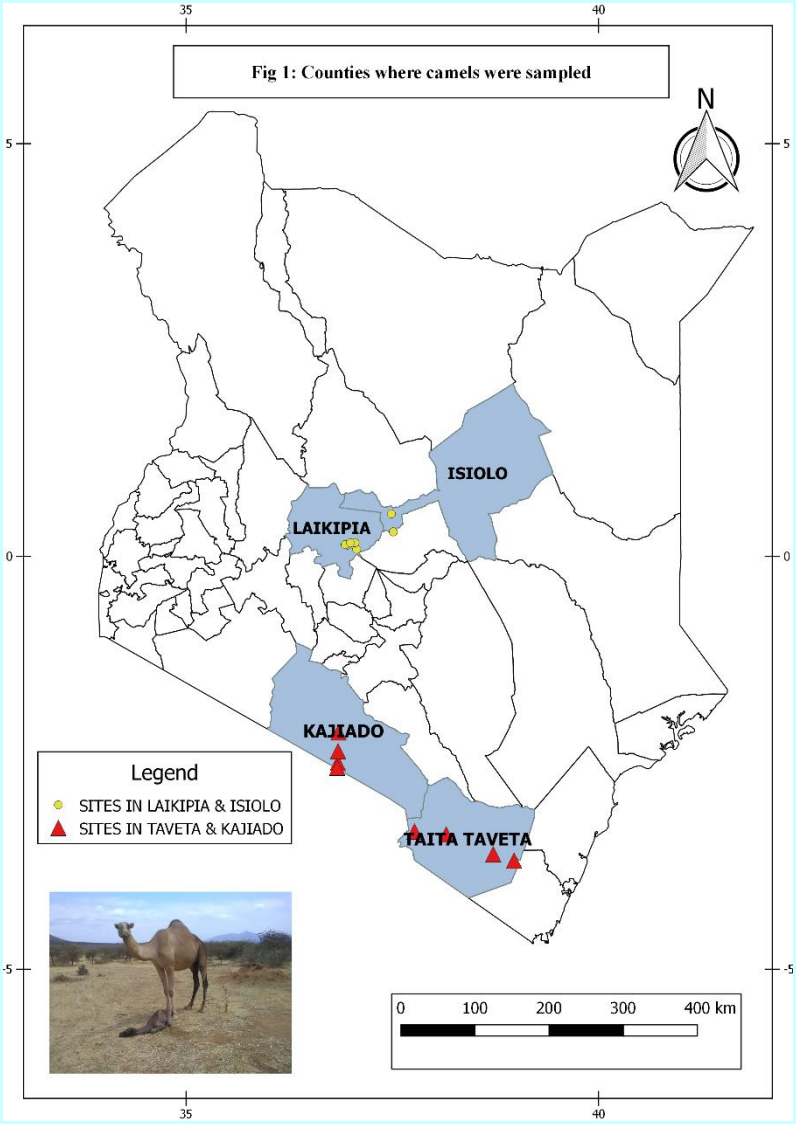
Table 1. Demographic characteristics of the study counties

County	Area (km^2)	Sub-counties	Temp range	Annual rainfall	Human population (2009)	Camel population (2016)*	Other livestock (2016)	Dairy cattle (2016)
Isiolo	25,700	Isiolo‡, Merti‡ Olondonyiro	12-28°C	150-650mm	143,294	65,916 (5.8%)	1,144,393	252
Laikipia	8,696	Laikipia East‡; Laikipia North‡; Laikipia Central; Laikipia West; and Nyahururu.	16-26°C	400-750mm	399,227	8,072 (0.5%)	1,576,370	53,936
Taita Taveta	17,084	Taita (Wundanyi), Mwatate‡, Voi‡ and Taveta‡.	21-23°C	650mm	284,657	2,603 (0.3%)	842,195	27,310
Kajiado	21,900	Kajiado Central‡, Kajiado North, Loitokitok‡, Isinya, Mashuuru.	20 - 30°C	200 – 700 mm	807,070	840 (.02%)	3,869,080	72,718

(Sources: Laikipia County annual report 2016; Ministry of Livestock and Fisheries, Loitokitok sub-County Livestock department annual report for 2015; KNBS, 2016, livestock report)

Purposive sampling was used targeting households that were secure, accessible and willing to participate in the study, to collect data on mastitis. In June 2015, all lactating camels from three camel ranches and three manyattas from Laikipia County, and 21 households in Isiolo County were sampled. Additional data was obtained in August and September 2018, where 3, 4, 7 and 4 camel herds from Kajiado, Taita Taveta, Laikipia and Isiolo counties respectively were sampled. In Loitoktok, cattle were chosen from 52 farms that were randomly selected from a list of 170 active members of Loitoktok Dairy Farmers Cooperative. In addition, four manyattas were purposively selected where all lactating cattle were

screened for clinical and sub-clinical mastitis giving a total of 136 cows.*Figure 1: Map of Kenya showing the counties where camels were sampled*



Milk samples collection and determination of mastitis prevalence

Animals were examined for clinical and subclinical mastitis (CM, SCM) as per standard protocols (Seifu and Tafesse, 2010; Atif, 2014). Milk from each quarter was aseptically collected and subjected to California Mastitis Test (CMT) to detect SCM and results scored as negative or 0, traces, 1, 2 and 3 (the later four considered positive) as described by Quinn *et al*., (1999). An animal was SCM positive when at least one of its quarters had CMT score of at least traces.

Bacterial isolation and identification

Bacterial culture was done on milk samples from quarters with SCM or a Somatic Cell Count (SCC) of 500,000/ml and above to determine colony growth and morphological characteristics. Bacteria were identified microscopically through gram-staining reaction, morphology and arrangement of the stained bacterial cells. Catalase test for differentiating gram-positive cocci and rods, and indole test for differentiating gram-negative cocci were undertaken as described by Radostits *et al.*, (2000).

Antimicrobial sensitivity test

Bacterial sensitivity was tested against an array of eight antibiotics using the Kirby-Bauer disk diffusion method (NCCLS, 1999). Commercially available antibiotic disks (Hilmedia, India) were used which included ampicillin (AMP, 25 mcg), tetracycline (TET, 25 mcg), co-trimoxazole (COT, 25 mcg), streptomycin (S, 10 mcg), kanamycin (K, 30 mcg), Gentamycin (GEN, 10 mcg), sulphamethoxazole (Sx, 200 mcg) and chloramphenicol (C, 30 mcg). Each antibiotic impregnated disk was applied onto the surface of blood agar plate inoculated with bacteria and incubated overnight at 37^{o}C. The susceptibility or resistance of each isolate was determined by measuring the diameter of the respective zones of inhibition. Sensitivity status was determined as sensitive (S), intermediate (I) or resistant (R)

Data entry and analysis

Data was entered and managed in Ms-excel program to generate descriptive statistics. Prevalence of mastitis was calculated as the number of camels diagnosed with mastitis divided by the total number of camels examined at a particular point in time. Sensitivity was calculated as the number of isolates that were sensitive to the eight antibiotics (as determined by diameter of zone of inhibition) divided by total number of isolates tested and expressed as a percentage.

Results

Mastitis prevalence in camels

Different forms of mastitis vis-à-vis chronic, clinical and sub-clinical were observed in the study population (Table 2). Four (4%) percent of camels had chronic mastitis in form of blocked teat and shrunken non-functional udder. Prevalence of clinical mastitis ranged from 0-5% while subclinical form (SCM) ranged from 11 to 61%. Seasonal variation in prevalence was observed in Isiolo County. Subclinical mastitis was several folds higher than clinical mastitis in all counties. *Staphylococcus species* was the most frequently isolated bacteria followed by *Streptococcus species*. Other bacterial species isolated were bacillus, pseudomonas, *E. coli* and other coliforms. Some milk samples with clinical and subclinical mastitis did not yield any bacteria on culturing.

Bovine mastitis prevalence

Prevalence of clinical and SCM was of 6% and 22% respectively (n=136). *Staphylococcus* (83 %) and *Streptococcus (17%)* were the prevalent bacterial species isolated. Their antibiotic sensitivity ranged from 0-100% (Table 3).

Table 2. Prevalence of camel mastitis and bacterial isolates from Laikipia, Isiolo, Taita Taveta and Kajiado Counties of Kenya

County	Form of mastitis	Prevalence	Bacterial isolates from selected samples						
			Staphylococcus	Streptococcus	Bacillus	Pseudomonas	E. coli	Coliforms	None
Laikipia (2018)	Clinical	10/198(5%)	8	0	0	0	1		1
	Subclinical	24/198(12%)	11	5	0	0	5	0	0
	None	164/198(83%)	19	5	4	5	4	4	0
Isiolo (2015)	Clinical	5/167(3%)	1	5	0	0	0	0	-
	Subclinical	80/167(48%)	31	27	2	0	0	0	-
	None	82/167(49%)	49	14	2	0	1	2	-
Isiolo (2018)	Clinical	0	-	-	-	-	-	-	-
	Subclinical	14/124(11.3%)	2	1	0	0	0	0	11
	None	110/124(89%)	2	3	0	0	0	0	0
Taita Taveta (2018)	Clinical	2/124(1.6%)	1	0	0	0	0	0	1
	Subclinical	22/124(18%)	4	0	0	0	0	0	0
	None	100/124(81%)	19	0	0	0	0	0	0
Kajiado (2018)	Clinical	0	-	-	-	-	-	-	-
	Subclinical	27/44(61%)	6	0	0	0	0	0	0
	None	17/44(39)	1	0	0	0	0	0	0

Antibiotic sensitivity of bacterial isolates

Staphylococcus and streptococcus species were totally sensitive (100%) to gentamycin and chloramphenicol. Sensitivity to tetracycline, kanamycin and ampicillin was equally good (> 95%). The antibiotic with least sensitivity was sulphamethoxazole at 50% to streptococcus and 59% to staphylococcus (Table 3). All staphylococci isolates from cattle showed a sensitivity of 100% to tetracycline, kanamycin, gentamycin and chloramphenicol. Among the antibiotics tested, gentamycin was the most effective towards the bacterial isolates. Seven *Streptococcus* isolates showed 100% sensitivity against tetracycline, streptomycin, kanamycin, gentamycin and chloramphenicol. Resistance to various antibiotics is evident in all study sites with Co-Trimoxazole and Sulphamethoxazole showing the highest level in both cattle and camels.

Table 3. Overall antibiotic sensitivity (%) of various isolates in camel and cattle milk from all study sites

Antibiotic	Antibiotic class	Camel		Cattle (Kajiado)	
		Staphylococcus (Laikipia)	Streptococcus (Isiolo)	Staphylococcus	Streptococcus
Ampicillin	Aminopenicillins	77	94	79	71
Tetracycline	Tetracycline	100	94	100	100
Co-Trimoxazole	Sulphonamides	31	63	54	43
Streptomycin	Aminoglycosides	100	81	96	100
Kanamycin	Aminoglycosides	77	88	100	100
Gentamycin	Aminoglycosides	100	100	100	100
Sulphamethoxazole	Sulphonamides	23	50	29	0
Chloramphenicol	Chloramphenicol	100	100	100	100

Discussion

Camels are an important source of livelihood in the study counties. Results show variation in camel mastitis prevalence between these counties and also seasonal variation within Isiolo County. This traditional camel keeping county with highest camel population had no clinical mastitis and recorded least prevalence of SCM. On the contrary, Kajiado County with least camel numbers, and majority of which are recent introductions had highest prevalence of SCM. Knowledge and experience of the camel keepers on camel husbandry practices appear to be paramount in control of mastitis.

The study further reported antibiotic sensitivity findings of mastitis causing bacteria in isolates obtained from camel and cattle milk in different counties of Kenya. Although there is a range of sensitive antibiotics in the Kenyan market, the findings also provide evidence of resistance at varying levels, with some antibiotic classes such as sulphonamides showing levels which discourage their use to treat and control mastitis. Chloramphenicol and gentamycin did not show resistance to the bacteria isolates from camels and cattle. Although kanamycin which is in the same antibiotic class with gentamycin has high sensitivity level (>95%), it is worth noting that resistance may be setting in suggesting that it is a matter of time before the other drugs in this class become less effective. This delayed development of resistance within the same antibiotic class could be attributed to more accessibility of one them compared with the other. Monitoring prevalence of resistance to antibiotics is crucial since the results reveal the possibility of transferring resistant bacteria and their genes among animals and from animal to humans (GOK, 2017). In dairy animals, the level of resistance to antibiotics is monitored through culture of both commensal and pathogenic bacteria. Several reports (Gitao *et al.,* 2014; Seifu and Tafesse, 2010; Maichomo *et al.,* 2014) have identified *Staphylococci*, *Streptococcus*, *Corynebacteria*, *Bacillus* and *E. coli* as the species causing mastitis in cattle and camels.

The research findings revealed continued development of antibiotic resistance in dairy animals hence the need to develop more vaccines against infectious diseases. Antimicrobial use (AMU) and development of antimicrobial resistance (AMR) globally has been shown to have adverse effects on human medicine including the transfer of bacteria with decreased antibiotic sensitivity (Caswell *et al.,* 2003); resulting in the ban of use of antibiotics such as avoparcin, bacitracin, spiramycin, tylosin and virginiamycin in livestock (Bogaard *et al.,* 2000) in many European countries. In these countries, research has shifted towards prevention with emphasis on the use of vaccines. Kenya has domiciled this

approach as detailed in the national action plan on prevention and containment of AMR (GOK, 2017) to prioritize alternative disease control options such as vaccination.

Conclusions and recommendations

The study concluded that Sub clinical mastitis is common among cattle and camels in the study areas hence appropriate control strategies need to be applied to lower the disease burden. *Staphylococcus* and *Streptococcus species* are the common bacterial causes of mastitis and Tetracycline, streptomycin, kanamycin, gentamycin and chloramphenicol showed very high sensitivity to bacterial isolates hence can be recommended for treatment of mastitis. Additionally, resistance was observed against penicillin, sulphonamides and ampicillin, thus antibiotic sensitivity testing should be carried out prior to their use in mastitis therapy among dairy animals.

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Super Ovulation and Embryo Harvesting in *Bos taurus* cattle: The Success Rates and Lessons Learnt in Kenya

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Abstract

There is a high demand for high producing dairy cows in Kenya and the East African region. The livestock sector contributes 10 - 12% of the gross domestic product (GDP), which represents 47% of the Agricultural GDP, in Kenya. Dairy farming contributes over half of these through milk production and sale of breeding stock. Over 80% of all milk is produced by small scale farmers in rural areas who depend on large scale breeders to provide affordable replacement heifers. The use of assisted reproductive techniques including artificial insemination, sexed semen, multiple ovulation and embryo transfer and invitro embryo production has propelled many countries to achieve sustainable production of milk and replacement heifers. It is difficult to have adequate and high quality replacement heifers due to low reproductive capacity and inadequate number of high quality breeding stock in Kenya. Attempts to bridge this gap with newer biotechnologies including multiple ovulation and embryo transfer have had variable success rates. This has led to higher cost of production thus discouraging the adoption of such high biotechnologies. The aim of the review was to evaluate the success of super ovulation technology in Kenya. The super ovulations resulted in variable embryo production with a range of 0 to 13 transferable embryos and successful transfer rates between 0 to 67%. Poor choice of donors, poor technique and lack of finance were among the factors that have contributed to the observed variations. Reproductive efficiency of the top producing cows through super ovulation may provide a solution to the high demand which has driven the prices of breeding cattle way above the ordinary farmer.

Key words: Biotechnology, Dairy Cows, Super Ovulation and cattle

Introduction

The livestock sector contributes 10 - 12% of the gross domestic product (GDP), which represents 47% of the Agricultural GDP, in Kenya (Mwangi and Omore, 2004); Kabubo-Mariara, 2009); Kios *et al.*, 2011). Dairy farming contributes nearly half of these through milk production and sale of breeding stock. The demand for livestock and livestock products is the fastest growing in the world with increasing trends at 114% in demand of meat and 133% for milk. The demand is clearly more than the current supply. To improve on food security, it is essential to double livestock production in the developing world by 2020 (Okeyo *et al.*, 2009). Developing countries have nearly two thirds of the world livestock population but produce only about a quarter to a third of the world‘s meat and fifth the milk. Low output in the developing regions is due to both low off take rates and low yields per animal (Rege, 2009). Kenya is faced with the challenge to rapidly increase agricultural productivity to help feed its growing population without depleting the natural resources base.

Modern biotechnology approach is regarded as a means to meet the objectives through addressing the production constraints of small scale or resource-poor farmers who contribute more than 70% of the food produced in the country (Rege, 2009). New biotechnologies can help achieve productivity increases but needs to be transferred to the producers to improve on the impact (Ehui *et al.*, 2009). One high

quality dairy cow could produce up to 32 embryos per year compared to the conventional method where the farmer has to wait for nine months for a calf that could be either male or female (Muchemi, 2011). The reproductive potential of a female newborn calf is enormous. There are an estimated 150,000 potential ova in a dairy cow. Through natural breeding, only a fraction of the reproductive potential is realized and an average cow will have one calf per year. Under normal management conditions, a cow produces an average of 8 to 10 calves in her lifetime. The reproductive potential of the female has largely been underutilized. Embryo transfer is a technique that can greatly increase the number of offspring that a genetically superior cow can produce (Glenn, 2004).

The advent of practically feasible technique for the superovulation of the higher producing cows and embryo transfer to animals with the low genetic potential has opened up for further possibility for the herd improvement (Brockington *et al.,* 2000). The technique permits a move away from the present situation in a herd producing calves for replacement to one with the propagation of only a few of the highly producing dairy cows. The cow to cow pathways of inheritance would thus contribute more to the overall genetic improvement of the herd (Cunningham, 2001). The MOET has the capacity to reduce generation interval. It is also useful in progeny testing program due to reduction in generation interval (Inskeep, 2004).

Factors such as species, treatment protocols, breed, age, health, nutrition, season, ovarian status, gonadotrophin preparation and repeated superovulation have been shown to affect superovulation and the quantity and quality of embryos produced (Sirard *et al.,* 2006). Other factors include; lactation status of donors and the time of embryo recovery after insemination (Sirard *et al.,* 2006). The success of MOET programs has been shown to be influenced by the superovulatory responses and fertilization rates of the donors and the survival rates of transferred embryos (Baruselli *et al.,* 2004).

Over 80% of all milk is produced by small scale farmers in rural areas of Kenya. Most dairy cattle breeders do not have adequate high quality replacement heifers due to low reproductive capacity and inadequate number of high quality breeding stock. Most of these small scale farmers have no breeding objectives and mainly use artificial insemination or natural service to sustain milk production. The aim is for the cow to produce milk after calving and not the quality of the heifer produced. To sustain their demand, some of these farmers turn to large scale breeders for quality breeding stock. Attempts to bridge this gap with newer biotechnologies including Multiple Ovulation and Embryo Transfer (MOET), Invitro Embryo Production (IVEP) and gender selected semen has not been successful due to variable output and lack of suitable protocols. This has led to high cost of production of heifers thus discouraging the adoption of such high value biotechnologies. These biotechnologies have a great impact on the dairy industry in Kenya especially the accessibility to high quality breeding stock with high productivity. The objective of the study was to determine the success rate of multiple ovulation in dairy cows in Kenya and lessons learnt.

Materials and methods

The study utilised secondary data on super ovulation of donor cows and obtained from the Agricultural Development Corporation (ADC) farm in Trans-Nzoia County, Kenya. Data obtained included the number of donor cows super-ovulated, response to superovulation, lactation status of the donors, the number of embryos harvested was used. This retrospective study examined data collected over a period of six years from 2009 to 2014 from the Agricultural Development Corporation (ADC). The ADC being the custodian of the national cattle stud herds has been the leaders in adoption of new technologies and MOET in particular. Over 70% of the country's MOET programs have been done at ADC. Data stored contained, data regarding super-ovulation and flushing (n=44), data regarding embryos (n=108), data regarding breed type (n=4) and the lactation stage in days.

Super-ovulation and insemination procedure

On day one (1), donor cows were given 2ml of prostaglandin (estroplan or prosolvin). Cows were observed for signs of heat on day 2 and 3. Intramuscular administration of Fertagyl 2.5 ml was done on day 3. On day 8 synchrony was induced using Controlled Intravaginal Drug Release (CIDR) device plus 2mls Ciderol**.** On the evening of day 12, superovulation was performed by administering Luteinizing

Hormone /Follicular Stimulating Hormone (LH/FSH) FolIitropin at rate of 4mls at 6pm and another 4mls at 6am on day13. At 6pm of day 13, 3mls Follitropin was administered. On day 14, two injections of the same hormone were administered at 12 hours interval (2.5mls and 2mls dose, respectively). On day 15, an injection of 1.5mls Follitropin and 3mls prostaglandin (Prosolvin) was administered at 6am and 1ml of Follitropin given at 6pm. Removal of CIDR device was done on day 16, and the last treatment of Follitropin administered 12 hours apart at a dose of 1ml. Twelve (12) hours after the last treatment, triple insemination using thawed semen was done 12 hours apart on observed standing heat. Embryo flushing was performed on day 24.

Embryo recovery and evaluation

Embryo recovery was performed 7 days after the last insemination using standard nonsurgical method. (Elsden *et al.*, 1976). To collect the embryos non-surgically, a small synthetic rubber catheter (silicone catheter) was inserted through the cervix and a flushing medium was flushed into and out of the uterus to harvest the embryos. Each uterine horn was filled and emptied 5 to 10 times using an embryo filter with a pore size of 60-70 microns. The embryos collected by uterine flushing were classified according to the rules of the international Embryos Transfer Society (IETS) (Robertson and Nelson, 1998). The embryos were classified into: A-Morula, B-Early blastocyst C-Blastocyst, D-Mature blastocyst and E-Hatched blastocysts. Only B, C and D were considered as transferable.

Data type

Information was collected on the following parameters;

- Breed of the donor (Holstein Friesian, Guernsey, Jersey, Aryshire).
- Body Condition Score (1 to 5)
- Lactation stage in days.
- Number of embryos flushed.

Data analysis

The data were analyzed using regression analyses. Simple descriptive statistics was used. The variables have been tested looking for the significant relations. The model was specified as;

$$Y_i = \beta_0 + \beta_1 X_i + \varepsilon$$

Where Y_i was the number of embryos; X_i were the independent variable (X_1=BT1, X_2= BC, X_3=LAS) and ε=error term. BT1-Breed Type; BC-Body Condition; LAS-Lactation Stage.

Results

Though there were no particular trends, the super ovulations resulted in variable embryo production ranging from 0 to 11 transferable embryos as seen on Table 1. The average number of embryo per donor was 2.51±2.14. Out of a total of 43 donors those that did not ovulate were 14 (33%) while the highest donor gave 11 embryos (2%).

Table 1. Number of transferable embryos per donor cow

Number of Embryo	Frequency n=43	%PG
0	14	32.6
1	8	18.6
2	7	16.3
3	2	4.7
4	2	4.7
5	1	2.3
6	2	4.7
7	4	9.3
8	2	4.7
11	1	2.3
Chi-square		36.767***

Factors influencing super-ovulation of Donors

The regression results indicated that the significant factors that influence the ovulation were the BT ($p \leq 0.05$) and LAS ($p \leq 0.01$) (Table 2). The Body Condition Score ranges from 1to 5 where 1 is very emaciated and 5 is very obese. The Body Condition Score (BCS) has a significant effect on the number of embryos obtained. A higher number of embryos were obtained from animals at BCS 4 compared to those animals in BCS3. Lactation stage of the donor which ranges between 60 and 210 has significant effect on the number of viable embryos harvested (Flushed). The number of viable embryos decreased with the decrease in lactation stage (days). Animals that were ninety days and above post partum super ovulated better than those that were in the early stage of lactation especially sixty-five and less.

Table 2. Ordinary Regression model on factors influencing number of embryos flushed (dependent variable=number of embryos)

	Unstandardized Coefficients		**Standardized Coefficients**	**t-value**	**Sig.**
	β	S E	B		
Constant	-1.651	2.776		-0.595	0.555
BT1	-0.755	0.339	-0.271	-2.227	0.032
BC	0.541	0.707	0.093	0.765	0.449
LS	0.042	0.008	0.617	5.076	0.000
R-squ.	43%				
F-value	9.754***				
N	43				

Key ***; **; * significant at 1%, 5% and 10% respectively

Lactation stage of the donor has significant effect on the number of viable embryos harvested (flushed). The number of viable embryos decreased with the decrease in lactation stage (days). Animals that were ninety days and above post partum ovulated better than those that were in the early stage of lactation especially sixty-five and below as shown in Figure 1.

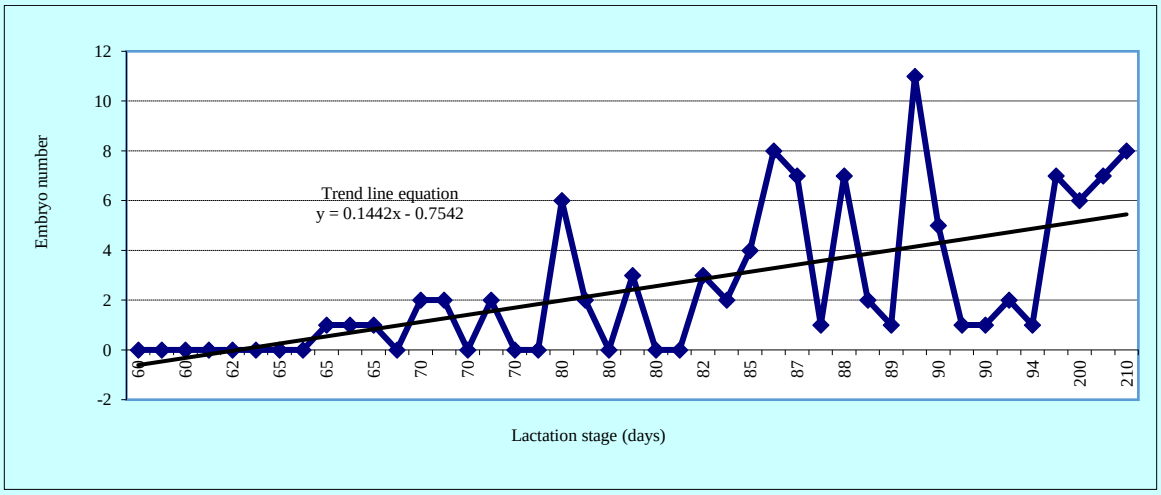

Figure 1. Number of embryos per donor cow over lactation period

Discussion

A significantly higher number of viable embryos were obtained from Aryshire cows when compared to other breeds (Jersey, Guernsey and Friesian). Other Authors obtained different results from different breeds (Breuel *et al.*, 1991; Bo, 2006). It is still unknown whether this could depend from physiological status influenced from management and production levels.

Conclusion and recommendation

Objective of the study was to determine the success rate of super ovulation and embryo harvesting in *Bos taurus* in Kenya and lessons learnt. Some of the key influencing factors on the super-ovulation were Breed Type (BT) and Lactation Stage (LS). Further investigations are necessary to determine why some breeds are more superior in ovulation than others. On-farm harvesting of embryos has practical difficulties and requires trained personnel and equipments for evaluation and packaging of embryos at the farm site. The application of this technology can improve reproductive efficiency in dairy cattle and harvested embryos can be frozen and conserved in a bank for future use. It is recommended that the donors used for super-ovulation be 90 days post partum.

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Prevalence for Porcine Cysticercosis in Busia and Kakamega Counties, Western Kenya

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Abstract
Cross-sectionals surveys were conducted to determine the actual prevalence for porcine cysticercosis infection at the farms and slaughter slabs in Busia and Kakamega Counties. The Enzyme-linked immunosorbent assay (ELISA) test was performed for sera from farms and slaughter slabs. For slaughtered pigs, the daily meat inspection report was also collected. Four hundred sera from farmers in 7 villages and 5 slaughter slabs from Busia and Kakamega Counties were analyzed for the presence of *T.solium* antigen using the ApaDia Ag-ELISA assays. During the study, 113 pigs' blood was collected and carcasses inspected and passed fit for consumption. The seroprevalence of *T.solium* cysticercosis in pigs at the farm level was 4% (8/200, X^2= 176.7200 at p<.0001) in Busia and 2.3% (2/87, X^2= 79.1839 at p<.0001) in Kakamega County. At the slaughter slabs level, the seroprevalence in the 2 Counties was 4.8% (4/84, X^2= 68.7619 at p<.0001) in Busia and 6.9% (2/29, X^2= 21.5517 at p <.0001) in Kakamega. Results of the chi-Square indicated a highly significant difference between the overall prevalence of Porcine cysticercosis (PC) in the 2 Counties at farm level (3.8 %, X^2= 255.892 at p <.0001) and slaughter (5.3 % X^2= 90.274 at p <.0001). Results from this study indicate that the disease is prevalent in Busia and Kakamega Counties. It is therefore concluded that there is an ineffective control and eradication of porcine cysticercosis in the two Counties. This is mandatory to increase income from pig production and trade in the pork value chain.

Keywords: Cysticercosis, Pig, Prevalence, Production, Slaughter, Busia, Kakamega

Introduction

Porcine cysticercosis (PC) is a zoonotic food borne parasitic disease of global public health concern in pigs and humans. The disease is caused by *Taenia solium* larvae which also causes taeniasis in humans (Arora and Arora, 2012; O'neal *et al.,* 2012). The Food Agriculture Organization and World Health Organization classify PC as one of the major neglected tropical diseases and one of the re-emerging diseases (FAO/WHO, 2014; WHO, 2017). The prevalence of PC is highest in rural areas where domestic pigs scavenge in poor sanitary conditions.

The zoonotic tapeworm *T. solium* has a two host life cycle, the indirect with humans as the definitive host, and pigs as a normal intermediate host harbouring the larval cysticerci (Donadeu *et al.,* 2017). Cysticercosis in pigs results from the ingestion of *T. solium* eggs directly by faecal-oral route, or environments contaminated with human harboring adult *T. solium* whereas humans are infected through undercooked pork or from the environment (O'neal *et al.,* 2012; Fleury *et al.,* 2013).

PC infection cause huge economic losses from massive pork carcass condemnations and barrier to accessing formal markets for pig producers, especially smallholder farmers. They are developmental issues relevant to transforming livelihoods of resource poor farmers and the World Health Organization has responded by committing to rolling out PC control by 2020 (WHO, 2015).

Studies on PC in smallholder systems focusing on prevalence and risk factors were conducted but often ignored to adopt one health concept, despite recognizing that it is a parasitic zoonotic disease. It is thus necessary to provide further epidemiological information for planning appropriate control strategies because PC prevalence can stifle growth of the pork sub-sector. Porcine cysticercosis can be a barrier to accessing formal markets, a cause of economic loss to farmers and traders arising from condemned carcasses, and it is linked to epilepsy cases in humans. Therefore, from the PC public health aspect, this

study assessed the approximate prevalence of PC at the farm level in 7 selected villages and in 5 slaughter slabs through ELISA test in Busia and Kakamega Counties.

Material and Methods

Study area and design

This research was conducted in Mundika, Bugengi, Nango'ma, Lwanya and Murende and Buyonja and Shihalia villages of Busia and Kakamega County respectively. Kahyega, Shinyalu and Malinya (Kakamega County) and Musambaruwa and Matayos (Busia County) slaughter slabs were used (Table 1).

The research was conducted through a cross-sectional survey to determine the prevalence for porcine cysticercosis infections at the farms and slaughter slabs in Western Kenya. A total of 162 pigs rearing household and 5 slaughter slabs were selected from which blood samples were collected from 400 pigs. The variation in number of pigs per County and villages depended on the County's pig population and Village's pig availability at farm level; and the minimum daily number of pig slaughtered per slaughter slab.

Sample size and sampling procedure

The population of pigs in Busia and Kakamega Counties were 48, 225, 00 pigs and 25, 225, 00 pigs respectively ((KNBS Census, 2009; Softkenya.com, 2011) , a minimum sample size (n) was 400 pigs ($n = \frac{N}{(1+Ne^2)}$ (Yamane, 1967), where n = corrected sample size; N = pig population size and e = 0.05 is the margin of error.

Sampling involved multistage procedure within nine villages. In each household visited, a maximum of 5 pigs excluding those younger than three months, lactating sows and pregnant sows, was randomly sampled for blood sampling for seroprevalence test whereas at slaughter, pigs to be slaughtered in the period of data collection were also subjected to blood sampling followed by the collection of daily meat inspection records.

Methodology

Blood sampling at farm and slaughterhouse

A 5 ml blood sample was collected using vacutainer seringue from the external ear or the jugular vein of pigs. The blood sample was collected and transported in cool box at 4 ° - 8 °C to the International Livestock Research Institute (IRLI) and Directorate of Veterinary Services laboratory for Busia County and the laboratory of Veterinary disease control for Kakamega County. Blood samples were then separated by centrifugation at 3000rpm in 5 minutes at 20°C to obtain cleaner serum from pigs at farm and slaughter slabs levels. The serum was then dispensed into 2ml labeled Eppendorf tubes and stored at 40 °C and transferred to Immunological laboratory of Animal Science department at Egerton University, Njoro, Kenya, then frozen and stored in freezer at 4 - 8 °C until time of use. The serum samples were therefore analyzed for the presence of porcine cysticercosis parasite antigens (Ag) using ApaDia Ag-ELISA assays.

Meat inspection record

Records of meat inspection were collected on daily basis for the pigs slaughtered during the period of data collection**.**

Laboratory and data analysis

The qualitative determination of viable metacestodes (cysticerci) of Taenia solium in porcine serum samples was performed by the apDia Cysticercosis Ag-ELISA to screen positive pigs following the instructions from the manufacturer's manual (Brandt *et al.*, 1992; Dorny *et al.*, 2004; Rodriguez *et al.*, 2009; Deckers *et al.*, 2010). Porcine cysticercosis prevalence was compared between Counties using Chi-square test.

Results

Pigs proportions and characteristics

Sera from 400 pigs were collected in Busia and Kakamega Counties. A total of 287 pigs were from farm level. Two hundred 200 pigs were from 5 villages of Busia and 87 from 2 villages of Kakamega Counties. At the slaughter slabs level, 113 pigs were from 2 slaughter slabs in Busia (84 pigs) and 3 in Kakamega (29 pigs) Counties Sera were analyzed using the apaDia Cysticercosis Antigen (Ag) ELISA (REF 650501), the Enzyme Immunoassay for the qualitative determination of viable metacestodes (cysticerci) of Taenia spp.

Busia County had a higher number of 102 (63.75%) pigs rearing households surveyed with 200 (69.69%) pigs at farm level and 84 pigs (74.3%) at slaughter slab level while Kakamega County had 60 (36.25%) pigs rearing households with 87(30.31%) pigs at farm level and 29 pigs (25.7%) at slaughter slab level. Results in Figure 1 below showed that a total number of 287 pigs were examined at production level in both Busia and Kakamega Counties

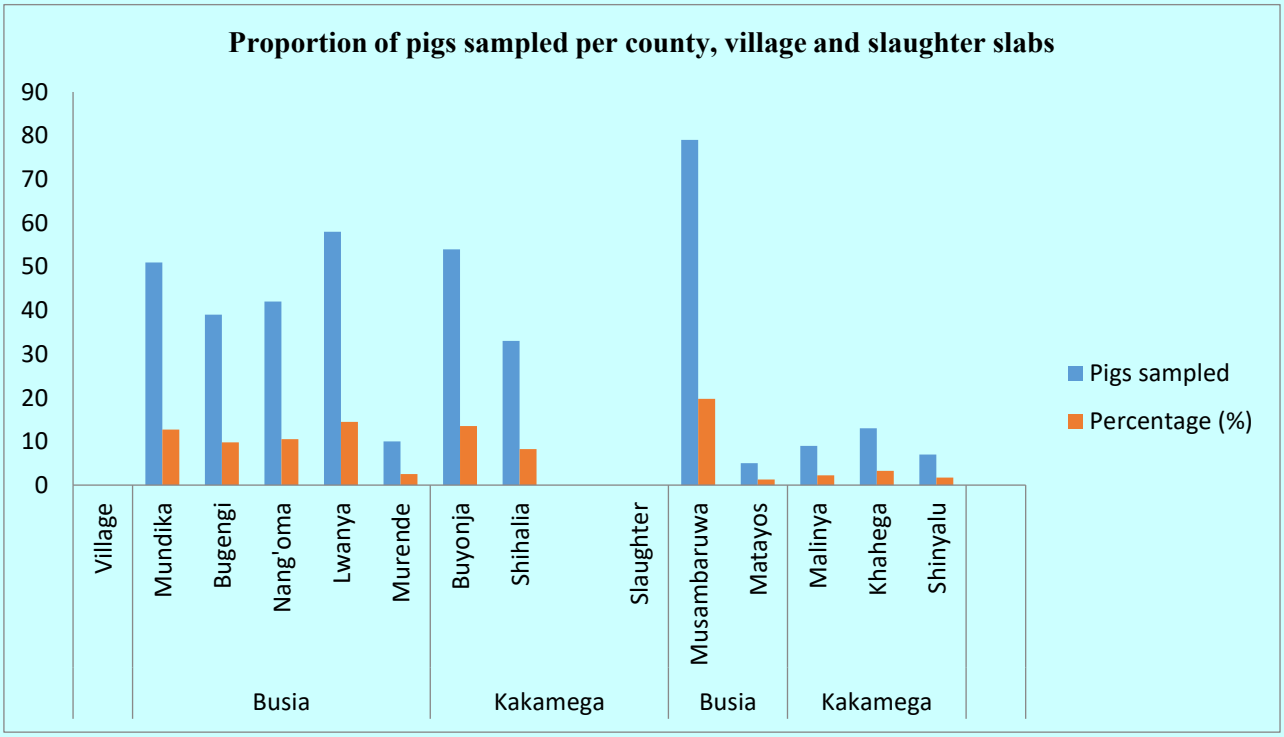

Figure 1. Proportions of pigs sampled

Herd characteristics

At farm level, female (65.2%, (187/287) were higher than male pigs (34.8%, (100/287). Furthermore, four categories were considered, 70 (24.4%) piglets; 79 (27.5%) weaners; 77 (26.8%) growers and 61 (21.3%) were breeders. The majority of pigs sampled from slaughter slabs were from Busia County (84/116). With reference to sex, 53.1% (60/113) of the examined pigs were males and 49.6% (53/113) (females). Considering the category, the samples were composed of 7 (6.2%) piglets; 23 (20.4%) weaners; 67 (59.3%) growers and 16 (14.2%) were breeders.

Prevalence of porcine cysticercosis

Therefore the prevalence was computed from the serology tests and ELISA positive cases were from samples at farm and slaughter slab level using the formula: $\text{Observed prevalence(Op)} = \frac{\text{Total diseased positive pigs(TD+)}}{\text{Total pig samples(n)}} * 100$, Where Op = Observed Prevalence of disease $(T\ D^{+})$ = Total diseased positive pigs and n = Total pigs sample.

Table 1. *Seroprevalence* by County/Village at farm level based on Ag-ELISA

County	Village	Pigs sampled	Positive cases	Prevalence (%)	County *X2*	*p value*	Overall X^2	*p value*
Busia	Mundika	51	5	9.8	176.72	<.0001	255.892	<.0001
	Bugengi	39	2	5.1				
	Nang'oma	42	1	2.4				
	Lwanya	58	1	1.7				
	Murende	10	0	0				
	Sub/Total	200	9	4.5				
Kakamega	Buyonja	54	1	1.9	79.184	<.0001		
	Shihalia	33	1	3				
	Sub/Total	87	2	2.3				
	Total	287	11	3.8				

Results in Table 1 above show the PC seroprevalence at farm level where 9.8% in Mundika village, 5.1% in Bugengi village, 2.4%, 1.7% and 0% in Murende village in Busia County whereas Buyonja and Shihalia villages in Kakamega have 1.9% (1/54) and 3.0% 1 respectively. The actual overall prevalence using ELISA was 4.0% (8/200, X^2= 176.7200 at p<.0001) for Busia and 2.3% (2/87, X^2= 79.1839 at p<.0001) for Kakamega at farm level. Prevalence of porcine cysticercosis at farm level in Busia was similar (50.0%) for male and female pigs with 75.0% breeders and 25.0% piglets. For male pigs affected, 50% were weaners, 25% growers and 25.0% piglets. Results from this study recorded an average of 1 and 2 pigs per farmer in Kakamega and Busia Counties respectively.

Table 2. Seroprevalence by County/Village at slaughter slabs level

County	Slaughter	Pigs sampled	Positive cases	Prevalence (%)	County *X2*	*p value*	Overall X^2	*p value*
Busia	Musambaruwa	79	4	5.1	68.7619	<.0001	90.2743	<.0001
	Matayos	5	0	0				
	Sub/Total	84	4	4.8				
Kakamega	Malinya	9	0	0	21.5517	<.0001		
	Khahega	13	2	15.4				
	Shinyalu	7	0	0				
	Sub/Total	29	2	6.9				
	Total	113	6	5.3				

At slaughter slabs level (Table 2), results from 113 pigs examined in the two counties shown that in Busia 4 of 84 pigs sera from two slaughter slabs analyzed were found positive for cysticercosis in Musambaruwa slaughter where Matayos slaughter slab were found free 0% of disease in the period of the study. Sera from three slaughter's slabs in Kakamega shown, with 0% for Malinya, 15.4 % for Khahega and 0% Shinyalu. Prevalence of porcine cysticercosis at slaughter slabs was 66.7% of male pigs and 33.3% of female pigs in the two study areas. Considering the categories of pigs, 50% were growers, 33.3% weaners and 17.7% breeders.

Discussion

The 4% Porcine cysticercosis seroprevalence observed at farm level in Busia and 4.8% at slaughter slabs level in Busia and 6.9% in Kakamega Counties is an is an indication of the existence/presence and persistence of this food borne, zoonotic parasite disease of public health concern globally (Arora and Arora, 2012; O'neal *et al.*, 2012) in the selected villages of the study areas. Githigia *et al.*, 2005; Mutua *et al.*, 2007; Kagira *et al.*, 2010 had also reported existence of PC in these Counties. These results are in agreement with the findings of Mutua *et al.*, (2011) who reported a prevalence of 5.1% in Busia and 3.5% in Kakamega. This indicates that Pork consumers in Western Kenya are likely to be

exposed to PC infection due to the high prevalence as by Githigia *et al.*, 2005; Mutua *et al.*, 2007; Kagira *et al.*, 2010) and which in eight years has persisted.

The pigs sampled were from rural villages of Busia and Kakamega Counties where farmers practice the free range system of production and the inadequate meat inspection observed (Kagira *et al.*, 2009). The prevalence can be attributed to subsistence pig production system in which pigs freely scavenge for food in poor sanitary conditions and which easily predispose them to infections by *T. solium* (Rottbeck *et al.*, 2013; Thomas *et al.*, 2016). The results are in agreement with the findings of Moyano, (2014) who stated that poor pig management and inadequate meat inspection sustains the life cycle of *T. solium*, and makes the disease become endemic and prevalent in both humans and pigs. This prevalence reported in this study may be associated with the free ranging practice also to the inadequate meat inspection (Kagira *et al.*, 2009) in the study areas.

Seeral epidemiological studies confirm that keeping pigs in the free-ranging system increases the risk of the pigs to acquire the infection *(Sarti et al., 1992; Pouedet et al., 2002; Ngowi et al., 2004; Sikasunge et al., 2007; Assana et al., 2010;* Pondja *et al., 2010; Ngowi et al., 2013; WHO, 2015).* Moses *et al.*, 2010) In Busia , Kakamega and elsewhere in some endemic areas, farmers have toilets which are constructed near the pig's pens and farms and are not effectively used (*Ngowi et al., 2004;* Yohana *et al.*, 2013)). Children mainly do not use toilets because they remain alone at home and are not trained to use them. Various studies revealed that there is a significant relationship between lack of latrines and PC prevalence (Sikasunge *et al.*, 2007; Eshitera *et al.*, 2012). This is a human transmission to pig through household waste and water to sources to feed pigs (Maganira *et al.*, 2018).

The observed PC prevalence in smallholder pig farms of Busia is due to a weak or absent management practices to control PC infection or no efforts is made to control the disease and the one health concept is ignored. This is similar on the result from Nsadha *et al.*, (2014) in Uganda who found that porcine cysticercosis has remained a neglected disease after 6 years period. The practice of free ranging system of production in the study area has persisted and is an indication that the only purpose of pig production is the income generation for family subsistence (Mutwa *et al.*, 2010). These results are similar to the finding by Emilio *et al.*, (2017) who reported the free range pig management as the most risk factor in PC infection.This result shown that smallholder farmer is not contributing to much to the pig husbandry development in the study areas because since 2006, research has been done and feed constraint and diseases have been highlighted as main constraints (Nantima *et al.*, 2015). Even though that farmers are thinking that pigs never become sick.

With reference to that the smallholder pig production has to improve livelihoods and provide an affordable source of high quality protein (Chiduwa *et al.*, 2008), this results confirm that pig farming systems in rural villages of Busia and Kakamega Counties are still traditional in which pigs are in scavenging system or at most confined at night and/or seasonally to protect the crops. This results corroborate with Mwape *et al.*, (2013) who stipulate that the prevalence of porcine cysticercosis infection is mainly facilitated by a contaminated environment and by the fact that tapeworm carrier can be found at the production level (Lescano *et al.*, 2007).

Results from slaughter slabs level (4.8 %) for Busia and (6.9%) for Kakamega can be associated to inadequate meat inspection following that in the period of the study all pigs slaughtered were found reported fit for consumption in all slaughter slabs.

Concerning the number of pig kept per farm, results from this study indicated that the pig production in the two Counties has not thrived. Similar results had been reported by Githigia *et al.*, 2005, Mutua *et al.*, 2007 who reported an average of 1 - 2 indigenous pigs per farmer in the same Counties. Nantima *et al.*, (2015) also reported 72.4% of households with the same size in Busia County.

Conclusion

In this study, PC was prevalent. The seroprevalence of PC by ELISA test at farm level was 4.0 and 2.3% % in Busia and Kakamega County respectively, whereas at slaughter slab level, it was 4.8 and 6.9 in

Busia and Kakamega County. This test is sensitive in detection of PC infection whereby through meat inspection no disease was detected and all meat was passed fit for consumption. This can be interpreted that meat inspection in the two areas of study is not done adequately as by multistage survey and personal observation. This information will be valuable in understanding the risk to public health, assessment of area of interventions and identification of an effective design and implement control strategies for PC eradication for pigs and humans protection.

Recommendations

Further studies on the development of control strategy of PC and the prevalence of Taeniasis can be recommended considering that it is a tremendous economic importance for the pig sector and it is also of concern for public health. The pig confinement should be also implemented to avoid the persistence of the disease in the study area.

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CLIMATE SMART LIVESTOCK SYSTEMS AND ENVIRONMENT: IDENTIFYING AND ADDRESSING THE CONVERGENCES

Feed inventory and feed balance assessment: The case of 23 ASAL Counties of Kenya

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Abstract
Majority of livestock in Kenya currently perform below their potential largely due to poor nutrition as a result of dwindling natural resource base and lack of access to quality feeds. Data and information on the quanties, varieties and categories of animal feed resources in Kenya remains inadequate. In 2018, FAO and the State Ministry of Agriculture, Livestock, Fisheries and Irrigation supported the county governments in 23 ASAL counties to undertake an animal feed inventory and estimate feed balances. Results showed that out of 23 ASAL counties, natural (rangeland) grazing biomass contributed $\geq$ 55 % of the total feed base in 13 counties and > 80 % in 10 counties. In several counties, natural rangelands contributed 99 % of the animal feed basket. The contribution of cultivated fodders was negligible for most counties except Embu, Laikipia, Nyeri and Taita Taveta where they contributed 21–62 % of diet with the highest contribution being 56.8–62.0 % in Nyeri. The contribution of concentrates was also negligible for most ASAL counties. The total potential feed dry matter availability ($x10^3$ tonnes) and actual feed availability and use for all 23 ASAL counties was 28 795.3 and 14 656.9 respectively. Equivalent values for Crude Protein, CP ($x10^3$ tonnes) were 3 431.5 and 1 660.1, and for embedded Metabolisable Energy, ME ($x10^6$ MJ) values in the feed available were 214 548.8 and 109 537.0 respectively. The overall feed balances of DM, CP and ME for the 23 counties were negative (-44 %, -44 % and -62 % respectively) indicating a severe deficit. The only counties with a positive balance for some components were Samburu for CP (+25 %), Tana River for DM and CP (+15.6 % and +34 %) and Tharaka Nithi for DM and ME (72.5 % and 12.5 %). Potential feed availability had positive balances for Isiolo, Tana River, Tharaka Nithi, Taita Taveta, Lamu, Kilifii and Kwale for all three feed components (DM, CP and ME). A national feed inventory covering all the counties, including medium and high potential counties and funded by the counties, is required in order to develop a national animal feed strategy. Detailed recommendations are provided in the detailed report of this study.

Introduction

The FAO African Sustainable Livestock 2050 project has estimated that the livestock sector in Kenya is valued at US$ 678 billion and annually accounts for 13.4 % of agricultural value added, or US$ 3.1 billion excluding draft power, and contributes 27 % of agricultural and manufacturing labour force (FAO, 2018a). As in other industrialized economies, livestock is anticipated to become the largest contributor to agriculture.

In 2050 the human population in Kenya will increase from the current 46 million to an estimated 96 million with 41 million people living in urban areas compared to 12 million today (UN, 2007). Consumers will have higher incomes, with GDP per-capita projected to be US$ 6 500 in 2050, over five times its current level (FAO, 2018a). Projections indicate a massive increase in the demand for animal products. Currently per capita consumption of meat is low, less than 10 kg for any type of meat. In aggregate, consumption of beef and milk will increase by over 170% between 2010 and 2050 – by 0.81 and 8.5 million tonnes respectively. To cover the gap created by this projected increase in demand, a massive increase in the number of animals and animal productivity is necessary. The cattle, goat, sheep, poultry and pig populations are estimated to increase by 94 %,145 %,132 %, 375 % and 231 % respectively by 2050 (FAO, 2018a).

Currently,most livestock in Kenya perform below their potential largely due to feed shortages in terms of quantity and quality. Over the past decades, communities primarily engaged in pastoralism in Arid and Semi-Arid Land (ASAL) counties, which hold 60–70 % of Kenya's livestock. These areas have

been increasingly affected by droughts with child malnutrition rates in some counties constantly above emergency levels. Available evidence indicates that pastoralist malnutrition and destitution is principally driven by pasture and water scarcity, as the natural resource base in the rangelands is shrinking fast. Livestock mortality and loss in the 2008–11 drought cost the country US$ 12.1 billion (GoK, 2012), with some households regularly losing up to 50 % of their livestock in drought years.

To accommodate and address both these dichotomies, as well as the associated climate change and adaptation arguments, the livestock management system in Kenya will change, and core to this must be a major improvement in animal feed availability and nutritional management. Thus, a complete feed inventory together with the institutionalization of a feed security system is required in Kenya.

Materials and Methods

In 2018, through the joint efforts of the Ministry of Agriculture, Livestock, Fisheries and Irrigation (MoALFI), FAO and 23 ASAL County governments, the potential and actual feed inventories, the feed requirements for all livestock species; and the feed balances based on both potential and actual feed inventories were established for all 23 ASAL counties.

Several tools were adapted and some developed; these were: an Excel-based tool for collecting data on 'potential feed inventory'; a Word-based tool for collecting field data on 'competitive uses of feed resources'; an Excel-based tool for converting 'potential feed inventory to actual feed Inventory'; a word-based template for capturing 'county-level information on feed industries, feed suppliers and other actors in feed value chain'; an Excel-based models for 'estimation of dry matter, metabolizable energy and crude protein requirements of different animal species'; and tools for 'feed security assessment at ward/livelihood and household levels'. State and county MoALFI staff were trained and supported to collect data in the 23 ASAL counties.

Potential and actual feed inventories were generated and data compared. Not all feed resources potentially available are used as feed for livestock due to competitive uses such as fuel, compost and fencing. In addition, in the rangelands, not all vegetation is palatable or can be grazed due to steep slopes and existence of national parks and protected lands. Of the crop-based feed resources and grazing pasture the available dry matter (DM), crude protein (CP) and metabolizable energy (ME) was assessed. Based on the official livestock population figures at the county level and the herd composition structure the DM, CP and ME intake needs for the different species were estimated for each county.

The results are presented in five clusters. Pastoral North East (PNE) Cluster, consists of Isiolo, Tana River, Wajir, Mandera and Garissa counties; Pastoral North West (PNW) cluster, consists of Turkana, Samburu and Marsabit Counties; South East Marginal Agriculture (SEMA) cluster, consists of Tharaka Nithi (Tharaka), Meru (North), Kitui, Makueni and Embu (Mbeere) counties; Agro-pastoral cluster (AP) has Laikipia, Kajiado, Narok, Nyeri (Kieni), West Pokot and Baringo counties; and Costal Marginal Agriculture (CMA) cluster, comprises of Taita Taveta, Kwale, Kilifi, and Lamu counties.

Results

Of the 23 ASAL counties, natural (rangeland) grazing biomass contributed $\geq$ 55 % of the total feed use in 14 counties and > 80 % in 10 counties (Table 1). The feed basket of all counties in PNE and PNW clusters consisted almost exclusively of grazing biomass with minimal contribution from other feed resources. The contribution of roughages was substantial (54–96 %) for all counties in SEMA cluster except Kitui where the contribution was lower (23.6–33.6 %) than that of grazing biomass. The contribution of cultivated fodders was negligible for most counties except Embu, Laikipia, Nyeri and Taita Taveta. For these counties, the contribution of cultivated fodders was 21–62 %; and the highest contribution was 56.8–62.0 % for Nyeri. The contribution of concentrates was also negligible for most ASAL counties.

Table 1. Contribution of grazing biomass, roughages, cultivated fodders and concentrates to actual feed availability

County cluster/county	% Contribution			
	Grazing biomass	Roughages	Cultivated fodders	Concentrates
Pastoral North East cluster				
Isiolo	83–86[1,2]	0.15–0.20	0.02–0.06	0.0005–0.001
Tana River	96–97	0.9–3.1	0.1	0.7–1.2
Mandera	99	0.36–1.0	0.01–0.02	0.03–0.06
Wajir	99.9	0.06–0.16	0.02–0.04	0.01
Garissa	96–97	1.2–2.9	0	0.2–0.3
Pastoral North West cluster				
Marsabit	99.6	0.005–0.01	0.02–0.04	0..5–0.001
Samburu	93.7–95.9	0.59–1.82	0.03–0.05	0.003–0.005
Turkana	99.6–99.9	0.11–0.34	0.002–0.005	0.004–0.006
South East Marginal Agriculture cluster				
Makueni	3.3–7.8	90.2–95.9	0.2–0.3	0.2–2.9
Embu	0.5–1.1	54.2–62.9	34.3–39.5	2.3–5.1
Tharaka Nithi	0.2–0.5	84.4–88.6	8.2–11.3	2.3–5.0
Meru	2.5–5.6	83.4–90.7	3.5–3.6	4.1–7.3
Kitui	54.8–65.9	23.6–33.6	0.2–0.5	0.5–0.8
Agro-pastoral cluster				
Narok	34.3–58.7	34.6–61.5	2.0–2.3	3.2–4.7
Baringo	54.9–78.6	12.7–29.7	10.6–13.1	0.04–0.1
Laikipia	36.0–56.6	10.6–21.0	27.6–39.4	0.6–1.1
West Pokot	60.6–82.5	15.1–36.5	0.1–0.2	1.9–2.7
Kajiado	79.3–91.2	6.0–15.8	1.4–3.0	0.6–0.9
Nyeri	8.5–20.5	19.7–27.3	56.8–62.0	1.4–3.0
Coastal Marginal Agriculture cluster				
Taita Taveta	31.6–59.0	18.8–31.1	21.4–37.0	0.4–0.8
Lamu	30.8–35.6	35.1–50.1	0.1–0.7	13.2–28.7
Kilifi	65.7–72.9	11.4–18.7	1.6–1.8	8.9–13.9
Kwale	84.8–92.1	5.7–12.7	0.07–0.2	1.5–2.8

[1]*Contributions as dry matter (DM), crude protein (CP) and metabolizable energy (ME) were different and hence the range is given*

[2]*Green, relatively high contribution; yellow, relatively low to medium contribution; white: very low contribution*

The total potential DM (x10^3 tonnes) feed availability and actual feed availability and use of all 23 ASAL counties was 28 795.3 and 14 656.9 respectively. Equivalent values for CP (x10^3 tonnes) were 3 431.5 and 1 660.1, and for embedded ME (x10^6 MJ) values in the feed available were 214 548.8 and 109 537.0 respectively.

Table 2. Feed balance in 23 Arid and Semi-Arid Lands counties

County cluster/county	Feed balance based on potential feed availability (%)			Feed balance on actual feed availability and use (%)		
	Dry matter	Crude protein	Metabolizable energy	Dry matter	Crude protein	Metabolizable energy
PNE[1] cluster	-35.9	-8.7	-45.3	-69.0	-56.3	-75.3
Isiolo	104.0	131.6	24.0	-27.0	-16.8	-56.5
Tana River	178.0	227.3	78.1	15.6	34.0	-26.3
Mandera	-86.0	-79.7	-89.5	-91.9	-88.4	-93.9
Wajir	-46.5	-18.5	-62.5	-67.4	-51.2	-77.1
Garissa	-43.4	-12.6	-29.5	-70.5	-55.2	-63.1
PNW cluster	-48.7	-17.7	-62.7	-72.0	-54.6	-79.7
Marsabit	-8.6	69.2	-12.5	-52.7	-13.3	-55.3
Samburu	-80.6	145.1	37.8	-14.8	25.2	-34.9
Turkana	-71.3	-53.4	-80.7	-82.5	-71.7	-88.2
SEMA cluster	-14.7	-30.5	-66.2	-47.0	-62.2	-78.9
Makueni	-6.3	-40.6	-35.5	-49.1	-69.4	-62.8
Embu	-3.4	-36.8	-34.6	-34.0	-56.4	-55.1
Tharaka Nithi	91.9	3.3	17.8	72.5	-18.1	12.5
Meru	-40.6	-50.7	-87.8	-67.9	-78.4	-91.9
Kitui	-33.3	-14.3	-68.0	-68.0	-59.7	-84.5
Agro-pastoral	-13.1	-20.1	-45.1	-52.5	-61.0	-70.0
Narok	-22.6	-38.7	-52.5	-54.2	-69.2	-72.2
Baringo	-18.6	-17.0	-51.9	-59.4	-62.9	-76.2
Laikipia	-13.1	-18.4	-26.2	-47.2	-56.4	-54.3
West Pokot	-43.0	-49.7	-59.2	-64.8	-71.0	-74.6
Kajiado	42.4	56.7	-13.7	-34.5	-31.1	-60.2
Nyeri	-40.8	-72.5	-66.6	-54.9	-81.6	-74.6
CMA cluster	87.6	128.9	16.8	-37.7	-27.8	-61.7
Taita Taveta	80.1	87.7	12.2	-23.0	-42.9	-50.6
Lamu	48.9	79.0	20.5	-61.1	-47.8	-71.4
Kilifi	113.2	166.1	33.4	-28.6	-8.3	-54.2
Kwale	99.4	168.7	1.4	-38.5	-19.2	-61.7

[1]PNE, Pastoral North East; PNW, Pastoral North West; SEMA, South East Marginal Agriculture; AP, Agrpastoral; CMA, Costal Marginal Agriculture
Red: deficient; green: surplus

Discussion

The overall feed balances of DM, CP and ME for the 23 counties were negative (-44%, -44% and -62% respectively) indicating a severe deficit of both DM and nutrients for the number of livestock. The only counties with a positive balance of some components of the actual feed availability were Samburu for CP (+25 %), Tana River for DM and CP (+15.6 % and +34 %) and Tharaka Nithi for DM and ME (72.5 % and 12.5 %).

The feed availability was highest in PNE cluster with CMA cluster having the lowest actual feed availability and use. Proportion of various categories of feed resources in each county and county cluster, and of the contribution of various animal species to the total feed requirement were calculated and are detailed in the project report.

For the actual feed availability and use, all clusters had negative balances with CMA cluster having the lowest negative balance. CMA cluster also had the least negative balance for potential feed availability. PNE cluster showed severe negative feed balance in terms of DM, CP and ME by 69, 56 and 75 % respectively (Table 2). Among counties in this cluster, Tana River had the best availability of feed resources against the feed requirement. The DM, CP and ME feed balances of PNW cluster was negative by 72, 66 and 80 % respectively. Among counties in this cluster, Samburu county had the best availability of feed resources against requirement. The deficit of DM, CP and ME in the SEMA cluster were 49, 62 and 79 %. Among counties in this cluster, Tharaka Nithi county had the best availability of feed resources against requirement. AP cluster also had severe negative feed balance in terms of DM,

CP and ME based on both potential and actual feed availability and use. The deficits of DM, CP and ME were 53, 62 and 70 % on actual feed availability and use basis. Among counties in this cluster, Kajiado county had the least of feed resources against the feed requirement. The CMA cluster had a negative feed balance in terms of DM, CP and ME based on actual availability and use basis. On the other hand, feed balances based on potential feed availability were positive for this cluster.. The deficiencies of DM, CP and ME were 38, 28 and 62 % on actual feed availability and use basis. In this county cluster, Kilifi though in negative balance had the least deficit of feed resources against the feed requirement.

A common observation for most counties was that based on actual feed availability and use in the grazing land, the number of livestock that can be sustainably reared is much lower than the current population, suggesting the need for increasing feed availability or animal off-take.

Conclusions and Recommendations

In all the23 ASAL counties, the livestock feed requirement was higher than the feed availability. Considering the massive shift required to fulfil future animal source food production l*et al.*, .,one maintain current numbers, major efforts are required in changing existing production systems and the mindset of producers into a market-oriented system.

Livestock in many counties depend on grazing biomass and hence putting in place good rangeland management practices, including planned grazing, reseeding and rehabilitation of denuded lands and control of invasive species is required. Building the capacity of livestock cooperatives or Community Based Organizations (CBOs) and ranchers to do this and to undertake feed and fodder production and conservation should be considered. However, in most of the pastoral areas, irrigation or water harvesting technologies would be required for successful fodder production.

Equally important in all counties is feed conservation. The production and strategic storage of straw-based densified blocks/pellets and use of urea and molasses in liquid and as block for overcoming feed shortages during dry periods is considered promising (FAO 2007; FAO, 2012a). In agropastoral areas that have a greater proportion of crop residue use, provision of forage chopping machines to farmers to reduce the size of forages including straws for easy storage and feeding, and for increasing feed intake and animal production would enhance efficiency of available feed resources (FAO, 2011). Processing of unconventional potential feedstuffs that are currently wasted (e.g., coffee pulp and husk, banana pseudo-stems and leaves, avocado skin and kernel, mango peels and kernels etc.) to utilizable form and an increase in grain milling and feed processing units would increase feed availability (FAO, 2016). Capacity building of women in groups and cooperatives to procure and run agro-processing plants would create jobs and empower women.

Commercialization of livestock production by encouraging market driven approaches to pastoralists and agro-pastoralists is vital. Such efforts should go together with capacity development of pastoralists on pasture/fodder production, management, conservation and use of feed supplementation technologies. Similar training on feed supplementation strategies and use of total mixed ration is required for county extension staff, and the strengthening of extension by the counties must be considered. Strengthening linkages between farmers and pastoralists or agro-pastoralists for co-existence and peace building could result in improved crop residue utilization and sustainable use of rangelands. Establishment of a livestock feed security unit at the county level for planning, programming, management and monitoring of the livestock sector and to oversee development of livestock feeds and a livestock feed database is important.

Development of policies and strategies at national and county levels (e.g. County Rangeland and Community Grazing Management, Livestock Trade and Marketing) and their alignment at both national and county levels would provide enabling environment to realise technical and institution building options presented above. In addition, formulation of guidelines and regulations for controlling watering points and settlements; and development of strategies/guidelines on public-private partnership involvement in pasture and fodder production and conservation, and on use of spatial plans to guide on

stock routes, grazing corridors, holding grounds etc. are needed. Thus, Participatory Land Use Planning must be included in county and national planning.

Once feed availability is assured, the genetic improvement of animals to obtain high yielding and fast-growing animals with high feed use efficiency, and identification of locally adapted forage species and establishment of their production systems, were some of the research areas that were identified. In extreme droughts, efficient utilization of browses through incorporation of polyethylene glycol (tannin-inactivating agent) could be considered (FAO, 2007).

Animal feed needs and availability must be considered in the broader development perspective and not predominantly during emergency (FAO, 2012b; Makkar and Ankers, 2014). There is need to carry out the same animal feed inventory in medium and high potential counties where there may be a surplus of feed; and once this is known, to develop a national and county feed strategies. Counties will need to factor costs of such an exercise on an annual basis into their County Integrated Development plans CIDPs) and budget accordingly.

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Evaluation of Dual Purpose Sorghum Varieties for Grain and Forage Yield for Livestock Feed at Mariakani, Kilifi County

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Abstract
Sorghum yields in Kenya are low despite the crop potential as a climate change adaptation resource for feed and food due to its high water use efficiency and drought tolerance compared to maize. There are no dual purpose sorghum varieties selected or bred for the coastal semi-arid areas of Kenya. A study was carried out to evaluate the performance of nine dual purpose sorghum varieties selected for the dry highlands and lowland semi-arid namely; E6518, BM30, E1291, Ikinyaruka, Lanet 1, BJ28, Nguugu, Singida and Mugana. The one season trial was carried out in the long rains of 2018 and was set up in a completely randomized block design replicated three times at Mariakani Beef Research Centre. Appropriate agronomic practices and data were collected. The varieties height at maturity was higher than that reported from Lanet and recorded shorter days to 50% flowering. The latter was attributed to the above normal rainfall received during the trial period as well as the high temperatures characteristic of the coastal region. Grain yield ranged from 0.8 ton/Ha to 3.2 tons/Ha while total biomass yield ranged from 9.9 tons/Ha to 19.5 tons/Ha. Mugana, Singida, Nguugu and E6518 took more than 100 days to soft dough stage making them unsuitable for grain yield in the study area. The preliminary results indicate that Singida, Mugana, Nguugu and E6518 may be suitable for forage production only while BM30, BJ28, E1291 and Ikinyaruka may be considered as dual purpose. Nutritional analysis is recommended as well as one more season for conclusive results. The need for evaluation of more varieties is emphasized.

Key Words: Sorghum, Semi-arid, Nguugu, E6518, E1291, Mugana, Singida, BJ28

Introduction

Globally, sorghum (*Sorghum bicolor* l. Moench) is the fifth most important crop after wheat, rice, maize and barley (Tawar *et al.,* 2019). It is an important food crop for about 750 million people globally, in addition to providing fuel, building material and livestock feed. However, sorghum is only considered a major feed crop in developed countries where processing technologies on animal feeds have been developed while in Africa, it is largely planted as food crop. Consequently, there are very few sorghum varieties evaluated for livestock (Njiru *et al.,* 2010). Sorghum in Africa is the second most important cereal crop after maize. However, in most areas, sorghum has and continues to be considered as a poor man's crop and its production in many areas has remained at subsistence level.

Sorghum is grown in a wide range of altitudes and environments ranging from sea level up to 2500 meters above sea level. The crop tolerates salinity better that maize as well as acidic soils besides doing well in nutrient poor soils as well as under relatively high temperatures that would generally affect the other cereal crops (FAO, 2019). Sorghum is a hardy crop and has been reported to produce 3 tonnes per hectare under rainfall of 120 mm in Israel's Negev desert planted using micro-catchments with no fertilizer (Berliner, 1993). The implications of the aforementioned study is that sorghum can be planted anywhere as it has been reported to be more efficient in moisture utilization than maize and other cereals

While sorghum has excellent feed qualities (Ouda *et al.,* 2005; Njiru, 2010), it usually comes a close second to maize when animal feeds are considered. However, the increasing temperatures and reduced precipitation may make sorghum an adaptation crop due to its' hardy qualities (Jesse *et al.,* 2017). Jesse *et al.,* (2017) reported that some sorghum varieties may not be suitable under temperatures above 33^0C and recommend widening the genetic diversity in a study done at Kansas, USA.

In Kenya, although sorghum is an important crop, average yields at farm level have remains low at 0.85 t/ha despite there being sorghum varieties with grain yield potential of 2 to 5 tons/ha and forage yields

of up to 28 tons/ha of dry matter (Ragwa *et al.,* 1997; Mngoja *et al.*, 2012). The low yields have persisted as sorghum is normally planted in the marginal areas and when it narrows to farm level, it is planted on the less fertile sites. Further, producers hardly use certified seeds but instead rely on landraces with minimal if any inputs despite the availability of high yielding varieties. Mngoja *et al.,* (2012) notes that inadequate knowledge of new varieties due to poor technology transfer compounded by poor market commercialization infrastructure also contribute to the low levels of production.

Like in many parts of the country, efforts towards increasing cereal production in the coastal semi- arid areas has been focussing on maize despite the incessant crop failure almost every season. Recent effort to promote sorghum growing in the region is focusing on the grain for food and industrial use. Therefore, little effort if any has ever been put towards considering the dual purpose sorghum varieties in the coast region. Karanja (2012) noted that sorghum is second in importance in feed processing in Kenya after maize where the white grain which has minimal tannins is preferred. Since sorghum has comparative advantages in water use and considering the ensuing climate change, the need to identify dual purpose varieties that can do well in the coastal semi-arid areas is urgent. Mngoja *et al.,* (2012) indicated that low altitude areas depending on short season rains require varieties that mature within 100 days while varieties for the highlands and mid altitudes may take up to 180 days to mature. Since there are no dual purpose sorghum varieties selected/bred for the coast semi-arid areas, dual purpose varieties selected for high altitude cold semi-arid areas at KALRO Lanet and varieties selected/bred for the low altitude semi-arid areas by ICRISAT were identified as pioneers for the trials.

The overall objective was to evaluate the performance of the dual purpose sorghum varieties selected for high altitude low rainfall areas and lowland semi-arid areas in the lowland coastal semi-arid areas at BRC – Mariakani.

The specific objective was to

- Evaluate the performance of the dual purpose sorghum varieties at the Coastal dry lands for grain and forage production.
- Recommend dual purposes sorghum varieties for planting in the lowland coastal semi-arid areas

Materials and Methods

The study was carried out on-station at KALRO Mariakani Beef Research Centre. The Centre is in Kilifi County, Kaloleni Subcounty, Mariakani ward. The centre lies at 3° 53´S 39° 28´ E. and is in agro-ecological zone 5 (Lowland livestock-Millet Zone) Jaetzold and Schmidt (1983). The mean annual rainfall is 800mm bimodal in distribution with the long rains in April/May and short rains in October/December. Temperatures vary from 20° C to 34° C. The soils are developed on fine sandstones and siltstones (Mariakani sandstone). The soils are well drained, very deep brown, friable to firm, lacking in organic matter and acidic.

The cumulative rainfall at the study sites is as shown in Figure 1. The total rainfall received in 2018 of 1013.3 mm was slightly elevated from the annual mean of 800 mm.

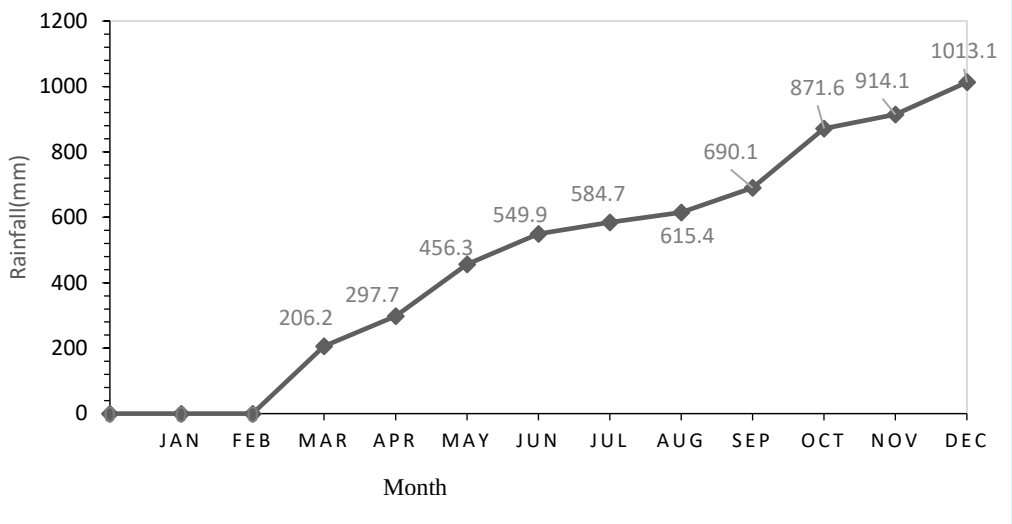

Figure 1: Cumulative rainfall amounts received at Mariakani in 2018

Figure 2 shows the rainfall monthly distribution for 2018. The total rainfall for 2018 was received in 70 days which were higher than normal years.

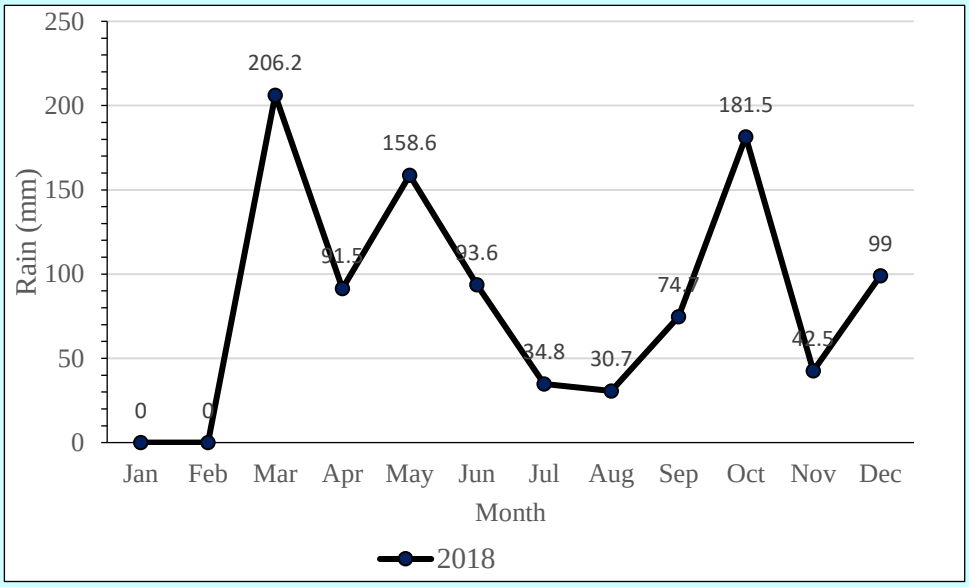

Figure 2. Rainfall Received at KALRO Mariakani in 2018

The study was carried out in one season covering the long rains (MAM) of 2018. A total of nine dual purpose sorghum varieties comprising of six varieties selected for the cold dry highlands namely; E6518, BM30, BJ28, E1291, Ikinyaruka and Lanet 1 and three varieties selected for the lowland semi-arid areas namely Nguugu, Mugana and Singida were obtained from KALRO Lanet and International Crops Research Institute for Semi-Arid Tropics (ICRISAT) respectively.

The seeds of the nine varieties were sown at the onset of the long rains in 2018 in completely randomized block design with three replicates. The nine varieties were planted in 4metre by 3metre plots where a total of four rows were planted by drilling with two rows measuring four metres for each variety making a net plot of 6m^2. The plant spacing was 75 cm between the rows and 10cm between plants, giving a total of 41 plants in a row. In each plot, thinning to attain the correct plant density was done three weeks (21 days) after sowing. Data on the number of plants after thinning, plant height at thinning and maturity, days to 50% flowering, exertion, panicle length, diseases rating, shoot fly damage, stalk borer, lodging, days to soft dough stage was collected. Bird scaring was done to reduce bird damage and grain and

stover biomass fresh weight were obtained for each variety. Dry forage dry matter production was obtained by oven drying 300 samples for each plot at 80% for 72 hours.

The varieties release information from Kenya Plant Health Inspectorate Services (KEPHIS) and performance data for the varieties obtained from KALRO Lanet (Table 1) was used as reference data. Information of the three species from ICRISAT, Mugana, Singida and Nguugu from literature on registration status was scanty but it was indicated that Mugana, and Singida are landraces (Sheuda, Pers comm).

Table 1. KEPHIS Release Data on Growth and Production Performance of the Dual Purpose Sorghum Varieties

Variety	Plant height at maturity(m)	Panicle length (cm)	Days to 50% flowering	Days to hard dough stage	Grain yield	Forage yield (Ton/Ha) *1	Special attribute
E6518	300	20-30	170	230	3	7.2	High quality forage
Ikinyaruka	170	30-40	115	160	7	8	Quality forage
Lanet-1*[1]	250	20-30	110	154	3	-	Not registered
BJ 28	100	20-30	50	110	2-3	(17)	Dual purpose
BM 30	250	30-40	115	210	6	(28)	-
E1291	170	30-40	115	160	6 (2.7)	2.7	Dual purpose, good beverage quality
Nguugu[2]	282.1	-	80-72		0.8	(44.2)	?

*Source. KALRO Lanet and Njiru et al., 2010; *[1] Not in KEPHIS registration list [2] Not released by KEPHIS*
*1 () Forage yield from a study

Njiru (2010) in study to evaluate dual purpose sorghum varieties for semi-arid areas described Nguugu as a tall variety with an average height of around 282.1cm with leaves average length of 83.8cm and 6.5cm width and a stem diameter of 6.0 cm with moderate tillering. The plant usually has about 12 leaves per plant at hard dough stage which has low degree of senescence.

Statistical analysis using One-way ANOVA was carried out in GenStat 15th Edition to examine the effect of variety on days to 50% flowering, panicle length, exertion, days to soft dough stage, grain yield and forage yield.

Results and discussion

Preliminary performance of the sorghum varieties

All the sorghum varieties emerged within a range of 6 to 8 days except for Lanet 1 which did not germinate in all the plots. The grain yield for E6518 was not estimated as it took too long to mature and the cost of scaring birds was prohibitive. The mean performance of the sorghum varieties at Mariakani in regard to panicle length, days to 50% flowering and maturity plant height at maturity, as well as total biomass production shown in table 2.

Table 2. Performance of Sorghum Varieties at Mariakani

No	Species	Days to 50% flowering	Panicle Length (cm)	Plant height at Maturity	Days to soft dough stage	100 seed weight (gm)	Forage yield ton/Ha	Grain yield ton/Ha	Total Biomass yield ton/Ha
1	E6518	110	33.8^{a}	373.1^{a}	133	0	13^{bc}	-	13^{c}
2	BM30	62	16.8^{c}	188.3^{cd}	85	5.3^{ab}	9.9^{cd}	0.8^{c}	10.7^{b}
3	BJ28	62	21^{bc}	107.1^{e}	80	5^{bc}	6.7d	3.2a	9.9^{b}
4	Ikinyaruka	62	19.7c	150.4^{de}	85	4.7^{bc}	9.8^{cd}	1.6^{b}	11.4^{bc}
5	E1291	62	24.5^{b}	175.2^{cd}	85	4.3^{c}	10.2c	1.7^{b}	11.9^{bc}
6	Lanet-1	0	-	-	-	-	-	-	-
7	Mugana	78	31.3^{a}	345.1^{a}	108	4.7^{bc}	16.5^{a}	3^{a}	19.5^{d}
8	Nguugu	67	25.5^{b}	269.2^{d}	107	4.3^{c}	15.5^{ab}	2.8^{a}	18.3^{d}
9	Singinda	67	21.4^{bc}	230.6^{bc}	125	6^{a}	11.7^{ab}	2.7a	14.4^{c}

Plant Height at Maturity

There were significant differences in plant height among varieties ($p<0.001$). Plant height ranged from 107.1 cm for BJ28 to 373.1 cm for E6518. Though E6518 was the tallest, it's height was not significantly different from that of Mugana (345.1). The grand mean of the plant height for all the varieties at Mariakani was higher than the mean height of the varieties reported at Lanet. Generally, it was expected that the plants height at maturity would be shorter due to the high temperatures which have been reported to depress sorghum growth. The latter could have been due to the favourable weather for the particular season of year where more rainfall than the average normal was received as well more rainy days (70).

Panicle Length

There was a significant difference in plant panicle length among the different varieties. The panicle length ranged from 16.8cm in BM30 to 33.8 cm in E6518. The panicle length for all the varieties was within the range that was reported for the varieties in Lanet except for the panicle length for E6518 which was higher.

Days to 50% Flowering

Days to 50% flowering ranged from 62 days recorded for BM30, BJ28, Ikinyaruka, and E1291 varieties to 110 days for E6518. Generally, the number of days to 50% flowering of the varieties from KALRO Lanet was greatly reduced by almost a third (average 71days) at Mariakani compared to that reported for the varieties at Lanet (170days). A reduction to days to 50% flowering was also observed in Nguugu at 67 days compared to reported 72-80 days (Njiru, 2010). The shorter days to flowering could probably be due to the high temperatures at the study site.

Days to Hard dough stage

The days to soft dough stage for the varieties at Mariakani ranged from 80 days for BJ28 to 133 days in E6518. The days to hard dough stage at Mariakani were about a half shorter than for the varieties at Lanet. E6518, Mugana, Nguugu and Singinda days to soft dough stage were more than the 100 days threshold recommended for areas that have short rain season like the study area (Mngoja *et al.*, 2012).

Forage yield

The forage yield was significantly different ($P<0.05$) between the varieties. The forage yield ranged from 6.7tons/Ha in BJ28 to 16.5 tons/Ha in Mugana. The yield reported from this study for E6518. E1291 and Ikinyaruka was higher than that expected as per the release data by KEPHIS but lower than the yield data from KALRO Lanet. The lower forage yield from this study compared to Lanet yields could be due to differences in rainfall and temperature between the two areas as moisture stress and high temperatures have been reported to reduce yield.

100 Seed Weight

The 100 seed weight was significantly different between varieties and ranged from 4.3 grams for Nguugu and E1291 to 6 grams for Singinda. The 100 seed weight for varieties BJ28, E1291, BM30 and Ikinyaruka were higher than that reported by Ouma and Akuja (2013) from trials carried out at Koibatek. The latter differences could be probably due to differences in rainfall as the crop at Mariakani was produced under 1013 mm rainfall while that in Koibatek was produced under about 800 mm rainfall.

Grain yield

The grain yield was significantly different ($P<0.001$) between the varieties. The yield ranged from 0.8 ton/Ha in BM30 to 3.2 tonnes in BJ28. The grain yield from Mugana (3ton/Ha) Nguugu (2.8 ton/Ha) and Singida (2.7 ton/Ha) were not significantly different from that of BJ28. The grain yield from Nguugu was higher than that reported from earlier studies of 0.8tons/Ha (Njiru, 2010). The grain yield for BM30, E1291, Ikinyaruka and BJ28 were lower than the yields reported from Lanet probably due to the high temperatures which have been reported to lead to yield reduction (Hammer *et al.*, 2015).

Total Biomass Yield

The total biomass yield varied significantly ($p<0.001$) with the variety. The biomass yield ranged from 9.9 ton/Ha for BJ28 to 19.5 ton/Ha for Mugana. The Biomass yield for all the varieties obtained from

Mariakani is lower than that reported from Lanet probably due to the high temperatures and rainfall differences. Mugana and Nguugu total biomass was significantly higher than the Lanet varieties. The biomass yield of Singida was not significantly different from that of E6518.

Conclusion and Recommendations

The preliminary results for the evaluation of the nine varieties has given some indicative data regarding the performance of the dual purpose varieties in the coastal semi-arid areas. Some varieties like Lanet-1 that did not establish at all may not be suitable for the study area though there is need to check on the seed storage from the source to ascertain that it was not an issue of seed viability. E6518, Mugana, Nguugu and Singida days to soft dough stage was longer than the 100 days recommended for areas with short rainy season and therefore, they would be suitable candidates for forage sorghum (Mngoja, *et al.*, 2012). The grain yield of BM30 of 0.8 ton/Ha was the lowest but within the range reported for most varieties. It can therefore be tentatively concluded that BM30, BJ28, Ikinyaruka and E1291 can be considered as dual purpose varieties in terms of forage and grain yield levels. However, there is need to carry out another season trial to obtain data to give conclusive data based recommendations as well as carry out nutrient analysis to ascertain the levels of energy, protein and digestibility coefficients. There is need to carry out evaluation of more dual purpose sorghum varieties.

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Participatory Assessment of Land Degradation and Sustainable Land Management in Grassland and Pastoral Areas of Kenya: A case study of Isiolo and Garissa Counties

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Abstract
An assessment on land degradation and sustainable land management in grasslands and pastoral areas was conducted across Kinna and Garbatula wards in Isiolo County and Jara jara, Balambala, and Saka in Garissa County in August 2018. The aim was to link local knowledge and scientific approaches in the assessment and monitoring of land degradation (LD) and sustainable land management (SLM) in the dry lands of Kenya. The field assessment was conducted in four (4) phases which entailed the development of the base maps, data collection and general logistics. Preliminary base maps were developed from Google Earth Imagery, historical topographic maps, and spatial data on infrastructure and administrative units. The maps were prepared in ArcGIS and printed on A0 paper for use in the field. The mobile phone data collection tool (open data kit) included a range of indicators in four (4) thematic areas - landscape context, soil, water and biotic indicators. The assessment results showed that in Isiolo and Garissa, the pastoral communities have a detailed system of macro and micro landscape classification, primarily based on soils, altitude, vegetation, and patterns of land use. At the micro level, communities classify the landscape according to physical attributes and vegetation communities. The landscape units occur as part of a larger mosaic with different grazing potential and patterns of seasonal use. At the macro level local pastoralists in Garissa and Isiolo have similar basis for landscape classification, into two zones - Badhaa (forest/high altitude areas) and Gamojii/ Ghabib (lowlands/low altitude areas). The hybrid knowledge approach is beneficial although it faces challenges when linking the two different methods. To illustrate the opportunities and challenges of the hybrid approach, three result areas namely - grazing potential/plant production, land cover change, and degradation were considered in detail.

Keywords: land degradation, sustainable land management, local knowledge, scientific approaches landscape, grazing potential, pastoralists.

Economic Losses due to Poor Welfare of Meat Chickens in Kenya

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Abstract
The World Organization for Animal Health (OIE) defines Animal Welfare as 'how well an animal is coping with the environment where it lives. This definition is based on the five basic freedoms: freedom from hunger and thirst; freedom from discomfort; freedom from pain, injury and disease; freedom to express normal behaviour and freedom from fear and distress. As a follow up on the study on the impact

of environment on the welfare of broiler chickens and specifically to determine if the farmers were making any losses due to poor environment, handling, transportation and slaughter process World Animal Protection (WAP) designed a study in collaboration with University of Nairobi and one of the large poultry producers in Kenya. Primary data was collected from medium to large scale broiler farmers within four counties – Nairobi, Kiambu, Machakos and Kajiado - while additional secondary data was collected from condemned and rejected birds at a large scale processing plant in Kiambu. Results showed that 6% of the birds died as a result of keeping them in poultry houses which are poorly ventilated with inadequate and often wet litter under poor hygienic conditions. The findings estimate that for an average farmer keeping a flock of 22,000 birds, this loss is equivalent to KESs 24,002 per crop. The study further revealed that poor handling of live birds and loading onto crates prior to transportation to processing plants led to bruises on breasts, thighs and wings. In some instances, birds ended up with broken legs and wings. The bruising and fractures also occurred during transportation along rough roads, in some cases. Birds with bruises and broken limbs were downgraded i.e. they did not attract the premium price from processors. The study estimated a mean of 0.77% of the farmers' production was downgraded in each crop causing the farmer a loss of KESs 48,415. The report estimates that approximately 1.18% of the birds arrived at the processing plant when already dead due to suffocation. Such birds were outrightly rejected by the processing plant leading to the farmer losing a further KES 80,934 per crop. In conclusion, the study showed that large scale meat chicken farmers lost slightly over KES 153,000 per crop due to poor animal welfare practices on the farm and during transportation. This reduced their potential earnings by almost 20%.

Key Words: Birds, Farmers, Welfare, Meat, Processing Plants.

Changing Faces of Pastoralism in these Era of Climate Change in Northern Kenya

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Abstract
This paper reports the findings of coping strategies of pastoralists in the wake of climate change in northern Kenya. Reoccurring droughts in the arid and semi-arid areas (ASALs) has led to loss of livestock and assets resulting from diseases and deaths. Local communities coping mechanism to deal with climate change is by changing their ways of life to cushion them from natural calamities brought by the climate change phenomena. Changing their ways of life is the only option i.e use of Motor bikes as the mode of transport other than the use of donkeys and camels, use of radio and mobile phones as means of getting information and selling of livestock when prices are good, others include reserving areas near homes and feed collections and preservation during the times of plenty to be used in the months of scarcity. Treatments of the sick animals, settlements around manyattas and bringing milk from 'FORA' satellite camps for home use and sale has been adopted.

Challenges of feeding home based milking Animal in the dry season

In the pastoral systems found in northern Kenya, Camels, Goats, Sheep and Cattle are an important component of animal agriculture. In the arid and semi-arid areas of northern Kenya, goats rank second to camels in terms of drought resilience, ability to survive in hot and dry environments, and year round production of high quality animal protein. The majority of pastoral households who live in small rural towns in northern Kenya maintain a small herd of lactating goats or camels mainly for milk supply during the dry season. However, the major nutritional challenges faced in the management of the milking goats in the dry spell are inadequate supply of natural forage and lack of affordable quality supplementary feeds. The low forage productivity is farther aggravated by high grazing pressure around the rural towns and the changing climatic patterns leading to reduced goat productivity and risk on pastoral livelihoods. To address this problem, the first option is to preserve any pasture grass that grows around their homes establish pasture in their farms (planting of grass in arable pockets of their ecosystem), Purchase cereals and feed them direct, Purchase silage and green grass from the market

(Wajir market). These challenges have forced the pastoral households who live in small rural towns to acquire camels due to their long home grazing range (up to 25kms).

Grass planted in badassa for use and sale

Home based lactating goats supplemented with v long standing grass

In the pastoral areas of northern Kenya, emergency feed supplementation is increasingly being recognized as a strategy to correct nutrient deficiencies, maintain the body condition and milk production of lactating livestock. The Acacia riverine zones of northern Kenya support local plant species that are suitable for supplementary feeding of livestock. Local supplementary feeds of *Acacia tortilis* pods and grasses are stored for use during the dry spell. However, the challenge is the prolonged droughts and access to extension services for guidance on collection, preservation and utilization.

Whole *Acacia tortilis* pods packaged in polythene bags and stored in raised wooden beds

Pastoral woman chopping grass hay

Heap of whole *Acacia tortilis* pods

Watering

Since most of the people who used to herd have either gone with large animal away and children have gone to school the women have started taking the animals for watering .

Lady watering camels in a shallow well

Mobile alarm of banditry attack

Use of motor bikes and mobile phones improves communication

This is the game changer for it has made livestock very easy motor bikes transport people, milk and young once to for a and back and know its almost mandatory that every small stock must have a bike other than a donkey. Bikes have changed livestock in to easy undertaking. Carrying of young once very

fast to the new sites. Thirst within fora is a thing of the past for enough water is taken to for a's with the same transport.

Bike carrying newly born lamb to the boma from watering point

Phones give information very fast especially on banditry attacks, boreholes breakdown and livestock market prices. The information helps in decision making and actions are taken At the right time ost of the fora members over/under dose drugs during treatment of their animals.

Moran filling a syringe with drug

Woman carrying twigs for kids and lambs

Castration are known done using rubber band as opposed to burdizzo.

Woman on mobile phone

Other changes in pastoralist lifestyle include milk selling, this is becoming a big business, where milk prices change with the weather pattern. Prices are low during rainy season and expensive during the dry season (40-120/ltr). The transport system is well organized with all forms of transport (Donkey, mortal

bike, land rovers and even lorries). The Other chang include management systems such as breeding (castrations using rubber rings) acquiring of new.

Conclusion and way forward

Pastoral systems have resisted a succession of multiform crises in recent decades. Although current policies seek to encourage the sedentarization of these populations, decision-makers must put in place facilities of making livestock mobile and human settle. Pastoral resilience in the face of climate change can be achieved through mobile pastoral livestock and settled communities with infrastructures that support the industry.

This option may help sustain livelihoods of people threatened by climate variability. Mobility is one of the conditions for maintaining these communities. I Livestock in addition to providing considerable wealth to the State also provide more comprehensive benefits for the society.

Pastoral organizations, notably regional networks carrying strong dynamics and valuable information, must be strengthened when it comes to structuring and involvement in policy elaboration and institutional governance in the broad sense.

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Use of GIS tools in understanding the spatial variability of grazing lands: The case of Marsabit County

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Abstract

Pastoralism and small-scale crop production are the main economic activities in Marsabit County, northern Kenya. The county is remotely located and first-hand data on the use of natural resources is scarce. Remotely-sensed data can be useful in such areas with limited spatio-temporal data. A study was conducted to establish the main land use classes in Marsabit-central Sub County with a view to identifying the Normalized Difference Vegetation Index (NDVI) in various land use classes. The study used GIS tools to get further insights on the land use classes and productivity of Marsabit-central landmass. Land-use classes and Normalized Difference Vegetation Index (NDVI) were identified using LandSat data and Erdas Imagine software. The study revealed that crop fields, good grazing and poor grazing lands are important land use classes in Marsabit. These classes are necessary for provision of human food and livestock feed. Furthermore, crop fields and good grazing lands in Marsabit-central, are located in high altitude areas, while poor grazing lands cover the lower altitude areas. Additionally, the study findings showed that NDVI varies with different land use classes and also varies with the altitude. The NDVI is higher in crop fields and good grazing lands than in the poor grazing land areas. The NDVI can be used as a proxy measure of aboveground forage biomass and crop yield.

Key Words: Biomass, Normalized, Difference, Vegetation, Index, Data

Introduction

Remotely sensed data can be useful in areas where spatial and temporal first-hand data are limited. Marsabit County situated within ASAL areas of northern Kenya is vast and also remotely located. The utilization of Marsabit-central landmass is prone to change owing to climate change and variability; and growing human population. The information on land use classes and land productivity in Marsabit-central is scanty. Use of remotely sensed data and GIS tools can provide further insights on the land use classes and status of land productivity (Shalaby and Tateishi, 2007). The Normalized Difference Vegetation Index (NDVI) provides indication of land productivity under different seasons of the year. It is recognized as a robust approach of estimating green biomass, providing measure of primary land productivity (Wang, Price *et al.*, 2001). The NDVI can be used to monitor the aboveground biomass production. In Marsabit-central, the human and livestock population are natural resource-dependant. The livestock producers utilize natural biomass for feeding their livestock and they are also practise small-scale crop agriculture. Therefore, NDVI can provide proxy measure of food and feed availability in Marsabit-central.

Materials and methods

The method of analysis involved acquisition of Landsat imagery, and processing the imagery before further analysis. After processing of the Landsat imagery, different land use classes were identified and the NDVI computed.

Acquiring of Landsat imagery

The Landsat imagery data was downloaded from USGS website (https://earthexplorer.usgs.gov/). Landsat 7 ETM+ (Enhanced Thematic Mapper Plus) was used for this study. Bands 1, 2, 3, 4, 5 and 7 of the Landsat data were acquired. The Landsat data acquired has a resolution of 30 m * 30 m. The data was then processed before further analysis.

Land use classification

The Erdas Imagine, v 2014, was used to classify the existing land uses in the study area. Supervised classification method was employed. Supervised classification is a user-guided method of classification. The maximum likelihood classifier is one option in the supervised classification system of Erdas Imagine, v 2014, and this option was used (Long and Srihann 2004). The supervised classification method requires the user to have a prior knowledge or to have done ground-truthing of certain areas in the field. The number and the types of land use classes were determined by the user, based on the previous knowledge of the place and from the empirical field work. Therefore, the classification scheme included the following: forest, crop fields, good grazing lands, poor grazing lands and urban or settlements. The signature editor was used to identify these different known or "training" areas for each class of land use. Polygons were created around each training area and added to the signature editor. For each class type, training area was sampled 12 times and added to the signature editor. The 12 subclasses (training areas) were merged in the signature editor and this resulted in one type of land-use class. A single signature file containing different land use classes was produced and saved. Supervised classification of the entire landscape followed, using the signature file as the input data, so that, areas other than the training areas could be assigned to one of the land use classes. The supervised classes were assigned different colours, with each colour representing different land use classes. The land use classes are displayed in form of a map. In addition, the map composition function of Erdas Imagine, 2014, was used to add the properties of land use map. These properties include: map frame, scale of the map, as well as the compass direction.

Variability of land use classes with space

Pixel-based data on land use classes was generated for the entire landscape (study area). Sampling of land use classes at interval of 1.0 km along the Eastings of land use map and at interval of 0.5 km across the northings of land use map was conducted. The pixel-based land use classes were sampled for about 22.0 km transect along the Easting, covering about 80% of the study distance. At every single km along the 22.0 km transect, the type of land use class was identified for 47 pixels. Variability of land use classes from upper home fields to lower grazing lands is shown in graphical format (Figure 2).

Ground-truthing of the land use classes

Ground-truthing was conducted both during the long seasons of 2016 and 2017. It was carried out on high altitude areas of crop lands and within the lower adjacent areas of grazing lands. Ground-truthing involved the researcher visiting various sites and ascertaining the land-use classes. During ground-truthing sessions, the GPS machine was used to record geographical positions of the study sites. Each site represents different land use class. The area of study had about four administrative locations. In the crop fields, 3 farms in each of the four locations were selected. Maize and bean plots were randomly selected and their GPS locations recorded. 12 crop fields were ascertained and geo-referenced. In the good and poor grazing lands, the assessor stood in the middle of the grazing site and identified one direction randomly, moved some 200 m in the direction identified and recorded the GPS points. The 12 good grazing sites and 12 poor grazing sites were geo-referenced. In addition, 12 accessible points in the forest area were identified and their GPS locations recorded. The GPS locations of urban centre and households in the crop-fields under study were recorded. The ground-truthed land use classes were compared with the different land use classes computed with Erdas Imagine, v 2014.

Normalized Difference Vegetation Index

The NDVI is a proxy measure of land productivity (Tucker, Slayback *et al.,* 2001). The NDVI was computed for the long seasons of 2016 and 2017, from the Landsat image captured on 26th July 2016 and 26th May 2017, respectively. The NDVI was calculated using Erdas Imagine, v 2014, and it was computed from the image processed through focal analysis window of Erdas Imagine, v 2014. The final output image after sixth round of focal analysis was used as the input data for processing NDVI.
NDVI was computed using the formulae below:

$$NDVI = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}$$

Where RED and NIR stand for the spectral reflectance measurements acquired in the red (visible) and near-infrared regions, respectively.

Variability of NDVI from upper areas to lower grazing lands

In an effort to demonstrate the variability of NDVI with space, some 22 km transect assessment was run 9 times. The 22 km transect was used because it provided the largest range, covering about 80% of the study distance, but was short enough to avoid edge effects. Transects were arranged regularly on a grid across the landscape (study area). The beginning and end of the transect ranged from 37.97 Easting, 2.22 Northing to 38.16 Easting, 2.39 Northings. The transects were run for the long seasons of 2016 and 2017. The NDVI values across the 9 transects were averaged. One composite transect of 0-22 km distance was identified for the long season of 2016 and one composite transect for the long season of 2017. The transects of the two seasons showed the variability of NDVI values from the upper high altitude areas to the lower grazing lands. In addition, NDVI values were identified in the geo-referenced areas used for ground-truthing of land use classes: forest, the crop fields, good grazing lands and the poor grazing lands. The NDVI values in these land use classes were compared.

Results

Land-use classes

The important land use classes purposely used for food and feed production are the crop fields and the grazing lands. Maize and beans are the dominant food crops. Good grazing lands are mainly found on high altitude areas close to the crop fields, while poor grazing lands are located at further low altitude areas (Table 1 and Figure 1).

Table 1. Land use classes

Land use classes	Description
Good grazing lands	This class involves naturual pastures, Catttle which is the predominant livestock in the study area feeds on these pastures. Good grazing land are found mainly in higher home fields but also in lowland areas.
Poor grazing lands	There are mainly found in lowlands, and are characterized by grasses, shrubs, bareness, patchiness and stones. The land use class is used for livestock production
Urban/settlements	These include market centres, town and homes.
Forest	There is one natural forest in the high altitude area and adjacent to the crop fields. It is also close to the urban centre. There are various tree sp in this forest, examples are *Prunus africanas* and *Croton megalocarpus.*
Crop fields	These are mainly maize and bean fields, and they are the dominant crops grown by the farmers, within the study area. Khat (*Catha edulis*) production is also practiced by some farmers, but it covers only about 8% of total crop fields (GoK, 2011a).
Clouds	There are clouds mainly concentrated around the forest and upper crops field

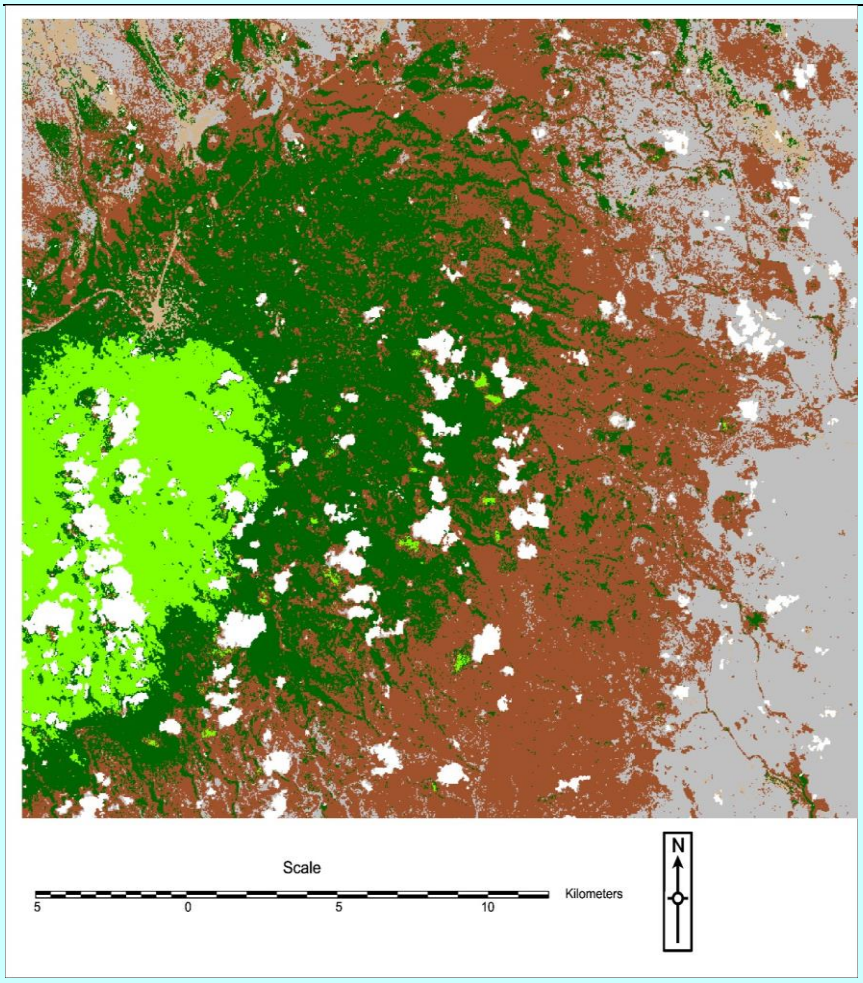


Figure 1. Land use classes

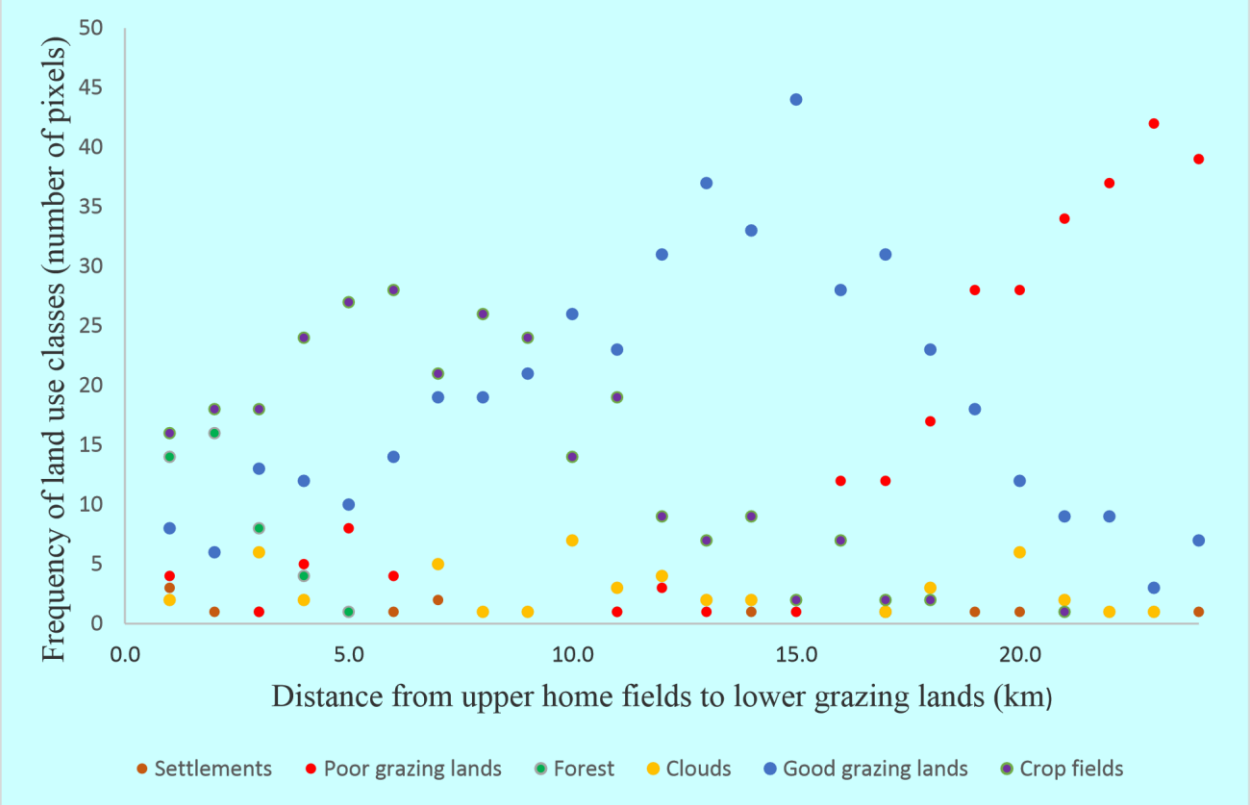
Legend

Good grazing lands		Forest	
Poor grazing lands		Crop fields	
Urban/human settlements		Clouds	

Variability of land use classes with space

In the upper home fields, the land use classes are dominated by forest, crop fields and good grazing lands. Moving further 17 km from upper home fields, the frequency of poor grazing land increases and takes more space than other land use classes (Figure 2).

Figure 2: Virability of land use classes with space.



The ground-truthed land use classes compare well with the land use classes determined through supervised classification. The ground-truthed areas of forest, urban/settlements and good grazing lands were all similarly classified by Erdas Imagine. Some 60% and 75% of ground-truthed poor grazing lands and crop fields, respectively, conformed to the supervised classes of Erdas Imagine (Table 2).

Table 2. Ground-truthing of the supervised classes: Image captured on 26th July 2016

		Predicted					
	Land use classes	Forest	Crop fields	Urban/ settlements	Good grazing lands	Poor grazing lands	Row total
Observed	Forest	12					12
	Crop fields		9		2	1	12
	Urban/settlements			12			12
	Good grazing lands				12		12
	Poor grazing lands		2		3	7	12
	Column total	12	11	12	17	8	60

Normalized Difference Vegetation Index

The original images used for the NDVI analysis were sourced from the Landsat images captured on 26th July 2016 and 26th May 2017, by USGS. In the long rain season of 2016, NDVI ranged from -0.28 to 0.65 and in the long rain season of 2017, it ranged from -0.17 to 0.63 (Table 3, Figures 3 and 4).

Table 3. NDVI for 2016 and 2017 long rain seasons

Statistics	NDVI 2016	NDVI 2017
Minimum	-0.28	-0.17
1st Quartile	0.02	-0.02
Median	0.07	0.04
3rd Quartile	0.17	0.18
Maximum	0.65	0.63

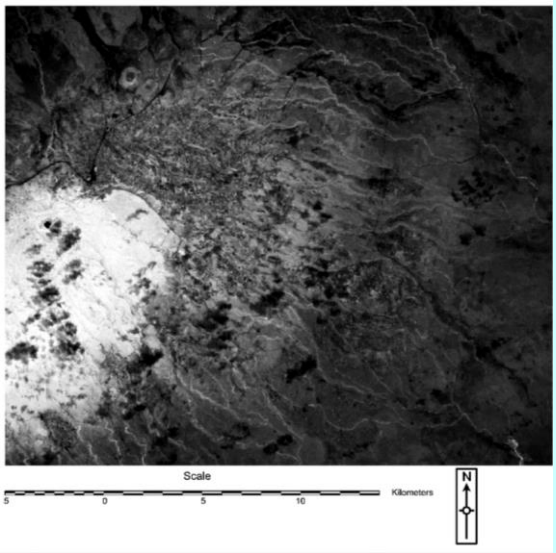


Figure 3. Normalized Difference Vegetation Index: Image captured on 26th July 2016

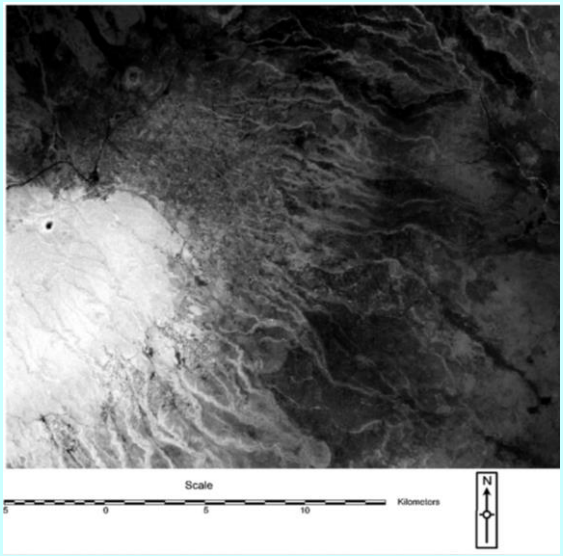


Figure 4. Normalized Difference Vegetation Index: Image captured on 26th May 2017

Colour	NDVI values
(White): High vegetation productivity	>0.3
(Light grey): High vegetation productivity	0.2-0.3

Colour	NDVI values
(Dark grey):Low vegetation productivity	0.01-0.2
(Black): zero vegetation productivity	<0.01

Variability of NDVI from upper home fields to lower grazing lands

The NDVI values reduced as it moved from the upper areas to further away into the distant grazing lands. The upper areas of 0-3 km are dominated by forest and 4-15 km mainly involve crop fields and good grazing lands. The furthest areas from home fields are poor grazing lands. The lowest NDVI values were recorded in the poor grazing lands (Figure 5).

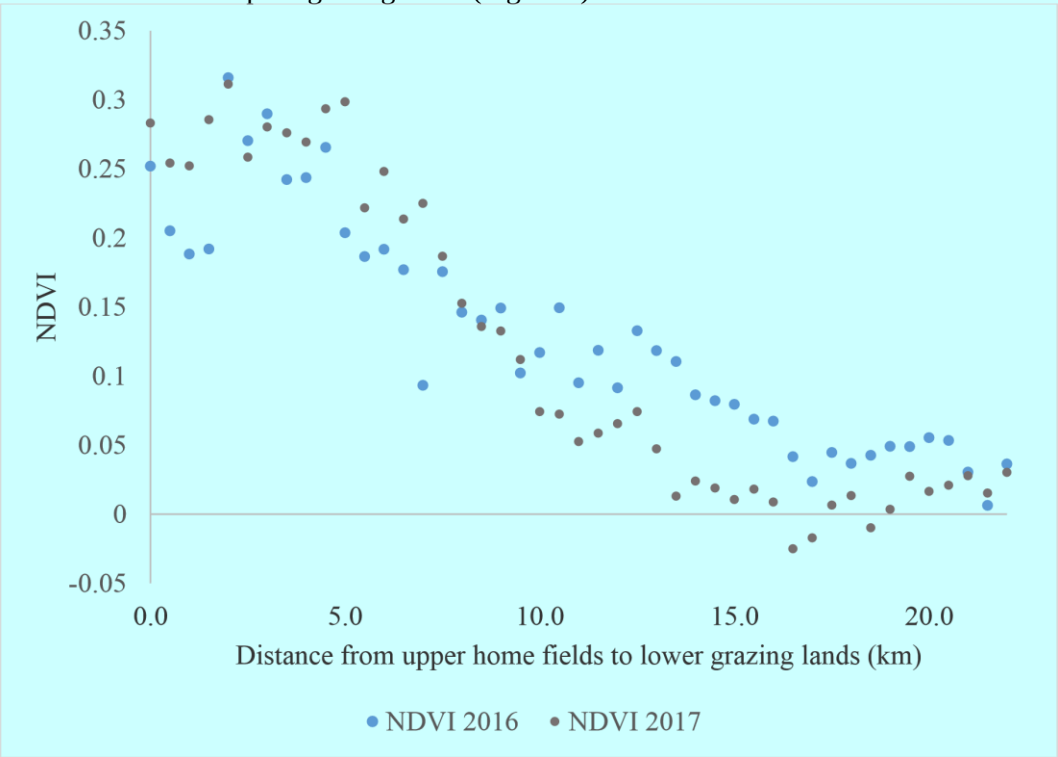


Figure 5. Normalized difference vegetation index: Variability with space

Altitude and Normalized Difference Vegetation Index

NDVI increases with the increasing altitude. The forest has the highest altitude while the poor grazing lands are found on the lowest altitude zone. The good grazing lands are found close to the crop fields, and both have higher altitudes. NDVI differs significantly with the altitude and the land use classes ($P \leq 0.05$) (Table 4).

Table 4. Relationship between NDVI and Altitude (n=12)

Land use classes	Altitude (m asl) – Means and SE	NDVI 2016 Means and SE	NDVI 2017 Means and SE
Forest	1550.3(26.2)a	0.51(0.01)a	0.46(0.01)a
Crop fields	1145.0(50.0)b	0.16(0.02)b	0.23(0.04)b
Good grazing lands	1044.6(23.9)b	0.13(0.02)b	0.19(0.08)b
Poor grazing lands	718.3(43.5)c	0.05(0.02)c	0.03(0.01)c
Altitude effect *P* value ($P \leq 0.05$)		<0.001	<0.001
Land use class effect *P* value ($P \leq 0.05$)		<0.001	<0.001

Means in each column that do not share a letter are significantly different at $P \leq 0.05$, by Tukey's HSD test. Values are given as mean at each land-use class with SE in parentheses.

Discussion

The land use classes identified using Erdas Imagine compares well with the land use classes ascertained during the ground-truthing exercise. Crop fields are concentrated on high altitude areas while the vast lowland areas are used for livestock grazing. Good grazing lands involve individual upper home fields

set aside for natural pastures and also common grazing areas in the lower zone used for livestock production. Poor grazing lands are situated about >10 km from the crop-fields, on the lowest altitude zone. The livestock in high altitude areas utilize the good and poor grazing lands. The existence of crop-fields and grazing lands in close proximity fits well with the diversified livelihood systems. It promotes the inter-linkages between the crop fields and the grazing lands. Crop-livestock integrated systems are the ideal food production system in the study area.Land use classification is necessary in dynamic production systems. However, land use classes are subject to climate change and variability, population growth and shifts in government policies.

The NDVI in the study area is higher in the upper home fields and reduces moving into the distant poor grazing lands (Figure 5). The NDVI varies spatially with the land use classes. The NDVI is higher in the forested areas, followed by crop fields and good grazing lands. The poor grazing lands class registered the lowest NDVI values. The NDVI reflects the level of land greenness, as well as characterizes the amount of healthy aboveground vegetation biomass. Forested areas are expected to record high NDVI due to the tree cover. Similarly, better NDVI is anticipated in the areas with crop fields and good grazing lands due to the cover of crops and natural grasses. However, low NDVI in poor grazing lands correctly revealed low cover of vegetation. Poor grazing lands are characterized by stoniness, bareland and low cover of grass biomass. Consistent with this work, the values of NDVI have been used as a forage scarcity index in Marsabit County and other similar parts of Kenya (Vrieling, Meroni *et al*., 2015). Additionally, the use of NDVI as a predictor for crop yields has been reported (Lewis, Rowland *et al*., 1998).

The arid and semi-arid areas of northern Kenya are historically known for pure pastoral production system. However, small-scale crop agriculture in the mountain and other arable areas has been adopted.Land use classification provides the policy makers, planners, scientists and other development partners with the opportunity for informed land-management decision. Specifically, studies about the NDVI provide useful insights on the productivity of various land use classes.

Conclusion

Crop fields and grazing lands are important land use classes for provision of human food and livestock feed. Crop fields and good grazing lands in Marsabit-central, are located in high altitude areas, while poor grazing lands cover the lower altitude areas. The NDVI varies with different land use classes and varies with altitude. The NDVI can be used as a proxy measure of aboveground forage biomass and crop yield.

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SUSTAINABLE LIVESTOCK PRODUCTION SYSTEMS

Livestock Transformation Agenda towards Higher Welfare Production Systems

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Introduction

The global population is at 7.3 billion persons with Africa's population estimated to be 1.21 billion persons (2015 Global human population). The global annual meat consumption is estimated to be 280 billion kilograms, the milk consumption 223 billion litres and 1 trillion eggs. According to the Nation Newsplex (2013), each Kenyan consumes an estimated 14kgs per year which is 2kgs less than the amount consumed each year during the independence period. Beef constitutes two thirds of all the meat consumed in Kenya, while goat, poultry and pork constitute 13%, 3% and 2% respectively and other meat products account for 15%. Across the world especially in America, one person consumes an estimated 86 kgs of meat per year, which is 5 times the amount consumed in Africa, 4 times the amount consumed in Europe and 2 times of what is consumed in Asia. In Kenya there is an increasing demand for meat to meet protein requirements in the absence of other alternative protein sources such as eggs. This has seen 93% increase in pork consumption in the last 50 years. The increased demand for meat in Kenya has led to an increase in meat prices for instance, a 56% increase in goat meat price in Kiserian and Kaisamis in Kajiado County by mid-2016. The livestock sub-sector contributes 12% of Kenya's Gross Domestic Product (GDP) and 19% of green gas emissions is attributed to livestock production. Livestock in Africa represent on average 30% of the agricultural gross domestic product (GDP) and about 10% of the national GDP. Up to 300 million people depend on livestock for income and livelihoods. Little or no attention to animal welfare is made in the laws and regulations of most African countries which has negative implications on food security, livelihoods, economic growth and trade.

About the World Animal Protection (WAP)

World Animal Protection (WAP) is an international non-profit animal welfare organization that has been in operation for over 30 years. The charity has regional hubs in: Africa, Asia, Europe, Latin America and North America, and offices in 14 countries. The international office is in London. The organization was previously known as the World Society for the Protection of Animals (WSPA). This resulted from the merger of two animal welfare organizations in 1981, the World Federation for the Protection of Animals (WFPA) founded in 1953 and the International Society for the Protection of Animals (ISPA) founded in 1959. In June 2014, the organization became World Animal Protection, at a cost of £168,000. WAP envisions a world where animals live free from cruelty and suffering by moving the world to protect animals.

WAP Theory of Change

WAP's activities are guided by a theory of change with three components as shown in Figure 1

WAP's Theory of Change

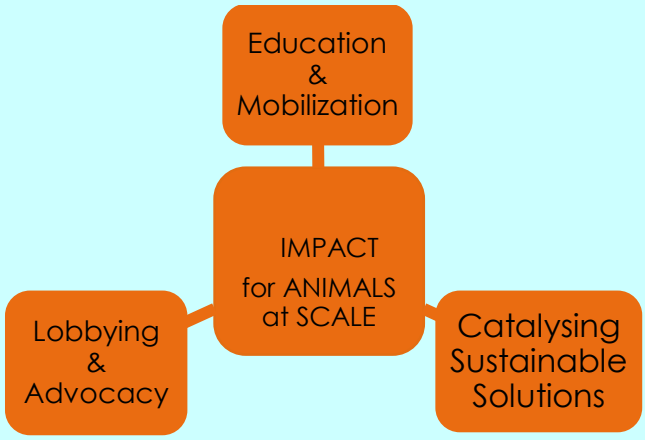

Figure 1 WAP's theory of change

Through **education & mobilization,** WAP creates awareness, enhances understanding, improves skills with an aim of changing attitudes. WAP mobilizes supporters to join them as campaigners, donors and advocates for animals, to demonstrate the scale of support for our cause.

Lobbying and Advocacy through Policy, Research & External Affairs engagement with relevant decision-makers and stakeholders is done with an aim of improving animal welfare policy and practice at national and regional levels in Africa and globally and to establish WAP as the partner of choice on animal welfare matters for businesses in Africa. WAP uses communication and media advocacy in creating greater urgency around animal welfare issues and positioning WAP in Africa as a relevant organization that is present in the current debate.

WAP catalyzes sustainable solutions by:

- Influencing business, law, policy, investment and practice
- Identifying what works around the world by working directly with individuals, communities and animals to develop practical models or to promote effective local solutions.
- Implementing projects aimed at helping thousands of animals today which can translate to helping billions tomorrow when adopted by those who have the influence and resources to implement solutions globally.

WAP has four global initiatives as outlined below: Universal Declaration on Animal Welfare (UDAW), Animal Protection Index (API), African Platform on Animal Welfare (APAW) and Business Benchmark for Farm Animal Welfare (BBFAW).

1. **Universal Declaration on AW**
   The Problem: Animal cruelty & Suffering is a global issue, animals are sentient – they feel pain and animals need to be protected – urgently

   The Solution: To make a Universal Declaration on Animal Welfare (UDAW), to show global commitment to making protection of animals a priority, to inspire international, regional and national change and to drive industries that use animals to protect them.

   What WAP is doing: Since 2003, WAP has led an international campaign for the Declaration to be adopted at the United Nations General Assembly this cause has been supported by 46 government and 330 animal groups. In Africa – Kenya, Tanzania, Nigeria, Ghana, Liberia and Seychelles governments have supported and two million people have already added their voices.

2. **Animal Protection Index** https://api.worldanimalprotection.org/
   This Index produced by World Animal Protection assesses Animal Welfare policy and legislation against specific indicators – focusing on policy rather than practice. The indicators include recognizing animal protection, governance structures and systems, animal welfare standards, providing humane education, promoting communication and awareness. Positive and direct engagement with governments using API has brought long-lasting legislative change in a number of countries. In the year 2015, WAP had legislative changes in Australia, Indonesia, Thailand, Philippines and New Zealand with Australia supporting UDAW. Kenya scored [D] https://api.worldanimalprotection.org/country/kenya, compared to Tanzania [C], South Africa [C]

3. **Africa Platform on Animal Welfare**
   African Platform for Animal Welfare (APAW) is an AU-IBAR-led continental stakeholders' platform including veterinary authorities, livestock production, development & technical partners, relevant NGOs and Civil Society Organizations. Previously, APAW coordinated the Animal Welfare Strategy for Africa (AWSA), an integral part of Livestock Development Strategy for Africa (LiDeSA). AWSA was developed by AU-IBAR in close collaboration with key stakeholders in line with Universal Declaration on Animal Welfare (UDAW) and OIE standards while catering for the African context. WAP's support for the APAW is anchored on the following:
   - The principles of collaboration and partnership will guide our work in Africa.
   - We do not intend to physically expand in the African continent but will collaborate with partners to catalyze our work and to form partnerships that will help drive the animal welfare agenda forward supported by compelling evidence
   - We work with key businesses within the region to influence their animal welfare standards and drive change across whole business sectors.

4. **Business Benchmark for Farm Animal Welfare**
   Business Benchmark for Farm Animal Welfare (BBFAW) is the first global public ranking of the world's leading food companies on farm animal welfare. The ranking is based on publicly available information on company's farm animal welfare policies, practices and performance and provides an annual review of how well major food companies are managing and reporting their approach to farm animal welfare. The ranking allows recognition of food companies making farm animal welfare a critical business issue.

   BBFAW's objective of BBFAW is to drive higher farm animal welfare standards in the world's leading food businesses. BBFAW produces a range of materials on issues such as the business case for farm animal welfare, best practices in management and reporting, and new/forthcoming farm animal welfare-related regulations and policies. Furthermore, BBFAW conducts structured and extensive engagement programmes, encouraging investors to pay more attention to farm animal welfare in their investment processes and companies to improve their practices, performance and reporting on farm animal welfare.

WAP Campaign Areas

WAP has four campaign areas namely:

i) Animals in communities (ending inhumane culling and responsible pet ownership)
   Focusing on b**etter lives for dogs, WAP is w**orking with governments of 25 countries globally to adopt humane and ethical dog population management policies and practices. In Africa, WAP is working with Kenya, Senegal, Tanzania and Ghana on iimplementation and adaption of a 'One Health' approach to dog-related concerns & problems especially Rabies. In Kenya, WAP is working towards a National Strategy for Elimination of Rabies.

ii) Animals in farming (humane and sustainable agriculture)
   WAP is working with governments and value chain stakeholders to ensure that intensively farmed animals have a life worth living in addition to developing industry standards and regulations for high welfare production systems, research on impact of animal welfare on

productivity and raising awareness among consumers to recognize the link between the food they eat and animal welfare.

iii) Animals in disasters (disaster management)
WAP is working with governments on disaster preparedness, for instance pre – El Nino RVF vaccination in Baringo, Kenya and disaster response in the case of Malawi, Mozambique and Zimbabwe floods. WAP is also training and developing Veterinary Emergency Response Units (VERU) and improving lives of animals by working with target governments to change policy and practice around disasters.

iv) Animals in the wild (oceans and wildlife trade)
WAP is working with governments and supporters to save wild animals from being traded and used for entertainment, as luxury pets or products and as traditional medicines and saving marine life (ghost gear).

For further details on WAP Africa, visit website: http://www.worldanimalprotection.or.ke

Total Diet Ration Balancing for Dairy Cows

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Abstract
The dairy industry is a major food source for humans but has huge resource wastage and greenhouse gases emission due to inefficient use of feed resources to meet the nutrient requirements of dairy cattle. Rumen8 is a ration balancing software for dairy cattle that aims to lower the intensity of methane emission, increase milk yield and reduce feed costs which resulting in higher profit margins by lowering feed costs. It applies scientific equations to balance rations using available feed resources. Rumen8 was developed in Australia and was domesticated for Kenya through a compilation of a feed library encompassing more than 230 feeds found in Kenya and other Sub-Saharan African countries. This is because of the tropical conditions that result in high neutral detergent fibre in forages and the different forage species found in Sub-Saharan Africa that are not found in Australia. There is also varying nutritional content of forages due to agronomical practices and variation in commercial concentrates qualities. It was then piloted on 30 farms in North Rift, Central and Meru regions. The findings of the piloting were that good feed management and balanced rations are essential to optimize milk yield, margins and lower enteric methane emission per liter of milk. It was recommended that the farms need to practice good forage management in order to improve fodder quality in terms of metabolizable energy and crude protein and also lower production costs. The farms should also practice feed planning to ensure consistent availability of feeds on the farm which is essential for ration balancing.

Key words: feed costs, methane, milk, ration balancing, Rumen8, software, Sub-Saharan Africa

The Productivity of Dairy Herds in Government and Smallholder Dairy Farms

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Abstract
The demand for livestock products in developing countries is projected to double by 2050 (Delgado *et al.*, 2001). These products which include cattle milk, provides an opportunity for livestock keepers to increase household incomes by producing more milk for sale. In Kenya the livestock sub-sector contributes about 12% to the GDP and an estimated 42% of the agricultural GDP (SNV, 2008). The Kenya dairy sub-sector accounts for between 6 - 8% of the country's GDP (USAID/GOK 2009) and 80% of the marketed milk. In 2009 it was estimated that cattle milk valued at KES 197.018 Billion was produced (ICPALD, 2013). Smallholder dairy farmers estimated at about 1 million own more than 80% of the dairy cattle and contribute to 56% of total milk produced in Kenya (ICPALD 2013). However, the smallholder farms are characterized by low productivity estimated at 1,300 litres per animal per lactation (Omore *et al.*, 1999) and long calving intervals averaging 600 days (Odima *et al*., 1994). Therefore, any intervention that will increase productivity in smallholder dairy farms will contribute significantly not only to the livelihoods of the farmers but also to the country's GDP and employment. Against this backdrop, a study was undertaken in two government farms (one in Western and one in Central Kenya) and 5 smallholder dairy farms in central Kenya to determine their productivity. As this was based on available records three of the smallholder dairy farms were dropped due to lack of records. The production was characterized by low milk yield 1,168 litres per lactation (corrected to 305 days of lactation) and over 200 open days. The lactation curves did not follow the normal sigmoid curve but were characterized as collapsing resulting in the low milk production as yield did not peak at 8-weeks as expected. The scenario was attributed to lack of adequate quality and quantity feeds.

Key words: Productivity of dairy herds, low milk production, quality and quantity feed.

Donkey Slaughter for Skin Trade Impacting the Livestock Transformation Agenda in Kenya

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Abstract
The Agricultural Sector Transformation Agenda in Kenya is based on the belief that the sector supports Kenya's food security and economic development sustainably. The livestock sub-sector has a direct contribution to the realization of this strategy. In the context of livestock development, some animals including donkeys and horses have already been classified as emerging livestock due to inadequate information to support their production, inadequate policy and legal framework and socio-cultural beliefs that preclude their utilization. This study was conceptualized following reported high rates of donkey slaughter for skin trade. Brooke sought to investigate the effects of donkey skin trade on the livelihoods of smallholder farmers in 2018. The study was conducted in five Counties namely; Kitui, Narok, Nyandarua, Kirinyaga and Bungoma. Data was collected using household interviews, focus group discussions and key informant interviews. The study findings revealed that causes of decrease in donkey population varied between counties. In Kitui, Nyandarua and Narok, majority of smallholder farmers attributed a decrease in donkey numbers to being sold (83%, 48% and 36%). In Bungoma and Kirinyaga majority of small holder farmers attributed donkey herd decrease to death (49% and 46%). Across the five counties, a decrease in donkey numbers attributed to theft ranged between 13% and 29%.

In three of the counties (Narok, Bungoma, Nyandarua), respondents associated donkey hide trade to a decrease in income previously generated from donkeys. Half (50%) of the sampled respondents in Kirinyaga reported a decrease in income. On the contrary, in Kitui more than half (54%) of the respondents reported an increase in income. This increase in income in Kitui may be attributed to higher number of donkeys owned, hence selling them resulted in an initial increase in income. It was reported that a reduction in available donkeys has been detrimental to women, children and vulnerable groups (elderly and people with disabilities). Due to the important roles performed by donkeys, the following recommendations were made from this study: There is need for stakeholders to conduct further research to understand the impact of donkey hide trade on livelihoods and the agricultural sector. Inorder to curb donkey theft fueled by demand donkey skin trade, Brooke is supporting owner-led protection initiatives to improve security and safety for donkeys at risk. There is need for development agents, national and international organizations to work hand in hand with Brooke to ensure that donkey hide trade is regulated and measures put in place to limit this trade.

Key Words: Hides, Donkey, Trade, Counties, Income, Skins.

Review of the current status of East African Zebu Cattle in Kenya

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Abstract
Despite their size, Small East African Zebu, *Bos indicus,* make up a majority of the cattle populations in Kenya, yet they have been largely neglected and subjected to indiscriminate crossbreeding through lack of supporting policy and appropriate breeding plans. A literature review was conducted to consolidate information on the current status of East African Zebu cattle. The literature review revealed that opportunities exist for East African Zebu cattle not only to contribute to sustainable livelihood of the poorer livestock keepers in dry land, but also to play a key role in mitigating climate change, through investigating and understanding the methane emission of these herds under free ranging natural low-digestibility forage. Physiological adaptation to heat stress by East African zebu cattle is a most important trait for their survival as they have also enabled the survival of their keepers in harsh arid and semi-arid lands of Kenya. Therefore, it is paramount to maintain the potentiality of East African Zebu for our future generations in the ever-changing world.

Introduction
Dry land, characterized as stochastic ecosystem, is a birthplace of East African Zebu cattle *Bos indicus*. East African Zebu breeds co-exist with wild herbivores ensuring biodiversity of the ecosystem for resilience. A school of social scholars and travelers have documented and praised how well pastoral communities and their livestock are adapted to survive in the dry lands of Kenya. Conservationists often blame livestock overgrazing as it leads to degradation of dry land. Resilience of dry land has always maintained the ecosystem. Some scholars have argued that the socio-ecological disasters had been caused by marginalization of these pastoral societies. For a century, their cattle were seen as inferior animals as well as reservoirs of endemic diseases. Hence, their livestock movements were restricted. The livestock keepers were often forced to destock by selling animals to the Kenya Meat Commission. According to Department of Resource Surveys and Remote Sensing, cattle population trends in Kenya have been stagnant since 1960s (Rutten, 1992; Serneels *et al.*, 2001).

Majority of breeds found in Kenya are East African Zebu cattle, which are small bodied and of the shorthorn, thoracic humped Zebu. They have acquired adaptive characteristics through natural selection under dry environments. Dry lands are more than three quarters of Kenya's landmass. Both current devolution of agricultural sector functions to County Governments and community-based conservancies have given new opportunities. The small East African Zebu could now be integrated to sustainable

development. County Governments in dry lands are now able to make their informed decisions. The aim of this paper is to consolidate existing knowledge of East African Zebu in Kenya; and to suggest a renewed approach for survival of small East African Zebu and their keepers in dry lands of Kenya in the face of climate change and global warming

Results and discussion

Socio-economic background affecting Small East African Zebu

East African Zebu cattle have been largely forgotten by scientists and policy makers. They were discouraged through the existing policy frameworks. The Structural Adjustment Programmes of the 1980s and the 1990s has affected the socio economics of livestock keepers. There have been reduced extension services. The herd productivity in real term decreased using Livestock Production model and consumer index price (Mizutani Wells, 2016, Figure 1).

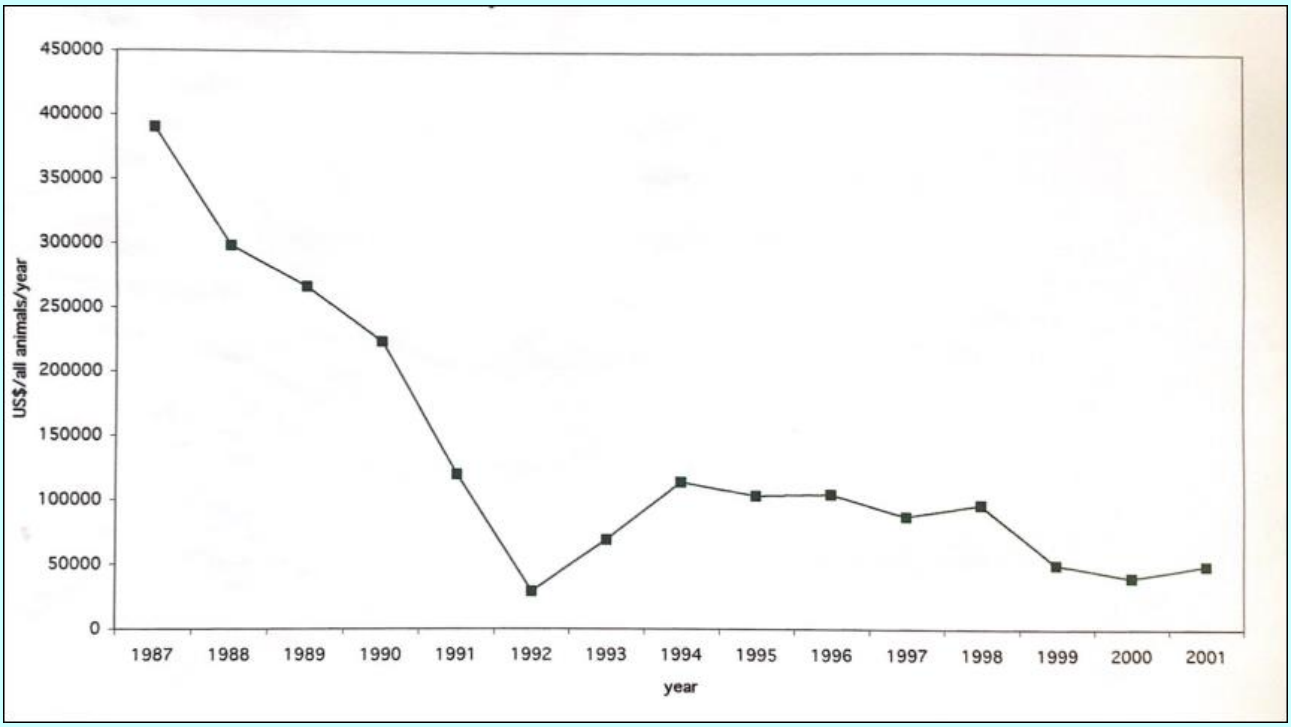

Figure 1. Trends of annual production of crossbred cattle herd in real price (from Mizutani Wells, 2016)

In neoliberal market, inputs such as fuel and drugs were raised; but the price of livestock remained stagnant. Moreover, when cattle shortage occur in Kenya, cattle from neighbouring counties flooded the market, which inhibited rise in price (Agroconsortium, 2003). Recently, East African Zebu cattle in Ukambani, have been offered free insemination service to upgrade animals (https://www.nation.co.ke/counties/kitui/Kitui-farmers-to-get-new-cow-breed/3444936-4939216-tj0hh8/index.html) and such venture may lead to extinction of this breed. Neoliberal market prefers animals to reach higher productivity in short period and there is no value measurement for survival traits of animals such as East African Zebu and this a major driver for indiscriminate crossbreeding.

Looking at livestock supporting framework in Kenya, we found out that there is no society for small East African Zebu and their records in Stud Book. According to Kenya National Statistics Bureau (2009), Kenya has 14.1 million heads of cattle of which about 80 per cent is perceived to be zebu. The population of East African Zebu cattle is currently unavailable; No breeding society of East African Zebu cattle is found in Kenya (http://www.klbo.co.ke). In 1920, the Royal Agricultural Society of Great

Britain created the East African Stud Book in Nairobi. Previously known as the Stud Book mandated to register imported European breeding animals; The Kenya Animal Genetic Resources Centre (http://kagrc.co.ke) offers no artificial insemination service semen for East African Zebu cattle. KAGRC was previously known as the Central Artificial Insemination Station (CAIS) which was established by Kenya Gazette Notice Number 557 of 19th June 1946 with the objective of controlling diseases and genetic improvement of European Dairy Cattle.

Despite above background, East African Zebu are still the majority of cattle in Kenya. It implies that livestock keepers still acknowledge the value of East African Zebu being hardy, drought tolerant, and heat resistant animals to help them survive in dry land.

Genetic History of Cattle Breeds

Following the archeological and ethnographical evidence (Blench and MacDonald, 2000; Hanotte *et al.,* 2002) conducted genetic molecular analysis of 50 indigenous cattle breeds. Results supported the previous evidence, that N'dama cattle *Bos taurus* originated within African continent, but Near East and European breeds *Bos taurus* influenced them. It reached the southern part of the continent by following an eastern route. The Zebu cattle *Bos indicus* genetic influence shows a major entry point through the Horn and East Coast of Africa. The latter are foundation of East African Zebu today. East African Zebu of Kenya (Epstein, 1955 and1971; Rege and Tawah, 1999; Rege *et al.,* 2001) are grouped into eleven breeds based on different societies and geographical locations. These breeds were later clustered into three groups by the genetic molecular characterization (Rege *et al.,* 2001), using the Ethiopian Boran, Nelore and Sahiwal as reference breeds for *Bos indicus* and Friesian and N'Dama as those for *Bos taurus*. The 3 groups are Boran (Kenyan Boran, Orma Boran, Kikuyu Zebu, Kavirondo Zebu), Coastal (Giriama, Duruma and Kamba Zebu), and Inland (Maasai/Samburu, Turkana, Nandi, Taveta, Teso Zebu; Rege *et al.*, 2001, see Figure 2).

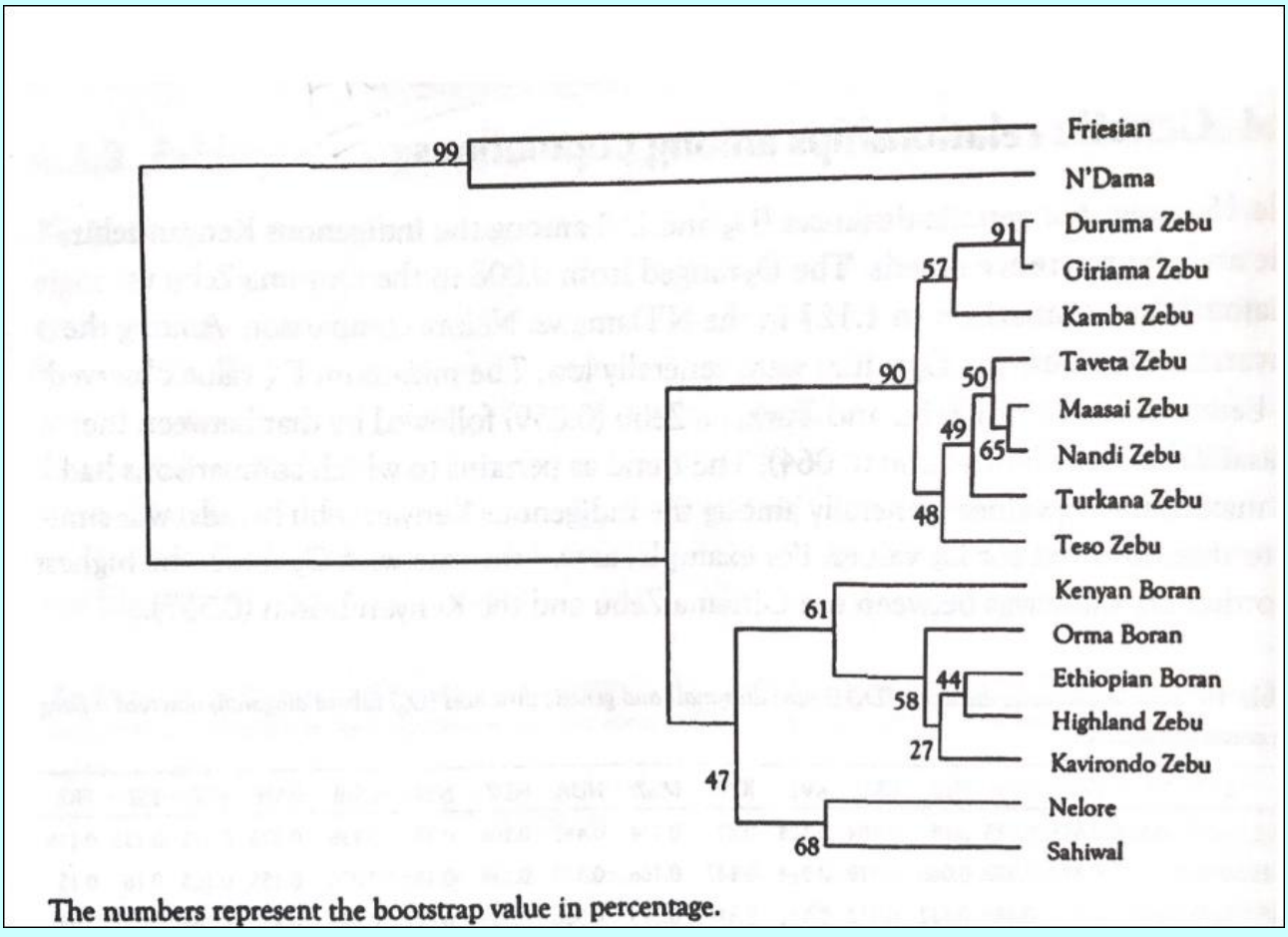

Figure 2. Molecular characterization of East African Zebu in Kenya (from Rege *et al.,* 2001)

UPGMA tree with standard genetic distances: 17 populations, 17 loci

On the basis of geological and breeding isolations, anecdotal reports indicate some pockets of intact breeds in the Coast, Ukambani, Turkana, Pokot, Samburu, Tinderet and Nyanza. However, no current data exist about purity of these breeds.

Breeding of East Africa Zebu

Due to uncontrolled crossbreeding and breed replacements with European breeds, unique genetic resources of East African Zebu breeds are endangered (Rege *et al.*, 2001, Hanotte *et al.*, 2002, Okeyo *et al.*, 2015). Zander and Drucker (2008) reported that livestock keepers prefer crossbreeding with European breeds in Kenya more than in Ethiopia, reflecting the strong market orientation in Kenya. Crossbreeding gives immediate genetic lift or hybrid vigour. For instance, unimproved Ethiopian Boran cattle crossed with Friesian having 50 per cent exotic inheritance yielded to 2000 kg of milk per lactation (Haile *et al.*, 2011).

Over the centuries, the livestock keepers kept their animals within close social tie by gifting or loaning animals. Sometimes they even raided livestock to get new lineage of breeds. By selective breeding of Zebu cattle in Zanzibar, Tanzania during the 1940s, Tinbury (1954) improved milk yield to 760-1140 liters per lactation in three generations. Kenya Veterinary Service in the early 20 centuries also kept indigenous Zebu cattle herds. It was mainly as control herds to investigate epidemiology and test treatment for Trypanosomiasis and tick born disease in order to improve animal health for imported breeds. Zebus are also being used as surrogate mothers in embryo transfer initiatives of breeders.

Kenya Agricultural and Livestock Research Organization (KALRO) has noted for two decades that the livestock keepers' express concerns about declining performances of their livestock mainly emanating from poor breeding and limited feed resources in rangelands (Ndungu *et al.*, 2003). Inbreeding is a possibility in pastoral herds resulting to inferior genetics. When purchasing breeding animals, communities purchase mostly females and upgrade with their males of proven origins. Efforts to establish a nucleus herd of East African Zebu cattle have been made at KALRO Kiboko Station / Centre since the early 2010s. This breeding programme now requires clear objectives that have consensus with the livestock keepers of Kenya.

Kenyan Boran cattle have undergone improvement through crossbreeding with Hereford *Bos taurus* and artificial selection by commercial farmers since 1920s (Maule, 1990; Boran Cattle Breeders Society of Kenya: www.borankenya.org). Since 2004, the embryos of improved Kenyan Boran have been exported into several countries aboard. However, lately some concerns have been expressed on breeding. Kenyan Boran nucleus breeding herds are in limited numbers of commercial farmers. They shared breeding stock over several decades. There is an indication that animals require higher maintenance and better environment (Mpofu, 2002; Haile *et al.*, 2011; Theunissen *et al.*, 2013). The Boran Group has unique genetic composition: European *Bos taurus* 25 per cent; African *Bos taurus* 12 per cent; *Bos indicus* 64 per cent (cited Haile *et al.*, 2011). This proportion may cause difficulty to make use of heterosis to improve production in the future. Continuous selective breeding for higher productivity in Kenyan Boran may have impaired adaptation of East African Zebu breed for the survival. There is need to understand and improve breeding systems of East Africa Zebu in order to improve and conserve small East African Zebu cattle genetics for next generations.

Adaptation: Physiological response for survival in hot and dry climates

Zebu cattle have acquired traits of adaptation to heat stress through: low metabolic rate; low maintenance; low production process; heat loss from body (Berman, 2011). Cattle usually respond to heat stress by reducing dry matter intake, lowering productivity, and decreasing reproductive performance (Kadzere *et al.*, 2002; Hansen, 2007).

Zebu cattle have larger sweat glands than European breeds (Nay and Hayman 1956; Dowling 1995). Hair coat of Zebu cattle enhances conductive and convective heat loss and reduce absorption of solar radiation (Jansen, 2004). At the cellular level during the early development of embryos, embryos from

Zebu are not sensitive less than from European breeds (Ealy *et al.*, 1993). In general, the higher cows produce milk, the lower their fertility become. Racangnolo and Misztal (2000) found a negative genetic correlation (r=-0.36) between the heritability for milk yield and heat tolerance. Zebu cattle were selected for diminishing heat stress by decreasing milk production (Bohmnova *et al.*, 2005). In India, Zebu crossed cows have longer calving intervals in contrast with pure Zebu cattle which expressed better reproductive performance (Mahadevan, 1958). Therefore, continued selection for milk may result in losing heat tolerant adaptability.

Several studies indicated that the metabolizable energy for maintenance for Zebu or Zebu crossbred was 10 - 25 per cent smaller than European beef breeds (Reid *et al.*, 1991; NRC, 2000; Chaokaur *et al.*, 2015; Kongphpitee *et al.*, 2018). Using cannula collection sac, Kennedy (1982) reported that in no heat stress environment, Zebu crossbred maintained greater weight than European breeds when given fixed amounts of roughage. He indicated that it might be caused by both more extensive ruminal digestion of organic matter and more efficient synthesis of body protein in crossbred than European breeds. Janet *et. al.* (2006) reported that Zebu cows react to food fluctuations mainly by mobilizing body fat reserves, whereas cows crossbred with European dairy breeds spend extra energy for milk production. However, much evidence is available that Zebu cattle, having low energy requirement, may mean slower growth rate and decrease response to improved nutrition or improved environment.

Thomas (1943) reported that Zebu cattle in Karamoja, Uganda are able to drink once every two days. Nicholson (1986) also found that Ethiopian Boran cattle are taken to the water at three-day interval. The calves were born 2-3 kg smaller and weaning weight was 10 per cent less at three-day watering but the compensatory growth within 2 years, provided that water was available daily in first two months of the dry season, at the period of high growth rates. Walking and night enclosing had less effect on productivity. Animals are selected for survival at poor quality pasture at dry season. This ability of Zebu cattle may be helpful to explore as it enabled livestock keepers to survive in dry land.

Adaptation: Physiological Response to resistance to disease

Much has been said on hardiness of Zebu cattle against disease; however, studies of disease tolerance traits of East African Zebu are inconclusive; as in general traits of *Bos taurus* appear to exhibit resistance to disease in Africa. Orma Boran in south west of Tana River, Kenya is reported to be Trypanosomiasis tolerance (Fivaz *et al.*, 1992, Terefe *et al.*, 2015). Zebu's response to ectoparasite may be exposure dependent. Landim Zebu cattle in Mozambique are reported to have resistance to foot and mouth disease (Felius, 1995). Gene may play an important role in selection for disease and parasite resistance or tolerance.

Methane Emission of East African Zebu cattle

Inter-government Panel on Climate Change (IPCC) reports methane cause 15-17 per cent of the global warming, and 15-18 per cent of the global greenhouse gas comes from livestock sector. Cattle contribute 61 per cent of methane emission (Steinfeld *et al.*, 2006; Gerber *et al.*, 2013; IPCC, 2018). Livestock sectors in developing countries are expected to reduce methane emissions. Although there is methodological challenges and complexity of ruminal microbes not fully understood, methane emission of cattle is studied extensively in European breeds. Cattle produce methane at 6-10 per cent of their energy intake (Blaxter and Clapperton, 1965; Johnson and Johnson, 1995; IPCC 2006; Knapp *et al.*, 2014). Methane loss increases with increase of dry matter intake. The methane loss per dry matter intake decrease beyond threshold of maintenance of animals as they are used for milk and meat production. However, at the higher dry matter intake, methane loss decreases as decreased dry matter digestibility and the associated increases in passage rate.

In general, as diet digestibility increase, variability in methane loss also increases. When digestible energy in relation to gross energy intake was low (Johnson and Jonson 1995, Figure 3), variation in methane loss was limited. However, this is done in very high-quality forage as the digestibility is more than 65 per cent. The natural forage in dry lands of Kenya would be only 30 - 50 per cent (Murray and Brown, 1993). There is need to investigate the methane emission by East African Zebu that are herded on natural forage of dry lands of Kenya.

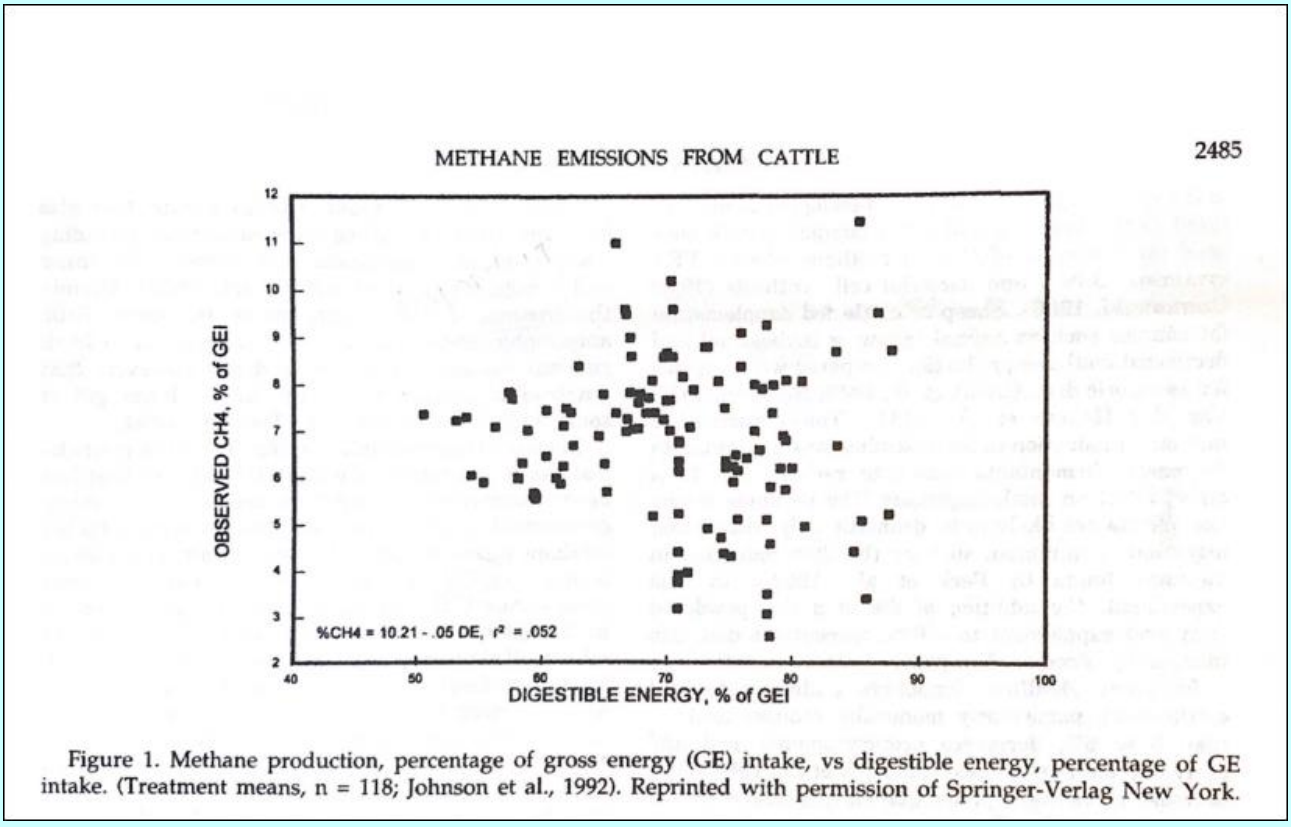

Figure 3. Methane production from Cattle (from Johnson and Johnson 1995)

In East Africa, Hungate *et al.*, (1960) at Muguga Veterinary Station studied rumen fermentation rates of Zebu on low quality roughage at crude protein 6 per cent: Zebu 182 (82-295) mu moles per gram per hour and crossbreds 169 (73-281). Crude protein in hay was about 6 per cent. They concluded fermentation rates differ time of feeding, to individual and to breeds. Hoppe *et al.*, (1977) compared rumen fermentation rate of wild herbivores and that of Maasai Zebu cattle: 210 (125-281) mu moles gas NTPD per gram of dry matter per hour for wildebeest, 261 (216-297) for coke's hartebeest, 272 (192-478) for topi, while Zebu 147 (97-172) mu moles gas NTPD per gram of dry matter per hour. Crude protein of ingesta in cattle was lowest 3.3 per cent; topi highest 6.2 per cent. No studies have been carried out on methane emission of East African Zebu. Elsewhere, using respirometric techniques Kurihara *et al.*, (1999) has measured that metabolizable energy intake for large zebu fed on tropical grass was lower, but methane emission was higher at 10.4 and 11.4 per cent than at 6.7 per cent for cattle fed on lucerne with high-grain diet. Using Tier 2 methodology of IPCC, du Toit *et al.*, (2013) in South Africa have estimated that enteric methane emission for a South African dairy cattle of 209.3 g per day fed on concentrate diet, 196.7 g per day fed on grass. Using Tier 2 methodology of IPCC, Kouazounde *et al.*, (2015) in Benin have estimated that enteric methane emission for three breeds of European cattle which are multiple purpose breeds fed on grass and crop residues, varied average 67.9 g (41.1 – 119.5) g, 80.8 g (46.3 – 126.8) and 110.1 g (67.7 – 177.8) per day. Dual-purpose animals produce a significantly less global greenhouse gas per meat than sole beef production. Using respirometric techniques, Lage *et al.*, (2017) in Brazil measured methane emission of large zebu cattle and crossbred with European breed fed on grass hay. They have indicated that body mass or size of animals is not the determining factors of food intake. Enteric methane emission was methane emission 104.1 g per day for crossbred heifers was higher than 82.1 g per day for large zebu heifers. They reported no difference in genetic groups and average are 15.8 g per kg dry matter intake, 25.9 g per kg digestible dry matter intake, 17.7 g per kg organic matter intake, 27.0 g per kg digestible organic matter intake. Patra (2017) has reported zebu cattle in India that average methane emission was 19.1 g per kg of dry matter intake, 35.8 g per kg of digestible dry matter intake, and 5.8 per cent of gross energy intake.

These inconclusive studies would open opportunity to investigate East African Zebu for its relationship with digestibility and the factors varying the methane emissions by animals free ranging on low quality pasture of dry land in Kenya. Moreover, most importantly there is need to address and measure effect of survival ability of small but hardy East African Zebu during the dry seasons in relation to crossbred animals in dry lands of Kenya.

Conclusion and Recommendations

To reduce global greenhouse gas and water use by livestock sectors, our focus needs to shift from productivity per animal to lifetime herd performance, and from productivity to sustainability meaning survival of the herds. Much opportunity exists to reduce global methane by promoting keeping of indigenous breeds of livestock and traditional extensive system in Kenya. As they are selected to survive at low quality feeds with small body at 250 kg. The methane emission may not differ greatly between species or breeds. The way to measure methane emission have to be developed for East African Zebu. This should incorporate the survival value of animals at critical time as well as their multiple-purpose benefiting the poor in dry land. Small East African Zebu cattle provide vital food and livelihood to the poor in dry land. They only consume livestock products modestly. According to United Nation, annual meat consumption of African Countries stays around 10 kg per person over the years, one tenth of developed countries (https://www.bbc.com/news/health-47057341).

Compared to other mitigating strategies for climate change, an adaptation of the East African Zebu cattle to restore resilience of the dry land ecosystem and poor cattle herders may easily be accepted. The voice of livestock keepers needed to be reflected in development of an appropriate genetic technology or selective breeding strategy. Community-based Zebu breeding approach may be an option; its breeding society could be formed. Concerted effort amongst researchers, livestock officers, and livestock keepers is urgently required for tackling climate change.

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Evaluation of Physicochemical Quality of Milk from Dairy Cows Supplemented with Liquid Brewer's Yeast in Smallholder Dairy Farms in Githunguri Sub-County, Kenya

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Abstract

A study was conducted to evaluate physicochemical quality of raw milk from dairy cows supplemented with liquid brewer's yeast (LBY) in smallholder dairy farms. The milk was delivered from different routes to Githunguri Dairy Farmers' Cooperative Society in Kiambu County, Githunguri Sub-County, Kenya. The main objective was to ascertain suitability for use of LBY as alternative feed source for dairy cows without compromising on milk quality. Thirty farms (sampling units) were randomly selected from three milk delivery routes (sampling frame). A longitudinal survey was conducted where farms were nested within routes and equal number of farms selected per route based on supplementation of lactating cows with either LBY or commercial dairy meal (CDM). A repeated measure analysis was performed using the Linear Mixed Models methodology by PROC MIXED of SAS for milk quality and questionnaire data was summarized using descriptive statistics. Milk samples were analysed for physicochemical parameters such as butter fat (BF), protein, lactose, total solids (TS), solid not fat (SNF), density, added water and milk freezing point (MFP). The results indicated significantly ($p<0.05$) higher milk protein levels and lower freezing point for milk from LBY supplemented cows (3.07±0.03% and -0.532 ±0.005°C) compared to those supplemented with CDM (2.99±0.02% and -0.516±0.005°C). This was an indication of positive effect of LBY supplementation on the two parameters. The other physicochemical parameters were not significantly affected ($p>0.05$) by the type of supplementation regime, although higher levels were observed on LBY supplemented diets than CDM diets. The study

indicates that LBY can be used as feed supplement for dairy cows without compromising on physicochemical quality of milk. In view of this, the research recommends use of LBY as a cost effective alternative protein source for dairy cows.

Keywords: Feed Supplement, Liquid brewer's yeast, Physicochemical Milk Quality, Smallholder Dairy Farms.

Introduction

Kenya has experienced spectacular growth in dairy sub-sector both in terms of the number of dairy cattle and milk production since its liberalization in 1992 (GoK, 2010). Dairy sub-sector accounts for about 4% of National Gross Domestic Product (GDP). In addition, it has a herd of over 3.5 million heads of pure bred dairy cattle and their crosses, 9.3 million indigenous cattle, 1 million camels and 13.9 dairy goats (Muia *et al.,* 2011; FAO, 2011) with annual production estimated at 5 billion litres of milk (Gichohi, 2014); making it the most developed in Sub-Saharan Africa. Milk production in Kenya is dominated by smallholder dairy farmers estimated at over 1.8 million and own 3.3 million cattle out of the national estimate of 3.5 improved dairy herd distributed all over the country. The smallholder dairy farmers contribute more than 80% of the total milk produced in the country (GoK, 2010). The sub-sector provides employment opportunities to more than 2 million people both in the formal and informal sectors, starting at the farm level to processing and marketing sectors, thereby contributing directly to poverty reduction and improved household income (Muriuki, 2011). The two main milk marketing channels in Kenya are the formal sector that comprise of government licensed cooperative societies and processors or informal (unlicensed) channels that sell directly to consumers, milk bars or traders (Omore *et al.,* 2004). Kenya is largely considered to be self-sufficient in milk and dairy products. It is the only country in Africa apart from South Africa, that is able to produce enough milk for domestic consumption and export save for occasional seasonal fluctuations during dry periods (Wambugu *et al.,* 2011). According to Ndungu *et al.,* (2016), increase in human population, urbanization, increased disposable income, greater diversity to meet nutritional needs and increased opportunities for domestic and external trade are expected to increase demand for milk and dairy products by 25% by the year 2025. This notwithstanding, food insecurity, low income and poverty are still major challenges among smallholder dairy farmers. This is generally due to inadequate and low quality feeds and high costs of inputs. The high cost of commercial dairy meal (CDM) has led to low levels of supplementation among most of smallholder dairy farmers, leading to low milk production.

In order to improve productivity in smallholder dairy farms, there is need to feed in-expensive and nutrient dense feeds to dairy cattle. However, supplementation with the available conventional protein sources such as cotton seed cake, soya bean meal, fish meal and sunflower seed cake is hampered by the high costs. Therefore, use of alternative high protein feed supplement such as liquid brewer's yeast (LBY) that is four times cheaper in Kenya than conventional protein sources is inevitable.

By-products from brewing process includes wet and dry brewer's grain, brewer's condensed soluble, liquid and dry brewer's yeast which pose serious disposal challenges to the industry (Kerby and Vriesekoop, 2017). The uses of sewer line and landfills as method of brewers' by-products waste disposal are expensive and unsustainable (Kerby and Vriesekoop, 2017). In order to reduce waste disposal costs, brewing industries sell these by-products as feedstuff for both ruminants and non-ruminant nutrition (Alaru *et al.,* 2018). Brewer's yeast is an excellent source of protein ranging from 35 to 65% (dry matter basis) of high biological value, greater quantity of amino acids such as lysine, leucine, isoleucine, valine, tryptophan, threonine and phenylalanine, with slight deficiency of sulfur amino acids (Mathias *et al.,* 2014). The by product has carbohydrates (35-45%), minerals (5-7.5%), lipids (4-6%), enzymes, RNA (Mathias *et al.,* 2014) and water soluble vitamins (Kerby and Vriesekoop, 2017).

Calves can be given up to 200 g of dried brewer's yeast per day (1.4 litres of LBY). Dairy cows may be fed 2.2 kg of dried brewer's yeast daily (15 litres of LBY), which will provide sufficient protein for 30 litres of milk but enough energy for only 10 litres of milk. Hence, LBY should be fed together with an energy-rich low protein feed. If the use of LBY is proven to be a viable option, then introduction of such

in-expensive protein source can play a significant role in enhancing dairy development in the country as it can be used by resource poor smallholder dairy farmers.

In order to remain relevant in the very competitive milk processing and marketing in Kenya, farmers must produce good quality raw milk. Quality of raw milk can be influenced by a number of factors such as chemical composition, physical properties, microbiological and cytological quality, sensory properties, technological suitability and nutritive value (Gargouri *et al.*, 2013). Achievability of quality raw milk with all the desirable physicochemical properties for processing is normally very challenging. This is due to factors such as genetic characteristics of the cow, feed composition and milk handling practices among other factors as has been demonstrated in studies by Kitchen (1981) and Mwangi *et al*., (2000). Nonetheless, nutrition plays a major role in milk production and its quality. This study was thus carried out to evaluate milk quality from cows supplemented using LBY.

Materials and Method

Study site

The study was conducted at purposively selected farms in Githunguri Sub-county within Kiambu County, Central Kenya. The area is located at about 1600 m above sea level and lies between latitude 1° 05´ and 1° 06´ South of the Equator and longitude 36° 53´ and 36° 55´. The soils are deep, well drained dark reddish to brown, friable clay, with a bimodal rainfall regime that starts in mid-March with a peak in April-May while the second rains begins in mid to end of October with annual average of about 1065 mm. The mean maximum monthly temperature in the region vary from 22.4°C to 27.6°C whereas the mean minimum temperature ranging from 11.3°C to 14.9°C.

Selection of farms

Farms were systematically selected based on availability of lactating Holstein Friesian dairy cows (the animals were multiparous), feeding regime, accessibility of the farms for ease of supervision of feeding trends and willingness of the farmers to participate. The feeding system practiced in the area was cut-and-carry stall feeding system where napier grass and crop residues are cut and fed to cows in stalls, commonly known as zero grazing. The animals were fed with napier grass and crop residues ad libitum to meet both maintenance and production requirements. Lactating cows were supplemented twice at the time of milking with either CDM (at the rate of 1 kg/3 L of milk production per milking) or LBY (at the rate of 2 L per milking). The cows were milked twice daily at 4:30 am and 2:30 pm during the experimental period.

Sample collection and preparation

Bulk milk samples were collected from the 30 farms weekly during morning milking for a period of 4 weeks. This gave rise to a total of 120 samples for analyses. Sample collection was conducted as per AOAC 925.20 procedures (AOAC, 1990). Samples were transported in ice cooled boxes for analyses at the Guildford Institute Laboratories of Egerton University.

Physicochemical analysis

The samples were prepared in accordance with the AOAC 925.21 procedures (AOAC, 1990). Thereafter, analysis for milk butter fat (BF), protein, lactose, total solids (TS), solid not fat (SNF), density, added water and freezing point (FP) was performed by mid-infrared spectroscopic method (AOAC, 1990) using milk analyzer Lactoscan® MCC30. Comparisons were performed by Garber method for milk BF%, Kjeldahl method for protein, the standard method for examination of dairy products was used to determine TS whereas lactose was estimated by getting the difference.

Experimental design

Milk produced from dairy farms was delivered to Githunguri dairy farmers' cooperative society through nine routes. Out of the nine routes, three were randomly selected for purpose of this study. Thirty farms (sampling units) were selected randomly from the milk delivery routes based on a list of farmers provided by the cooperative society (sampling frame). A longitudinal survey was conducted where farms were nested within routes. Equal farms were selected per route based on supplementation of lactating

cows with either LBY or CDM (LBY=15 farms; CDM=15 farms). Feeding and supplementation of the animals was conducted under supervision of the cooperative society extension staffs, agricultural extension officers and trial investigators. Baseline information was obtained during the first visit whereas milk samples were collected weekly from the farms during a 4-weeks period to assess effect of supplementation with or without LBY on physicochemical quality of milk.

Statistical analysis

Descriptive statistics was used to provide a summary on data obtained from the farmers who participated in the study. A repeated measure analysis was performed using the Linear Mixed Models methodology by PROC MIXED of SAS (2013). Treatment was fitted as fixed effect while route, farm and farm nested within route were treated as random effects. After testing several Covariance Structures in the model, Autoregressive (AR1) was selected based on lowest AIC, AICC, and BIC values (Littell *et al.*, 1998). Least square means of study variables were adjusted by Tukey method and declared different at 5% level of significance.

Results

Livestock management and feeding trend

About 37% of the farmers used feed troughs to estimate feeds offered to dairy cattle, 27% of them used gunny bags while 33% of the farmers did not estimated feeds at all. The findings indicated that most farmers (60%) supplement lactating cows at a uniform rate, 33% of them based level of supplementation on milk production but only 7% of the farmers supplemented cows using own assessment based on their levels of experience on dairy production. The amount of CDM fed to lactating dairy cows was estimated based on strategy of supplementation as indicated in table 1. However, LBY was supplemented by farmers at a uniform daily rate of 4 litres per cow per day (2 litres per milking).

Among the participating farmers, water used for domestic consumption and livestock was sourced based on priority from boreholes (70%), rivers (13%), rain water (10%) and dam (7%). Treated piped water was not mentioned by any farmer, an indication that water from the aforementioned sources was used in all farm operations.

Table 1. Livestock management and feeding trends

Parameters	Categories	n	Percent (%)
Feeding systems	Stall feeding	28	93.0
	Stall feeding and grazing	2	7.0
Forage conservation methods	Hay	4	13.0
	Silage	9	30.0
	Hay and silage	1	3.0
	Crop residue drying	9	30.0
	No conservation	7	23.0
Forage feed estimation	Do not estimate	10	33.0
	Gunny bags	8	27.0
	Feed troughs	11	37.0
	Others	1	3.0
Strategy of supplementation	Uniform rate	18	60.0
	Based on milk production	10	33.0
	Others	2	7.0
Sources of water	Borehole	21	70.0
	Dam	2	7.0
	Rain	3	10.0
	River	4	13.0

n = number of farms

Physicochemical criteria of milk

The determination of physicochemical components in foods and especially in dairy products is important for both regulatory and nutritional information purposes. Least square means for supplementation regime effect on the physicochemical composition of milk samples are presented in Table 2.

Dairy cows supplemented with LBY produced milk of superior protein quality (3.07±0.03) compared to (2.99±0.03) for CDM fed cows. Conversely LBY fed cows produced milk of lower freezing point (-0.532±0.005°C) than CDM supplemented (-0.516±0.005°C) dairy cows. The remaining parameters tested in milk were not significantly influenced by the feeding regimes, although higher levels were observed on LBY supplemented diets than CDM diets.

Table 2. Effect of liquid brewer's yeast on milk composition (Mean±SD)

Parameter	Supplementation		Overall			
	CDM	LBY	Mean	RMSE	Max	Min
BF (%)	3.69±0.07[a]	3.75±0.07[a]	3.72	0.5	5.44	3.05
Protein (%)	2.99±0.03[a]	3.07±0.03[b]	3.03	0.19	3.74	2.01
Solid not fat (%)	8.25±0.06[a]	8.38±0.06[a]	8.32	0.46	10.25	7.1
Total solids (%)	0.67±0.00[a]	0.68±0.00[a]	0.67	0.04	0.83	0.61
Lactose (%)	4.5±0.03[a]	4.58±0.03[a]	4.54	0.24	5.6	4.01
Freezing Point (^{0}C)	-0.516±0.005[a]	-0.532±0.005[b]	-0.524	-0.041	-0.315	-0.672
Density (g/ml)/ml	1.029±0.0002[a]	1.029±0.0002[a]	1.029	0.001	1.036	1.026
Added water	0.82±0.13[a]	0.87±0.13[a]	0.99	0.84	2.96	0

Different subscripts in the same row indicate statistically significant differences ($p<0.05$)

Kenya Bureau of Standards (KeBS) recommended raw milk components. Added water: o%; Fat content not less than 3.25%; Protein content: not less than 3.5%; Solids not fat; not less than 8.5%; Density should be between 1.028g/ml to1.036g/ml; Freezing point: Between -0.525°C to -0.550°C (Kabui *et al.*, 2015).

In the study, supplementation regimes had effect on parameters tested on route 1 but did not affect milk quality parameters tested in route 2 and 3. However, notable interaction between routes and supplementation trends was recorded in milk fat, protein, lactose and freezing point (Table 3).

Table 3. *Effect of LBY supplementation on milk quality from different delivery routes (Mean±SD)*

Parameters (%)	Supplementation					
	Route 1		Route2		Route 3	
	CDM	LBY	CDM	LBY	CDM	LBY
Butter fat (%)	3.46±0.34[a]	3.92±0.61[d]	3.85±0.50[bd]	3.58±0.30[abce]	3.77±0.50[c]	3.76±0.55[a-e]
Protein (%)	2.95±0.25[a]	3.17±0.28[b]	3.03±0.13[ac]	2.97±0.07[acde]	2.99±0.13[acd]	3.06±0.19[a-e]
Solid not fat (%)	8.24±0.32[a]	8.61±0.75[b]	8.30±0.35[ac]	8.15±0.18[ac]	8.20±0.34[ac]	8.39±0.52[abc]
Total solids	0.66±0.03[a]	0.70±0.06[b]	0.67±0.03[ac]	0.66±0.01[acd]	0.67±0.02[a-d]	0.68±0.04[acd]
Lactose (%)	4.46±0.21[a]	4.71±0.41[b]	4.54±0.19[ac]	4.46±0.10[acd]	4.50±0.14[acd]	4.59±0.28[a-d]
Freezing point (°C)	0.50±0.064[a]	0.549±0.056[c]	0.526±0.025[bc]	0.515±0.013[abde]	0.520±0.020[abde]	0.532±0.038[b-e]
Density (g/ml)/ml	1.029±0.001[a]	1.030±0.003[b]	1.029±0.001[a]	1.029±0.001[a]	1.029±0.001[a]	1.029±0.001[a]
Added water (%)	0.93±1.02[a]	0.54±0.81[a]	0.67±0.96[a]	1.24±0.97[a]	0.84±1.05[a]	0.84±1.1[a]

Different subscripts in the same row indicate statistically significant differences ($p<0.05$)

Discussion

Milk protein percentage of Holstein Friesian cows fed LBY based diet was significantly ($P<0.05$) higher than cows supplemented with CDM. This is in concurrence with studies by Poppy *et al*., (2012) and Shreedhar *et al*., (2016), which indicated higher protein levels in milk from cows supplemented with yeast culture. The trial was conducted at a time when farmers in the study area relied mainly on purchased animal feeds or conserved feedstuff, mostly dried crop residues and hay as presented in table 1. The high protein levels in milk from LBY supplemented cows in this study could be associated with improved nutritional value of poor quality forages, increase in number of rumen lactate-consuming bacteria and prevention of lactate accumulation (Beauchemin *et al.*, 2003). The high protein levels reported in this work similarly agrees with the findings of Kalmus *et al*., (2003). Protein levels within the 3 milk delivery routes were similar; which could be an indication of nearly the same management practices. Major variations were recorded in the interaction between delivery routes and supplementation regimes, which may suggested that any significant changes observed in milk protein level were nutritionally dependent.

Milk freezing point (MFP) was statistically significant ($p<0.05$) among supplementation regimes and their interaction with milk delivery routes. The decrease in MFP points to an increase in milk TS (Shreedhar *et al.*, 2016). This positively translate to higher yield of dairy products such as cheese; leading to increase in profit margin by the dairy cooperative society, thereby increasing income of members at the end of financial year. The findings of this study are in agreement with Shreedhar *et al*., (2016). Positive effect of yeast trial diet on milk components was equally recorded by Ayad *et al*., (2013). Adulteration of milk with water is one of the most likely factors that can affect MFP as it influences the concentration of water soluble components in milk. Earlier studies by Harding (1999), indicated that adulterated milk will have a higher MFP closer to zero degrees centigrade. In case no addition of water is detected, then the difference in MFP could be due to different levels of concentration of milk components in the aqueous phase (Bjerg and Rasmussen, 2005). Concentration of milk components can be influenced by other factors such as nutrition, water intake and stage of lactation or subclinical mastitis (Bjerg and Rasmussen, 2005). Lactose concentration and pH of milk have also been reported to have a significant effect in FP of milk (Hanus *et al.*, 2010). A study by Ayad *et al*., (2013) reported stability in blood glucose level in normal range on cows supplemented with yeast based diets but not in the control group. Steady supply of glucose is essential for production of lactose which is responsible for 53.8% of MFP (Hanus *et al.*, 2010; Otwinowska-Mindur and Ptak, 2018). Nutritionally related MFP problem may only be possible in a situation where the cow is either starved or fed on poor quality diets with little or no grains (Bowman, 2005). Farmers in the study area practiced stall feeding with proper guidelines on balanced nutrition under constant supervision by field agricultural extension staff and the Cooperative society technical staff. The significant differences in MFP revealed in the interaction between supplementation regimes and milk delivery routes could be due to slight climatic variations in different delivery routes that may not necessarily be associated with supplementation regimes.

The levels of BF, SNF, TS, lactose and density were not significantly affected ($p>0.05$) by the type of supplementation regime as presented in Table 2, although superior milk components were reported on LBY supplemented cows. The positive effects of LBY diet on milk BF content concurs with the findings of Harris and Webb (1990) and Putnam *et al*., (1997) that reported higher milk BF% on lactating dairy cows fed LBY based diet. Martin and Nisbet (1990), associated the positive effect on milk BF% with increase in number of cellulolytic bacteria which enhances fiber degradation, thereby improving the digestibility of the diet and increase in proportion of acetic acids among the fermented Volatile fatty acids in the rumen. The level of SNF and TS were statistically similar between milk delivery routes. This can be attributed to the fact that milk tested in the study was from cows of the same breed, implying that they would be uniform in genetic composition. A relatively uniform level of SNF can be achieved as long as diets are balanced in nutrients with adequate roughages. However, feeding of high fiber and low energy rations can depress SNF content (Harris and Bachman, 2003). Majority (93%) of the participating farmers practiced stall feeding as shown in Table 1. Under the feeding system, all cows were fed as a single group and bulk milk samples tested. Nonetheless, a significant difference in the interaction between LBY supplementation regime and milk delivery routes was recorded. This could be an indication of differences in LBY sources between the milk delivery routes. The insignificant increase in lactose level for cows on LBY diet compared to CDM diet can be attributed to the fact that the study was conducted at a time of limited forage in the area and farmers had to purchase varied hay types from different sources with diverse quality to feed cows. The LBY supplementation could have contributed to stimulation of cellulolytic bacteria in the rumen, increase in fiber digestion and flow of microbial protein from the rumen (Jouany and Morgavi, 2007). This further confirms the suggestion by Bruno *et al*., (2009) that feeding of yeast based diets improved milk lactose as compared to cows on control diets. In this study, the same levels of lactose percentage were recorded along the three different milk delivery routes. The results may suggest that apart from the difference in the supplementation regimes, forage quality and quantity fed within the sample routes were similar and could not affect lactose percentage. Milk density was similar among supplementation regimes, milk delivery routes and their interactions. The research outcome established that adulteration of milk was not commonly practiced by farmers in the study area.

Conclusions

The two supplementation regimes CDM and LBY affected physicochemical quality of milk in the study area. Higher Protein content and low freezing point was recorded in milk for cows supplemented with LBY compared to cows on CDM based supplement. The study indicated that LBY can be used successfully as a protein feed supplement in the dairy industry. Moreover, the hypothesized theory that use of LBY would lead to production of milk with inferior quality for process ability into different dairy products was nullified by the study results. Generally, physicochemical quality of milk delivered to Githunguri Dairy Farmers' Cooperative Society was good.

Recommendations

In view of the findings of this study, use of LBY as a cost effective alternative protein source for dairy cows is recommended. Additionally, there is need for capacity building to enable stakeholders in the dairy industry appreciate the importance of utilization of LBY as a cheaper protein source for dairy cows.

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Effects of technology adoption on dairy productivity inSmallholder households in Nandi County, Kenya

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Abstract

There is limited information on effects of technology adoption on dairy productivity in smallholder households in Nandi County. This study set out to investigate the effects of technology adoption on dairy productivity among smallholder farming households in Nandi County. Secondary data from the Department of Livestock Production office, Nandi County, and primary data collected using a structured questionnaire from 138 smallholder households was collated and analysed. Results showed that dairy cattle breeds and feed supplement technologies were highly significant and positively correlated to dairy productivity. The study concluded that, feed and mineral supplementation and improved breeds contributed to milk production. Extension channels like field days, radio and demonstrations that were most preferred by smallholder households are vehicles of information and technology dissemination. The study recommends that, the programme needs to concentrate its efforts on promoting these technologies in order to achieve quick gains in dairy productivity in smallholder households. The government should consider apportioning funds into activities that promote these technologies to leverage on the fast adoption as explained by diffusion adoption theory. The economic implication of technology adoption needs to be explored further to understand what increases adoption of technologies.

Introduction

The dairy sub-sector is the fastest growing food productive sector both in volumes and sales outputs worldwide (Lokuruka, 2016). In Kenya, dairying is a dynamic business, which plays important economic and nutrition functions in the economy. It is the largest agricultural sub-sector, touted to be larger than tea (Muriuki *et al*., 2004). The Kenyan government is concerned with the strategies that address productivity, food security, income and equity in smallholder households (Alila and Atieno, 2006). It is widely believed that fast economic development is achievable through technology adoption. In many parts of Kenya, policy and markets compel smallholder dairy farmers to change farming tactics by adopting new technologies whose potential for growth remains uncertain and risky. The smallholder farmers, who dominate production, expect future growth and suitable technologies for adoption. Market-oriented dairy production may fill this need for some smallholder producers. Technology transfer therefore becomes an immediate remedy, because technology is about efficient production, high yield interventions and less land utilization.

Lack of information on adoption of dairy technologies and market opportunities often discourages smallholder households and development agencies from undertaking and supporting meaningful dairy

production leading to continued reliance on subsistence farming. This leads to low productivity in smallholder dairy production resulting in low incomes and therefore exacerbating poverty. Despite promotion of numerous dairy technologies in Nandi County, there is lack of empirical data in Nandi County on the effects of technology adoption on the livelihoods of smallholder dairy keeping households. The overall objective of this study was to evaluate the effects of dairy technology adoption on dairy productivity in smallholder dairy keeping households in Nandi County. Specifically, this study sought to analyze the effects of dairy farm factors on dairy productivity in smallholder households in Nandi County, evaluate preferred extension methods by smallholder households participating in Extension Programme activities in Nandi County and determine dairy technologies that had an effect on dairy productivity in smallholder households in Nandi County.

Methodology

The Study Area

Nandi County is in the Northern part of Kenya, North Rift Region in the former Rift Valley Province. It straddles along the Equator at the Southern end. The Northern part reaches Latitude 00 34' N while the Western part reaches Longitude 34045'E and the Eastern part reaches Longitude 35025'E (Ngeno & Bebe, 2013). It covers an area of 2,884.4 km^2 with arable area of 2,340 km^2. It has six administrative sub-counties of Mosop, Chesumei, Emgwen, Nandi Hills, Aldai, and Tinderet. It borders Uasin Gishu County to the North and East, Kakamega County to the West, Kisumu County to the South West and Kericho County to the South. It has six AEZ, namely; UH1, LH1 (Tea/Dairy zone), LH-2 (Maize/ Wheat/ pyrethrum zone), LH3 (Wheat/ Maize/ Barley zone), UM1 (Coffee zone), and UM4. The annual minimum temperature is 16.5 ^{0}C, and the highest maximum temperature is 23.2 ^{0}C. The County receives an average annual rainfall ranging between 1200 mm to 2,000 mm. The Northern parts of the County (where we had two study sites, Kabisaga and Lolkeringet) receives rainfall ranging from 1,300mm to 1,600mm per annum; while the Southern half (where we had one study site, Kapsabet) is influenced by the Lake Basin atmospheric conditions receiving rainfall as high as 2,000mm per annum.

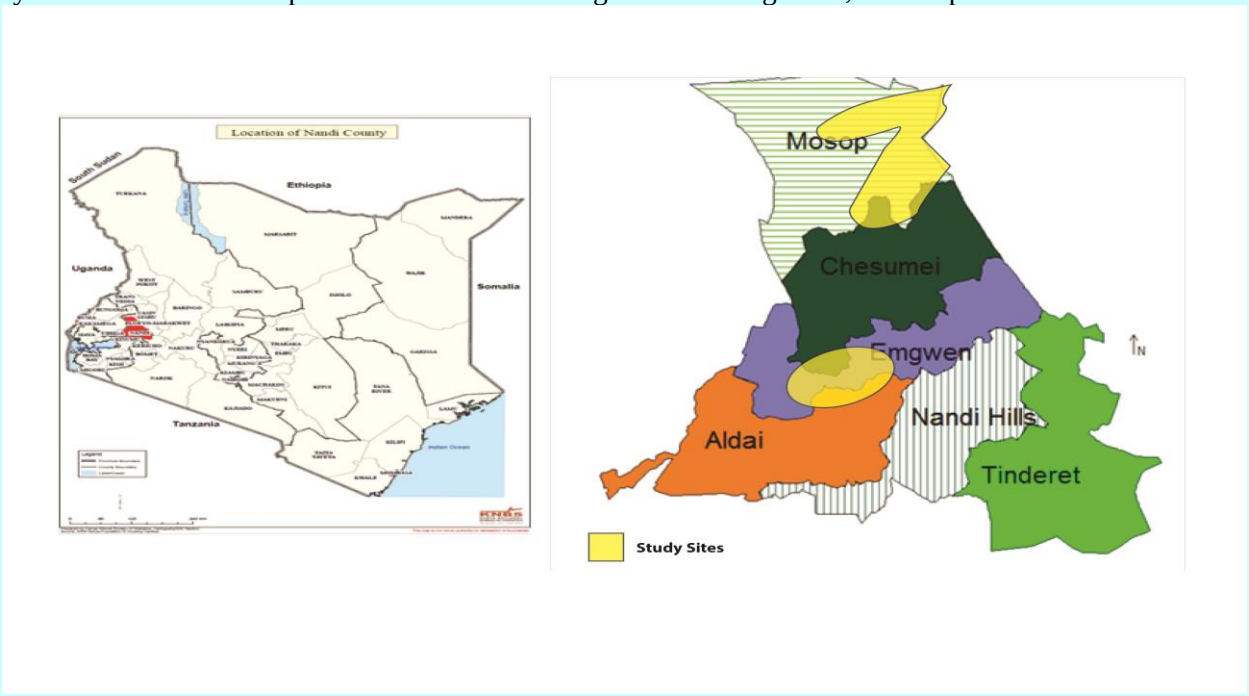

Figure 1. Map of Nandi County
Courtesy of the County Government of Nandi (2013)

Sample Determination

The sample was determined using the formula by (Athuarie *et al.*, .,, 2014, Sekaran, 2003)

$$n = \frac{Z\alpha^2 / 2 \quad p\,(1-p)}{e^2}$$

Where:
n = the desired sample size
$Z\alpha^2$ = the degree of confidence chosen (95% confidence level, the standard value being 1.96) (Sekaran, 2003).
p = the proportion of households in the target population, estimated to have no characteristics being measured, set at 10% (in this case purely crop farmers).
e = the permitted level of sampling error in a study, usually placed at 5%.

Target Population for the Study
Table 1 shows the target population and the sample size for the study

Table 1. Distribution of the Sample Size by Study Areas

DCA	Division	Locations covered	Size Km^2	No. of farming Households	Sample Distribution
DCA 1	Kapsabet & Kilibwoni	Kapsabet & Kipture	88	3,835	66
DCA 2	Kabiyet & Kosirai	Kabisaga & Sigot	79	2,667	45
DCA 3	Kipkaren & Kabiyet	Kabiemit & Lolkeringet	70	1,598	27
		Total	237	8,100	138

Source: Courtesy of Nandi County SDCP Office and Kenya National Bureau of Statistics

Data Collection and Analysis
A questionnaire was designed that incorporated closed ended questions on intrinsic and extrinsic factors to be measured for the independent variables and dependent variables. Descriptive statistics were used in analyzing the data. Summary statistics like frequencies, percentages, means, variance and standard deviations of variables were computed using SPSS version 20 and presented in tables. Inferential statistics established the relationships and direction between the variables. Such tools as correlations (Pearson Correlation Matrix and Spearman's rank correlation**)** and regression analysis were used to analyze quantitative data analysis (t-test, correlation, Chi-square, ANOVA and regression) (Saleem, 2012).

Results and Discussions

Characteristics of sampled households
The study revealed that 97.1% of households kept dairy cattle while 2.9% did not. Majority (92%) of the sampled households owned land while 8% were landless. The mean number of cattle owned per household was five. Sampled households practiced dairy farming under different production systems as show in Figure 2.

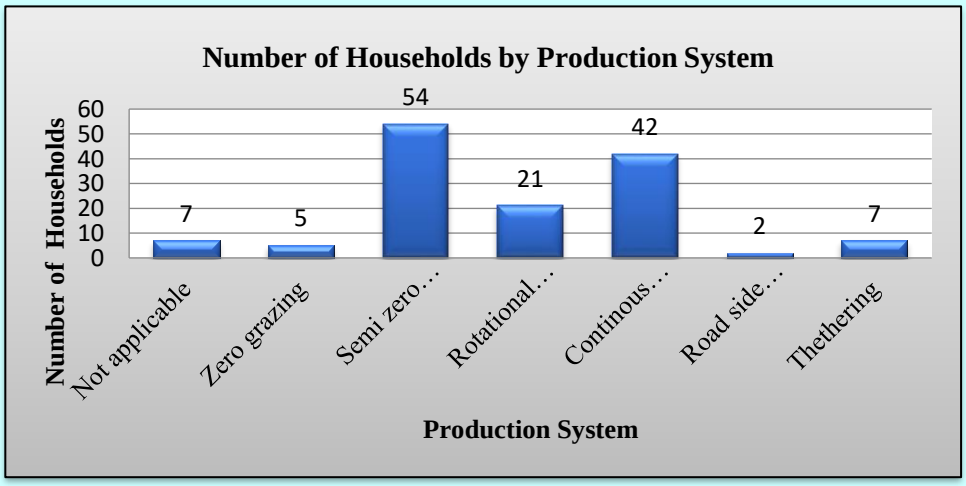

Figure 2. Dairy production systems

Milk production

The volume of milk produced by sampled households ranged from 1 to 24 litres as shown in Figure 3.

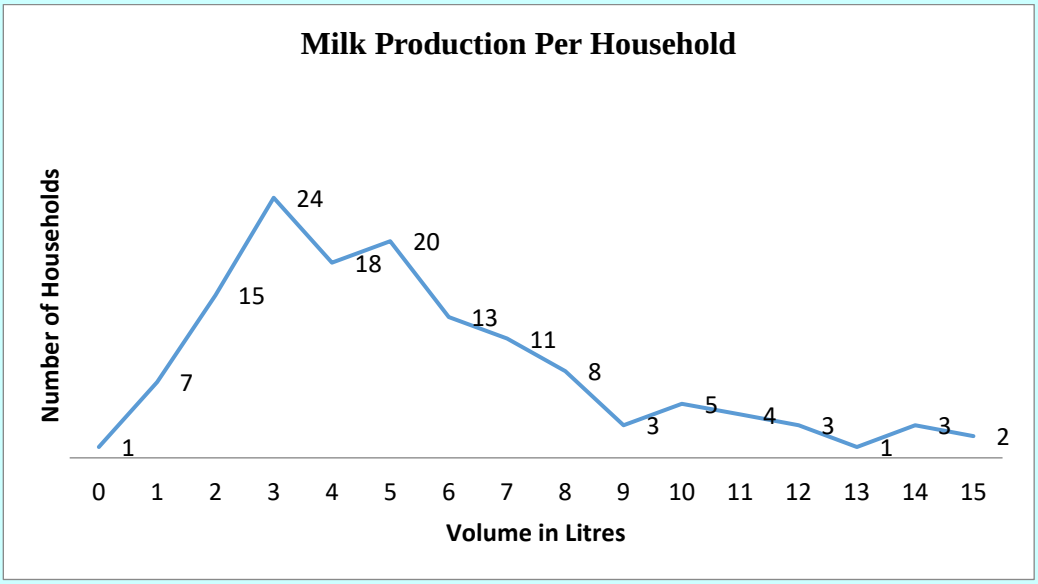

Figure 3. Volume of milk produced

Farmers' information sources

Farmers obtained information on dairy production from different sources as shown in Table 2.

Table 2. Farmers' information sources

Information sources	Proportion (%) of farmers
Field Days	83.30%
Radio	60.10%
Demonstrations	52.20%
Farmer Exchange Tours	43.50%
Farmers	42.80%
Non-Residential Trainings	35.50%
Residential Trainings	23.90%
Television	23.20%
White settlers	3.60%

Source: Field survey, 2018

The most common sources of information were field days (83.3% of the sampled households obtained information from field days) with radio and demonstrations cited as sources of information by more than half of the study sample.

Respondents Training Frequency by Study Site

The study set to find out how frequently the sampled households participated in training events on dairy aspects as shown in Table 3.

Table 3. Respondents Percentage Attendance in Trainings by Study Site

		DCA of Respondent			
Variable	Parameter	Kapsabet/ Kipture	Kabisaga/ Sigot	Lolkeringet/ Kabiemit	Total
Frequency of Attending Trainings	Not Applicable	14.5	10.1	18.8	43.5
	Once a month	31.9	18.1	5.1	55.1
	Twice a month	1.4	0	0	1.4
	Thrice a month	0	0	0	0
	Four times a month	0	0	0	0

Source: Field survey, 2018

A once a month attendance was reported by 55% of the respondents followed by 43.5% as those that the training did not apply to them, while a paltry 1.4 % were receiving the trainings twice a month.

Effect of dairy technology adoption on dairy productivity

The effect of adoption of various dairy technologies on milk production was as shown in Table 4.

Table 4. Correlation coefficients of dairy technology and milk production

Variable	PCC	p-value	Sign
Upgraded cows	.478**	p<.01	+
Upgraded heifers	.436**	p<.01	+
Upgraded calves	.179*	p<.05	+
Improved Pasture	.040		+
Improved Fodder	.081		+
Improved Legumes	-.065		-
Feed concentrate	.740**	p<.01	+
Upgraded Lactating Cows	.150		+
Minerals Supplementation	.677**	p<.01	+
Milk Produced Morning	.211*	p<.05	+
Milk Produced Afternoon	.238**	p<.01	+
Use of A.I. Service	.150		+
Bull Service use	.513**	p<.01	+
Upgraded In-Calf Cows	.147		+
Volume Milk Sales	1		

R Squared	0.774
Adjusted R Squared	0.738
Std. Error of the Estimate	1.676
R Square Change	0.774
F Change	21.280
df1	19
df2	118
Sig. F Change	0.000

*. Correlation is significant at the 0.05 level.
**. Correlation is significant at the 0.01 level.
Dependent Variable: Milk Produced
Source: Field survey, 2017

Results showed that there was a positive correlation between improved cattle breeds, use of feed supplements and milk production. The R^2 value in the model has a value of 0.774, an indication that the model was able to explain or account for 77.4% of variation on the dependent variable. Adjusted R square is considered a more accurate goodness-of-fit measure than R square, meaning the 73.8%. The F value of 21.28 is highly significant. The independent variables in the study were able to account for the variation in the dependent variable, milk production. The 22.6% that were not accounted for, were due to factors outside this study.

Conclusions and recommendations

The study established that majority of households keep dairy cattle and only 2.9% did not. The mean number of cattle owned per household was five. Factors that were positively correlated with milk production were improved breeds and use of supplements. It therefore implied that dairy productivity lies in improvement of the breed of cattle and supplemental feeding.

The study recommends that, the future programmes focus on promoting technologies using extension channels such as field days, radio and demonstrations that were most preferred by smallholder households. The economic implication of technology adoption needs to be explored further to understand what increases adoption of technologies.

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Effect of time of castration on finished sheep for market: the case of agro-pastoral communities in the ASALs of Narok, Kenya

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Abstract

A study was conducted to determine the effect of time of castration on finished sheep for market using a flock of 132 male weaner lambs, aged approximately 4 months. The lambs were reared and finished in on-farm feedlot system for a period of 99 days and marketed on-site in public auction was evaluated. The flock composed of weaner lambs, 80 pre-castrated and 52 late castrated on approximately 30 days before and day zero of the start of fattening period respectively. The castrate lambs were finished on a ration that consisted of a basal diet of communal grazing on standing green grass sward composed of mainly Rhodes grass, mixture of natural pasture grasses and wheat stubbles and ad libitum supplements of wheat straw, Lucerne hay and commercial mineral salts. All the lambs were watered daily from a rain-fed water pond. The lambs were allowed 8 hours of uninterrupted grazing and thereafter allowed to consume the supplements from feeding troughs strategically placed in the resting area of the feedlot. The lambs were penned at night in an open enclosed night kraal. The lambs, mainly of Dorper and crossbreds of Dorper and Red Maasai breeds were contributed by members of a local community based organization (CBO). Data collected included; plant species diversity, biomass yield, fortnight weight gain, survival rate, body score, morbidity and mortality. The lambs attained an overall average market weight of 30 kilograms. On average, the flock of prior castrated lambs attained mean live weight of 30.76 kg as opposed to 29.03 kg of lambs castrated on day zero. However, there was no significance difference ($p>0.05$) even though prior castrated lambs performed slightly better than the lambs castrated on day of entry into the feedlot. In a scenario where 2 batches are finished per year, the cost benefit analysis showed a BCR ratio of 1.3 and 2.6 for batches 1 and 2 respectively and hence a profitable venture. The current study demonstrated to CBO members that sheep lambs destined for fattening ought to undergo closed burdizzo castration at least a month before the start of the fattening phase. The fattening experiment observed that it was possible and profitable to finish and market both prior and day

zero castrated sheep weaner lambs for a period of 3 months and thus reducing the market age from the normal communal practice of 2-3 years to about 9 months.

Key words: Castration Sheep, Finishing, Markets, Narok Kenya.

Introduction

Low productivity, partly because of the relatively low degree of commercialization and the related limited adoption of modern technology in Kenya, is extensively reported albeit the wide and extensive body of knowledge and technology available in research domains in the country (Hansen *et al.*, 1986; Thompson, 1995). Quite often, the producers are reported to have limited exposure to knowledge on existing improved technologies to address: the feed challenge (LAPSSET, 2012; Manyeki, *et al.*, 2013); poor breeding practices (Koskey, 2004); inappropriate routine husbandry practices (Koskey 2004); inappropriate helminth control practices (Gatongi *et al.*, 1998; Nganga *et al.*, 2006) and poor markets and marketing strategies (Juma *et al.*, 2010). The situation is worse among the pastoralists (Ndathi *et al.*, 2012). Therefore, there is urgent need to reverse this trend by availing current best bet technologies and strategies to the mutton chain players at production level. A baseline survey conducted in Narok County (Katiku *et al.*, 2016; Maina, 2013) revealed challenges requiring intervention in sheep production to include: limited knowledge on general sheep husbandry; poor genetics (breeds and breeding); length of time to finishing of sheep for market too long ; lack of sheep management calendar; poor housing structures for sheep; poor nutrition of sheep (feeds and feeding), lack of record keeping; sheep diseases; and lack of prudent sheep helminth control practices.The KALRO with the support of the International Centre for Agricultural Research in Dry Areas (ICARDA) implemented a project "Improving Integrated Agricultural Production Systems for the Poor and Vulnerable in Dry Areas " with the objective of upscaling of tested, economically feasible, gender sensitive and climate smart technologies within a research to business (R2B) model. The study builds on previous attempts to identify the problems affecting the integrated sheep and wheat sub-sector and their implications for research and policy in Narok County (Hassan *et al.*, 1993, Nyagito *et al.*, 2002). It addressed the salient issues in the upgrading of the sheep value chain in Narok County and perhaps change it from the current subsistent status to a more commercial oriented enterprise**.**

Materials and method

Study area

The rainfed wheat- small ruminant production system in lower Narok was the designated county site. One cluster site Nturumenti in Narok East/North was the implementation site (Figure 1).

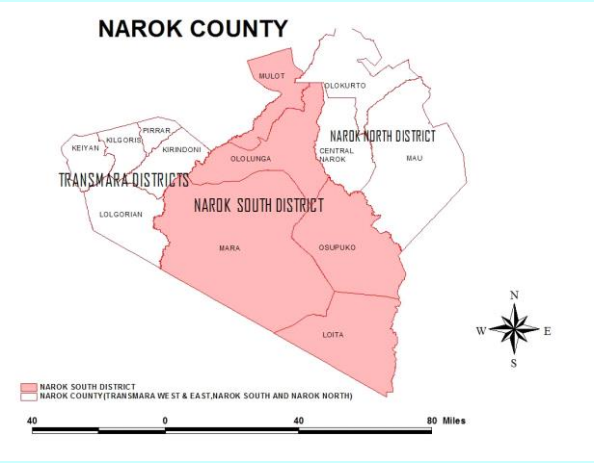

Figure 7. Map of Narok County

Pasture establishment

Rhode grass, variety Boma was establishment on 0.75 ha in April 2015 on land donated by the community. The plot served as seed bulking plot for harvesting seeds for expansion of the current study and for distribution to farmers. An additional 4 ha pilot plot was planted with forage for the feedlot

(mixture of Rhodes grass-Boma Rhodes sown with wheat variety Njoro II BW) in Osinon village, Nturumenti Sub-location, Ongata-Nadoo location to validate the model. The site is about 2 km from Nturumenti centre and 1.5 km off on the right of Ntulele - Mosiro road. The feedlot plot was subdivided into paddocks, feeding and watering troughs, hay barn and sheep pen constructed with the inputs donated by the project.

Feeding Trial

A pilot flock of 132 lambs aged 4 months were chosen for finishing. The flock composed of weaner lambs, 80 pre-castrated and 52 late castrated on approximately 30 days before and day zero of the start of fattening period respectively. The lambs were allowed to graze freely on the herbage planted around the feedlot facility for 8 hours per day. Later, they were fed on a supplement mixture consisting of wheat straw, Lucerne hay and molasses and allowed to lick on balanced mineral (vital kondooR) salt adlibitum. The feed ration for the lambs was determined based on nutrient requirement and consisted of the following; Boma Rhodes+lucerne hay+ wheat straw + molases + mineral + water. The supplement consisted of wheat straw and lucerne hay mixed with molasses and was fed communally based on requirement for fattening sheep. The wheat straw and lucerne hay were processed prior to mixing and feeding by chopping with a manual chaff cutter and fed in half split plastic drum feeding troughs. Each lamb was allowed to consume 0.75 kg of forage, 0.75 kg wheat straw, 0.5 kg lucerne hay, 0.209 kg molasses and 0.03 kg of mineral per day. A commercial mineral supplement for sheep, Vital Kondoo^{R} was fed ad libitum. The lambs were watered every other day in a rain filled water pan and penned at night in an open enclosure.

Control of helminth infestations in the feedlot sheep

At day zero, the sheep lambs were treated with a broad-spectrum anthelmintic (Valbazen^{R} 10%) and a pour-on acaricide (Spoton^{R}) applied for the control of ectoparasites. The sheep were faecal sampled at the day of introduction to the feedlot (Day 0), once in the middle of the fattening (Day 84) and at the end of the trial (Day 99).

Sheep monitoring during fattening

The lambs were castrated and introduced to the feedlot in December 2015. Their health was monitored and similarly to other production parameters. Among the health parameters recorded during this period were worm egg counts, body condition scores and live weights. An initial evaluation of the packed cell volumes was done to ascertain the possible level of anaemia, possibly associated with haemonchosis.

Management and analysis

Data records generated included, live weight changes, amounts of feed offered, diseases and treatment administered, amount of dewormer and date given, packed cell volumes, body scores, faecal egg counts, market value of lambs at time of entering the feedlot and at time of auction.

Statistical analysis

The data were entered in the computer using Microsoft Excel Version 8 for storage and further synthesis. The response variables were analysed for means, standard error of mean, standard deviation and variance using General statistics (Gen Stat 15th edition) program. Significance was tested at 0.05. Regression analysis was conducted for correlated attributes.

Results and discussion

Weight gain during period of fattening

The lambs entered the feedlot at a mean weight of 24.8 (s.e 0.52) kilograms (kg) and progressively gained weight rapidly up to day 42, stagnated then picked on 99 day (Figure 2).

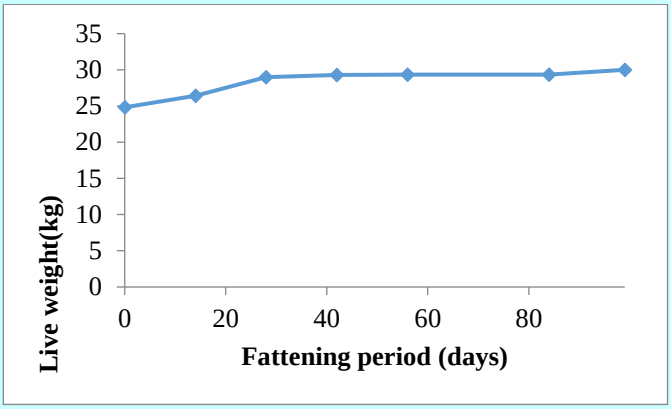

Figure 2. Growth curve of feedlot sheep at Nturumenti

Lambs castrated prior to entering the feedlot performed better but not significantly different (P>0.05) than the lambs castrated on the day of entering the feedlot (Figure 3) perhaps because of the stressed induced by the closed burdizzo castration and hence prior castration is better. The findings in the current study are consistent with those reported elsewhere. Baredo *et al.*, (2013) working with a pastoral community in Ethiopia, reported that farmers shortened the fattening period by 50%, from six months to three months. The finished sheep fetched better prices than their contemporaries. These authors associated the fast weight gain to better feeding of the sheep. However, such studies are rare in Kenya. Weight gain is associated with breed type, feeding and health among other factors. In the economies where sheep finishing is advanced, the exotic breed of sheep lambs must gain at least 300gm/day to be profitable. In the current study, sheep lambs, mainly crosses of the local RM breed (Katiku *et al.*, 2013, Maina 2013) gained at least 47.68 gm/day. This average daily gain was lower than that reported elsewhere (Khan *et al.*, 2014). Khan *et al.*, (2014) studied a local breed of Thali sheep lambs that recorded weight gain of 104 gm/day.

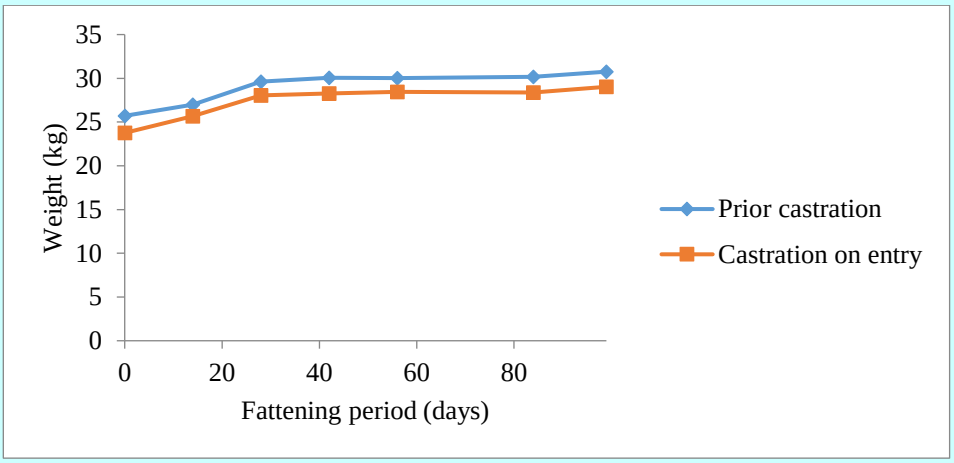

Figure 3. Effect of time of castration

Strategic deworming and Helminths control

In the feedlot sheep, results showed that Haemonchus was the most predominant nematode genera (64%) followed by Trichostrongylus (24%), Strongyloides (8%) and Oesophagostomum (4%). The PCV were within the normal range (14% to 45%). These genera, especially Haemonchus or stomach worm which is blood sucker, are among the common and most pathogenic nematodes in grazing ruminants. The results of the faecal egg counts over the three sampling periods are summarized on Table 1. The level of infection with gastrointestinal nematodes remained fairly constant throughout the fattening period based on the faecal egg counts. This was in spite of the anthelmintic treatments on Day 0 and Day 84. Upon comparisons of the three breeds in the flock, the Red Maasai had a higher mean worm egg counts followed by the Red Maasai x Merino crosses and Red Maasai respectively. This was consistent with known breed susceptibilities to gastrointestinal nematodes (Mugambi, *et al.*, 1997). The possible

explanation for the observed moderate infections even after interventions could be the confined grazing which could have predisposed the lambs to high larval challenge. This confinement is not common in the traditional grazing system in the trial area where animals are allowed to graze in a wide and dispersed area, thereby exposing them to low helminth challenge.

Pooled faecal samples were cultured and a differential larval (L3) counts carried out on Day 0 samples. This was to determine the common nematode genera in grazing sheep in the trial area.

Gastrointestinal parasitism in sheep adversely affects their productivity through reduced breeding efficiency, lowered milk production, reduced weight gains, decreased hair quality, reduced feed efficiency and negatively affect the immune system by decreasing the animal's ability to fight off other health problems.

Table 1. Comparison of helminth infection amongst the sheep at the day of introduction to the feedlot and at the day of auction

Day of sampling	Number sampled	Mean worm egg counts (epg)
0	91	1140
84	65	800
99	95	1024

Other diseases encountered

During the fattening scheme, two disease outbreaks were observed in the flock. These were sheep pox and blue tongue. The outbreaks were associated with the introduction of sheep from different farms, some of which could have been incubating the diseases. The two diseases were later contained through vaccination, sheep pox by the project team while blue tongue vaccine was administered with the help of the county veterinary office. The blue tongue outbreak also affected farmers' animals in and around the trial site. Sheep pox is a highly contagious viral disease of sheep characterized by nodules in the mouth, skin, and nose. The nodules can also appear in the tongues and udder. The disease is spread by insects or through contaminated equipment. It is controlled through strict biosecurity and vaccination.

A total of six deaths, equivalent to a mortality of 4.5%, occurred during the fattening scheme. This is consistent with observed in sheep farming, particularly in extensive systems. Although no post mortem examinations were carried out, these deaths were associated with complications from the disease outbreaks experienced. However, observations made by farmers on three of the dead sheep indicated impaction in the large intestines. They associated this observation to feeding of the sheep with molasses. This could not be independently verified.

Public auction of fattened lambs

The public auction was successful and an initial flock of 60 finished lambs weighing 30(kg) and above sold out and on live weight basis as the project intended. The remainders were disposed-off within a week. The project working with the CBO, managed to pioneer the sale of finished sheep lambs on live weight basis and through public auction forum which was a new experience in the area. The fattening experiment observed that it was possible to finish and market sheep for a period of 3 months rather than keeping them a year or so as is the normal practice. The prices realized from sold sheep lambs were far much better than the prices obtained when similar lambs are sold on visual appraisal at farm gate. The AFAPO CBO got a contribution of ten percent from the sale proceeds from each animal, amount totaling to KES 61000, money that is being used for table banking and as capital for loaning to individual community members to meet family expenses and therefore improving their livelihoods. The project pioneered a leaders meeting that brainstormed on the idea of establishing a livestock market yard in the village.

Estimation of economic profitability of sheep fattening scheme

Economic profitability of sheep lamb fattening scheme was evaluated through estimating the expected cost benefit parameters (net present value (NPV), gross margin (GM), benefit cost ratio (BCR) and internal rate of return (IRR)) for 2 batches of finished lambs within a year. The estimation were based on an Inflation rate of price per annum of 10%, a Depreciation on capital asset of 5%, a discounting rate of 11.50% which is the Current Central Bank of Kenya Interest Rate and Mortality rate per season4.5%.

The calculations are based on scenario where the farmers come together and contribute 132 sheep lambs for fattening under feedlot system. Under this scenario, the computed cost benefit parameters gave positive NPV, GM and CBR. The BCR, (1.3), was above one. This meant that the costs invested in the sheep lamb fattening scheme were recovered and high benefits realized. The discounted NPV was far above zero implying that it is worthy investing in sheep lamb fattening that has enhanced future benefit with supposedly very high IRR of above 500%.

Utilization of the proceed by gender after sale of sheep

Utilization of proceed of sale by gender was analyzed. The share of proceed was high for men (56%) followed by youth (23%) and lowest was women with 21%.

Conclusion

Pre-castrated and late-castrated sheep weaner lamb attained marketable weight within the same finishing period under grass and supplements of energy, protein and mineral. The 3 months communal rearing venture platform was possible in a rural set-up as opposed to individual farm rearing for a year or so as is the normal practice in most pastoral areas. The prices realized from finished sheep lambs and sold through public auction and on live weight basis were far much better than the prices obtained when similar lambs are sold on visual appraisal at farm gate.

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Factors Influencing the Uptake of Modern Beekeeping as an Adaptation Strategy to Climate Change among Smallholder Farmers in Kajiado County, Kenya

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Abstract

Modern bee keeping technologies have advanced over the years. However, satisfying the basic needs of the rural people to improve their living standards by adopting modern bee keeping technologies is still a challenge due to the relative slow adoption rates of the new technologies. The objective of this study was to determine the factors which influence the uptake of modern bee keeping technologies among smallholder farmers in Kajiado County. Data was collected from randomly selected smallholder farmers using multi stage random sampling technique. A total of 120 households were selected randomly. Data were collected from sampled households using a structured interview schedule. The structured interview schedule was pre-tested, revised and then administered by well-trained enumerators recruited from the study area. Descriptive statistics such as mean, standard deviations and frequencies were used to summarize the data while t-test and chi-square was used to test the hypotheses. The results indicated that age, sex, education, frequency of contact with extension agent, and frequency of participation in field days had positive and significant influence on adoption of modern bee keeping while farm size, family size and farm experience did not affect adoption. Based on these key findings, there is need for more extension efforts in terms of extension service in order to encourage farmers to adopt modern bee keeping. Improving smallholder farmers' access to farm credit through appropriate government interventions will also help smallholder farmers ensure food security at household level.

Key words: Adoption, Modern beekeeping, Socio-economic factors, Institutional factors.

Introduction

Climate change and variability are already evident in Kajiado County (GoK, 2004). Pastoralism is the primary source of income and food in this particular area. The recurrent droughts and unpredictable rainfall are increasingly affecting livestock and food security in this area and the local communities have no option but to diversify their economic activities. Bee keeping has been identified as a livelihood diversification option for this particular community who for many years have wholly depended on pastoralism as their main source of livelihood.

Bee keeping is the art of managing bees in order to obtain honey, bee wax among many other products. It provides food with great nutritional value, enhances seed production through pollination and conserves natural environment (Klein *et al.,* 2007). In addition to this, bee keeping requires little capital, less space and does not require good soil. Hence, it can be practiced alongside other farm activities. It can be carried out by men and women and is a suitable activity for women groups, youth groups etc. Because of these numerous economic benefits, bee keeping is emerging as a very successful agricultural practice for rural areas in developing countries (Kukonza, 2009). The government of Kenya in its strategy for development of apiculture and emerging livestock, has identified honey production and development of apiculture as one of the means by which people in the Arid and Semi-arid (ASALs) areas can earn an income and enable them to adapt to climate change sustainably.

In an attempt to diversify agricultural practices and improve food security in the country, efforts have been underway to generate and disseminate improved agricultural technologies among smallholder farmers. Modern beekeeping is one of the technologies promoted for enhanced production and natural resource management. Despite the Government's effort to systematically disseminate modern bee keeping technologies, very little empirical evidence has been presented relating to factors that affect adoption of these technologies. Very few studies have reported on the status and impacts of modern bee keeping in the country. The objective of this study was to determine factors influencing use of modern bee keeping technologies among pastoral farmers in Kajiado County.

Methodology

This study was carried out in Kajiado County, Kenya. Kajiado County is a semi-arid area (zone V) that is characterised by rough terrain with an annual rainfall of 300-600 mm. To the north, the escarpments of the Great Rift Valley rise to form the Ngong hills. The escarpments then stretch southwards to the Eastern side. On the floor are several hills and valleys forming a hilly and rough terrain with some areas having long stretches of grassland plains. Most of the land is covered by grass and shrubs forming shrub vegetation with acacia species being the most prevalent tree. This kind of vegetation is favourable for beekeeping. The main ethnic community found in Kajiado County is the Maasai. Population growth rate is 4.6 per cent; Household size is 4.2; Geographical area of 21,903 Km^2; average annual income US $400 in paid income; with infant mortality of 45/1000 (RELMA, 2005). The main economic activity among the Maasai in Kajiado County is pastoralism, (keeping cattle, goats, sheep and donkeys).

Data collection and analysis

Multi-stage sampling procedure was used to sample smallholder farmers for interview. Kajiado County was selected purposively based on the honeybee production potential, availability of bee flora and improved box hive promotion. Kajiado County was subdivided into 4 sub counties which were further subdivided into villages. A total of 120 respondents were selected for the study using simple random sampling. The structured interview schedule was pre-tested, revised and then administered by well-trained enumerators recruited from the study area. Descriptive statistics such as means, standard deviations and frequencies were used to summarize the data while t-test and chi-square was used to test the hypotheses

Results

The age of the farmers in the study area ranged from 18 to 66 years (Table 1), with 37.9% aged between 56-65 years, 31% between 46-55 and 5.2% between 18-35 years old. Table 1 shows that majority of the respondents did not attend school (37.9%), with 22.4%, 19.0%, 12.1%,

6.9% and 1.7% having attended lower primary, upper primary, secondary, technical college and university respectively.

Table 1. Socio economic profile of the respondents

	Description	**frequency**
Age (years)	18-35	5.2
	36-45	19.0
	46-55	31.0
	56-65	37.9
	66 and above	6.9
Education	Not attended school	37.9
	Lower primary	22.4
	Upper primary	19.0
	Secondary	12.1
	College	6.9
	University	1.7
Sex	Male	30
	Female	70
Experience in bee keeping	Less than one year	1.20
	1-2 years	2.47
	3-5 years	9.13
	5 years and above	87.20

Age is one of the important factors in describing households and age structure of a sample and indeed the entire population. In most adoption studies age has been found to affect adoption positively due to farming experience that old farmers have which aid in adopting new technologies. Based on this fact, age was hypothesized to have a positive relationship with adoption of modern beekeeping,

Table 2. Association between Age and Farm experience with adoption (n=120)

	Adopters		**Non adopters**			
Variables	mean	SD	mean	SD	T-test	Significance Level (2-tailed)
Age	38.9	8.00	43.6	6	2.621***	0.010
Farming experience	10.45	8.67	9.75	5.05		0.43ns
Family size	6.59	1.95	5.94	1.57		.630ns
Education					1.490***	.000

Ns-non significant, *** significant at p<0.01,**significant at P<0.05
Source: Field data (2015)

The mean age of household head for adopters and non-adopters is 38.9 and 43.6 years, respectively. An independent t-test was conducted to test if there was significant difference in the mean age of adopters and non-adopters. The t-value (t=2.262) showed statistically significant difference in the mean age of adopters and non-adopters .The non-adopters mean age was greater than that of the adopters and is significant at P<0.010 and the result is provided in Table 1. This clearly indicates that as the farmers grow older, they become reluctant to embrace technologies that they are not used to.

Family size: Family size in this study was considered as the number of individuals in the respondent's household. The mean family size is 6.9 and 5.9 for adopters and non-adopters, respectively. It ranges from two to 11 members of the family. The finding on the mean difference of both categories is provided in Table 2. The result shows that the mean family sizes of adopters are greater than non-adopters. The results show that there is no significance difference among the adopter categories (t= 0.483, p=0.630). This is because of the fact that most farmers have experienced shared labour to overcome labour shortage.

Education is very important for the farmers to understand and interprete the agricultural information coming to them from different sources. A better educated farmer can easily understand and interpret the information transferred to them by development agents.

Table 3. Education of household (n=120)

	Adopters		Non adopters	
Variables	mean	%	mean	%
None	3	6	15	21.4
Primary	9	18	40	57.1
Secondary	22	44	12	17.1
Tertiary	14	28	2	3.0
university	2	4	1	1.4
Total	50	100	70	100
T-test = 1.49 P= 0.010				

Source: Field data (2015)

From the above table, total number of farmers who had secondary school level of education and above was 76% for adopters' and 21.5 % for non-adopters. Education was found to be significant ($p<0.01$), implying that educated farmers are more likely to take up technologies than those who lack education. This shows that the education level of adopters of modern bee keeping technologies is higher than non-adopters of the technology, implying high level of education improve the farmers level participation in agricultural activities because it enhances the understanding of instructions given and enables one to access information needed to make a decision to use an innovation and practice a new technology. Education increases managerial competence and therefore enhances ability to diagnose, assess, comprehend, and respond to financial and production problems. These findings corroborate with Muya *et al.,* (2012) who found that education is a significant factor in facilitating uptake of modern beekeeping technologies. However, the findings contradict Tesfaye (2003), on soil and water conservation practices in Wello, Wolaita and Konso areas of Ethiopia who found no variation between literacy and illiteracy rates in terms of soil and water conservation.

Economic variables

Economic factors play an important role in determining the adoption of modern bee keeping technology. The main and significant economic factors considered in this study are the farm size, labor availability and off farm activities of the household.

Table 4. Association between economic variables and adoption (n=120)

	Adopters		Non adopters			
Variables	mean	SD	mean	SD	T-test	Significance Level (2-tailed
Farm size	13.9	10.6	11.2	9.9	1.609	0.010
Labor	3.07	1.5	2.5	1.3	1.396	0.247

Source: Field data (2015)

Farm size

(Table 4) clearly indicates that, the average farm size for non-adopters was 11.2 ha with a standard deviation of 9.9 while adopters had 13.9 ha and a standard deviation of 10.6. Farm size affects adoption..This study is in agreement with the findings of Spielman (2005) who pointed out that beekeeping can also be undertaken in small land and doesn't require fertile land to be practiced.

Labour

Availability of labour did not influence adoption of modern bee keeping. The average labour availability in terms of man equivalent for sampled households was 3.07 with standard deviation of 1.5 for adopters and 2.5 and 1.3 for non-adopters as shown in Table 3. The analysis ($t= 1.396$ and $P = 0.247$) shows the absence of significant mean difference between adoption categories.

Off farm activities

Table 5: Association between off farm activities and adoption (n=120)

	Adopters		Non adopters		X2	P
Off-farm activities	N	%	N	%		
Yes	10	95.8	12	20.5		
No	40	4.2	58	79.5		
Total	50	100	70	100	= 2.884	0.144

Source: Field data (2015)

From this study, there is no significant relationship between adoption and participation in off-farm activities. The fact that one does not participate does not make them adopt this technologies.

Institutional Factors

Contact with extension agents

The main institutional factors considered in this study included access to credit andcontact with extension agentsby adopters and non-adopters.

Table 6. Association between contact with extension agent and adoption (n=120)

	Adopters		**Non adopters**		**X2**	**P**
Contact with extension agent	N	%	N	%		
Yes	45	95.8	15	20.5		
No	5	4.2	55	79.5		
Total	50	100	49	100	= 7.651	0.053

Source: Field data (2015)

Extension services plays a great role in promoting modern bee keeping. During the interview, it was clear that farmers in the area had received services from extension officers working in the County. As shown in Table 6, 45 % of the adopters had been in contact with an extension agent. The contact of these farmers with the extension agents helps in providing more information about the technology and helps them to practice modern beekeeping more effectively. The chi-square result ($\chi 2$=7.651 and P=0.053) shows there was statistically significant difference between adopters and non- adopters with respect to farmers' contact with extension agent. This shows that farmers who frequently visit extension agent get more acquainted with the technology hence making an informed decision whether to adopt a technology or not compared to those who have not had any contact with an extension agent.

Field day participation

Field day is one of the most popular methods of transfer of technology information. Conducting field days on farmers' fields is a good way of showcasing a technology hence convincing other farmers to adopt new technology. During the field day neighboring farmers get an opportunity to observe how the new technology is put in to practice in the field. This situation may facilitate the adoption process. Table 7 clearly indicates that, few farmers attended field days compared to those who did not attend. To determine the relationship between field days with the adoption of modern beekeeping chi-square analysis was conducted.

Table 7. Relationship between field day attendance and adoption of modern beekeeping (%)

	Adopters		Non adopters		X2	P
Field day	N	%	N	%		
Never	20	52.6	49	52.3		
Sometimes	13	25.0	15	34.0		
Total once a week	10	13.2	2	4.54		
Most often	7	9.21	4	9.09		
Total	50	100	44	100	18.80	0.025**

Source: Field data (2010)

The chi-square analysis showed (χ^2=18.806, p=0.025) that there was a significant relationship at 5 % probability level as shown in Table 7.This study is in line with an earlier study by Makokha (1999) who found that participation in field days had significant influence on perception and hence adoption decision of farmers.

Access to credit

Credit access is an important component as far as agricultural production is concerned. It is thus believed that lack of access to credit may have significant negative consequences on various aggregate and household level incomes, including technology adoption, agricultural productivity, food security, nutrition, health and overall household welfare.

Table 8. Association between access of credit and adoption (n=120)

	Adopters		Non adopters		X2	P
Response of farmers	N	%	N			
Yes	30	42	12	24		
No	41	58	37	76		
Total	71	100	49	100	= 12.563	0.005

Source: Field data (2015)

From this study, there was a significant relationship between adoption and access to credit. (χ^2 = 12.563, P = 0.005) as shown in (Table 8). This can also be confirmed in distribution of percentage of respondents where only 24% of non-adopters had access to credit while the percentage difference between adopters is not as high as the one between non adopters.

Discussion

Education level of respondents was found to be positively and significantly influencing adoption decision of modern beekeeping. Most of the educated farmers are still young and therefore there is need to target them during on-farm research and modern bee keeping technologies promotion as they can easily understand the technology and convince others to adopt.

From this study, contact with extension agents had positively and significantly influenced adoption of modern bee keeping which clearly suggests the need for more targeted and continued extension services. Thus, there is need to strengthen the extension system operating in the areas and elsewhere so as to increase the flow of information for rural development. Clear messages on modern bee keeping should be included in the normal extension packages and training of both extension workers and farmers should be emphasized so as to improve their understanding.

This study further revealed that credit influenced adoption of modern bee keeping. Non-adopters were not using the existing credit in the area due to high interest rates. The government, research, extension, NGOs, and the private sector can look for ways of providing credit to beek keepersat reduced interest rates. Creating awareness about modern beekeeping technologies together with training will go a long way to increase the uptake of modern beekeeping technologies.

Recommendations

Appropriate education policies are likely to stimulate adoption of modern bee keeping. Agricultural extension services should be strengthened to enhance transmission of adequate information to farmers hence increasing technology adoption. However these should go hand in hand with financial support to provide farmers with capital for purchasing farm inputs.

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Important bee forage plants of African honey bee *Apis mellifera scutellata* (Hymenoptera: Apidae) in Southern Rangelands of Kenya

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Abstract

The study was conducted in Makueni County, southern rangelands of Kenya. The objective of the study was to identify and document the existing forage plants for African honeybee *Apis mellifera Scutellata* and also develop bee floral calendar of the study site. Based on the interview of the beekeepers and visual observations, a total of 34 vascular plant taxa belonging to 14 families which are important bee forage plant species were recorded, out of which 22 species were found to be major sources of nectar and pollen for honeybees. Long rain season (March to April) and short rain season (November to December) were identified as honey flow periods having a number of floral plants such as *Acacia mellifera, Acacia tortilis, Albizia amara, Melia volkensii, Zea mays, Eragrostis superba, Cajanus cajan, Cenchrus ciliaris and Lantana camara species.* Dry season (June to October and Feb to March) is the critical dearth period with a few flowering plants. Depending upon the climatic conditions, possibility of planting multipurpose plants was discussed. Based on available flora, major characteristics of these plant species, utility status and flowering duration a bee floral calendar was developed for the study site. Conservation of the floras, demends for focus on maintaining and multiplying the existing flora.

Key words: *Apis mellifera Scutellata*, bee flora, bee keeping, dearth period, honey flow.

Introduction

Most parts of Kenya are suitable for beekeeping although the highest beekeeping potential is found in the Arid and Semi Arid Land (ASAL) areas which constitute about 80% of Kenya's total land mass. The ASAL areas are rich in biodiversity in terms of bees and bee plants (Kagio and Mureithi, 1988). These include various trees species, shrubs, bushes and undergrowth that periodically flower at close intervals and with little moisture thereby availing nectar and pollen to the honeybees (Muya, 2004).

Beekeeping in Kenya plays a very significant role. According to Muya (2004), the livestock sub-sector, which is one of the six priority sectors in Kenya's vision 2030 of which bees are part, contributes about 10% of Kenya's Gross Domestic Product (GDP). Bee keeping alone contributes about 1.89% of this amount. Honey and other hive products have been desired for centuries due to their nutritional and medicinal value (Paterson, 2006), it has immense benefits in terms of provision of pollinators, which enhance crop yield and is essential for sustaining biodiversity (Bradbear, 2002). It is also feasible in marginal conditions and a suitable activity where people need to restore their livelihoods or create new opportunities, Kigatiira (1976) noted that the beekeeping industry in Kenya is worth millions of shillings and plays an important part in the economy of arid areas. In fact nowadays it is widely considered as one of the poverty-alleviation strategies both by the Kenyan government, Non Governmental Organizations (NGOs) and other actors supporting rural development in Kenya.

The forage source for honeybees of an area is a vital consideration for the development of apiculture. Bees and plants co-interact in a mutualistic system, in which plants offer food resources to bees and these act as the main pollinators of Angiosperms in different ecosystems. (Neff and Simpson 1993), this mechanism is facilitated by appropriate structural and functional characteristics of both honey been and plants. Honeybee *Apis mellifera scutellata* (Hymenoptera: Apidae) is speciated in Africa (Whitfield, 2006), and is considered to be a prolific producer of honey, this hymenopteran depends on both nectar and pollen to produce honey, propolis, beeswax, bee venom and other hive products and also to sustain themselves (Crane, 1999, Klein *et al.*, 2007). According to Crane (1990), apiculture is floral based industry and bees wholly depend on plants for their food; and from 250,000 plants in the world, about 40,000 plant species are important for honey bee as a food source. Sugars, the primary constituents of floral nectars, are the major energy source of bees for daily maintenance of the colony. The quantity and quality of nectars vary among plant species. They also contain amino acids, vitamins, and inorganic minerals that are important for fulfilling nutritional and homeostatic requirements of a bee colony (Southwick 1990; Nicolson and Worswick 1990). Nectar and pollen collection foraging by bees is a continuous process throughout the year in humid and sub- humid areas, where there is continuous succession of blooming of bee flora. The foraging activities of honeybees for pollen are greatly influenced by the weather conditions and availability of pollen. The dearth period which is characterized by prolonged dry spell is very harsh for bees and generally limted or no floral sources are available to bees, this in the long run causes food shortage even death of bee colonies.Therefore, the knowledge of the pollen flow periods is very critical and could be used to determine when pollen substitutes or supplements should be supplied in an apiary resulting in the better growth of the colony. The identification of bee flora is an indispensable part of the beekeeper's knowledge which is built over time through experience. The objective of this study was to determine and assess the diversity of plant species used as source of nectar and pollen by honeybees *(Apis mellifera S.*) as well as their flowering periods and availability in different seasons of the year.

Materials and methods

Study area

The study was carried out in Kibwezi Sub County which is a Semi Arid area. The sub county lies between 2°6′ S and 3°S and longitude 37°36′E, respectively and has a total area of 3954.6 Km². The area is mainly inhabited by agro pastoralists. The area is a typical semi arid land and characterized by low erratic and unreliable rainfall. The average rainfall and temperatures are 600mm and 23°C respectively. Due to its proximate position along the equator, the area receives bimodal pattern of rainfall, with long rains from mid March to May and short rains from November to December. This area forms part of the vast rangelands of Kenya, which occupy 80% of the country's total land area. They are classified into Agro-Climatic Zones (ACZ) IV and V on the basis of ratio of rainfall to open water evaporation (R/Eo) (Biamah, 2005).

Data collection and analysis

Data was collected using a semi-structured questionnaire. The information collected included various plants species preferred by honeybee for nectar and pollen, flowering periods and potential for improved

bee forage availability. This information was collected through face-to-face interviews with household heads, Focus Group Discussions (FGD) and field observations. A total of 60 beekeeprs were interviewed. Four FGD were held in four cluster areas after the household survey each involving 10 participants. The FGD was used to complement the information from the face-to-face interviews.

Statistical analysis

Data entry was done in Microsoft office excel 2010 and analyzed using the Statistical Package of Social Scientists (SPSS) version 10.

Results and discussion

Beekeepers knowledge on bee-plant interactions

According to the results of this study, majority (91%) of the beekeepers mentioned cross pollination as a benefit derived by forage plants from association with honey bees, furthermore, 88% of them knew specifically that honeybees collect nectar and pollen from various trees. This was an indication that beekeepers were knowledgable on beekeeping isssues. Based on color, size, aggresiveness and productivity, two different honeybee species existed predominatly in the study site. They were little honeybee *Apis florea s*. which was described as small but with ferocious nature, yellow stripped abdomen, generally small body size and produces more honey compared with others. The other one was the common hive bee *Apis mellifera s.* described *as* relatively larger in size with milder nature compared to *Apis florea s.* and generally black tinted as a whole. According to farmers' experience, the predominant species is *Apis meliffera s.* which was similar to the findings of S.K. Raina and D.M. Kimbu (2005).

Bee flora species abundance

A total of 34 bee forage plants belonging to 14 families were identified by the respondents, key informants as well as during focus group discussions. The life form of common bee flora species in the study area, were characterized mainly as trees, shrubs, herbs, *field and horticultural crops and grasses/undergrowth* visited by the honeybee *Apis mellifera scullata*. The predominant species belong to the family fabaceae 14 (41%) followed by species from the family Poaceae 7(20%) and Combreteceae 2(5%) while the families *Agavaceae, Anacardiaceae, Balaniticeae, Bombacaceae, Burseraceae, Caricaceae, Convolvulaceae, Malvaceae, Meliaceae, Moringaceae, Verbenaceae* were each represented by a single species (Table 1). The dominant species in the family Fabaceae is *Acacia species* while *a*mong the family poaceae, grass species were dominant. About 59.1% of the bee-visited plants were annuals while 41.9% were perennials. 20.4% of plant species produced only pollen, 8.6%) plants produced nectar while 71.4% produced both nectar and pollen (Table 1). Observations during sample collections showed that *acacia mellifera* was the most frequently visited plant by the honey bee Apis *mellifera scutellata* while the least visited was *Mangifera indica.*

Honey bee flora of the study area

About 96.1% of interviewed beekeepers responded that there are diversified types of bee flora. Many cultivated crops in the area serve as pollen, nectar, or both pollen and nectar sources. Mainly shrubs, cultivated crops, forbs, herbs, weeds and some woody plants are the main bee forages for the honey harvested in October while most woody plants are the main source of pollen and nectar for honey harvested in May. According to the bee keepers response there are a wide variety of plants which are used as honey bee flora. Respondents indicated that even though there are different types of bee plants in the area during wet seasons, there is a shortage of bee food during the dry seasons. They also indicated that bee forages had declined as compared with the past period due to deforestation and expansion of cultivated lands in the area. Participant farmers also listed major bee forages available and beekeeping activities conducted in their area (Table 1).

Table 1. Important Bee Forage Plants in the study area

Family	Botanical name	Common name	Vernacular name
Trees			
Fabaceae	*Acacia mellifera*	Honey acacia	Muthiia
Fabaceae	*Acacia tortilis*	Umbrella thorn	Mwaa
Fabaceae	*Acacia xanthophloea*	Fever tree	Musewa
Fabaceae	*Acacia seyal*	Umbrella thorn	Muaa/Mulaa/Mukela
Fabaceae	*Acacia drepanolobium*	Whistling thorn	Kiunga
Fabaceae	*Dalbergia melanoxylon*	African blackwood	Muvingo
Fabaceae	*Acacia brevispica*	Wait-a-bit thorn	Mukuswi
Fabaceae	*Albizia amara*	Bitter albiza	Kiundua/kiundwa/ kyundua
Fabaceae	*Albizia anthelmintica*	Worm-cure *albizia*	Kyowa/mwowa
Malvaceae	*Grewia bicolor*	Grewia bicolor	mulawa/Ilawa
Fabaceae	*Tamarindus indica*	Tamarind	Kithumula
Moringaceae	*Moringa oleifera*	Drumstick tree	Muvutu
Bombacaceae	*Adansonia digitata*	Baobab	Mwaamba
Combreteceae	*Combretum molle*	Velvet bush	Muama/ Kiama
Combreteceae	*Combretum hexalatum*	Bushwillow	mukokola
Meliaceae	*Melia volkensii*	Melia	Mukau
Balaniticeae	*Balanites aegyptiaga*	Desert date	Mulului/Kitului
Shrubs			
Burseraceae	*Commiphora africana*		Maulu
Fabaceae	*Acacia nilotica*	Nile thorn	Kisewa /Musemei
Fabaceae	*Albizia anthelmintica*	silk tree	Mwowa
Agavaceae	*Agave sisalana*	Sisal	Ikonge
Field and horticultural crops			
Poaceae	*Zea mays*	Maize	Mbemba
Anacardiaceae	*Mangifera indica*	Mango	Muembe
Fabaceae	*Phaseolus vulgaris*	Beans	Mboso
Fabaceae	*Cajanus cajan*	Pigeon pea	Nzuu
Poaceae	*Sorghum bicolor*	*Sorghum*	muvya
Caricaceae	*Papaya carica*	*Papaya*	Kipapai
Grasses/undergrowth			
Poaceae	*Eragrostis superba*	Masai love grass	Mbeetwa
Poaceae	*Cynodon dactylon*	couch grass	Ikoka
Poaceae	*Digitaria milanjiana*	digitgrass	Ndau
Poaceae	*Enteropogon macrostachyus*	Bush rye	Nguu
Poaceae	*Cenchrus ciliaris*	Fox tail	Ndaata kivumbu
Convolvulaceae	*Ipomea kituensis*	bindweed	Kiungu
Verbenaceae	*Lantana camara species*	white-sage	mutavisi

Generally, 40% of the common bee flora species identified in the study area were herbaceous species, 37% were tree species and the remaining 23% were shrubs. Hence, herbs were more dominant followed by trees and shrubs respectively. Herbs can grow easily in the different land use systems, even with little rain within a short period of time than trees and shrubs; most probably this may be the main reason for dominance of herbaceous bee flora species in the study area. Generally, Gergera watershed was one of the potential areas for bee forage with different bee flora species commonly grown. The availability of potential flowering plants and ample sources of water for bees are the two major factors for an area to be considered as potential for beekeeping (Tessega, 2009).

Respondents indicated that even though there are different types of bee plants in the area during wet seasons, there is a shortage of bee food during the dry seasons. Coincidentally, these bee plants are also used by local communities for charcoal production and timber especially the acacia species. Thus, most of the problems encountered in such areas in regard to poor honey production are related to lack of enough food sources and prolonged droughts. With the continuous increase in land pressure due to population growth, less and less land is projected to become available for bee foraging.

Floral calendar

Seasonal changes in the vegetation patterns, the foraging behavior of bees, and the manner in which the honey colonies interact with their floral environment are the major events that are recorded. A floral calendar for beekeeping is a time-table that indicates to the beekeeper the approximate date and duration of the blossoming periods of the important honey and pollen plants in an area. The experienced beekeeper will have acquired much of this information over the years, but published charts are also available for many areas. Assembling a floral calendar for any specific area requires complete observation of the seasonal changes in the vegetation patterns and/or agroecosystems of the area, the foraging behaviour of the bees, and the manner in which the honeybee colonies interact with their floral environment. The accuracy of a floral calendar, and hence its practical value, depend solely on the careful recording of the beginning and end of the flowering season of the plants and how they affect the bees. The preparation of an accurate, detailed calendar will therefore often require several years of repeated recording and refinement of the information obtained.

Discussion

Among many factors, availability of potential flowering plants and ample sources of water for bees are the two major parameters for an area to be considered as potential for honey production. According to the results of this survey, the honeybee plants of the study area comprise trees, shrubs, herbs and cultivated crops and the species with their composition and population varies widely from area to area. Vegetation features of an area are considered to be an important indicator of a potential of an area for beekeeping. According to the results of this study, the honeybee plants of the study area comprises of trees, shrubs, herbs and cultivated crops which are a source of nectar and pollen. These important honeybee plants were recorded in vernacular, common and scientific names with their flowering periods (Table 1). This variation in vegetation characteristics of the area could be potentially suitable for effective distribution of honey production at various seasons. The annual honey production in study area comes from *acacia species* which usually flowers from March- April and also in the month of September. Some beekeepers explain that honey produced in May is usually mixed with honey from sisal due to proximity of sisal plantation in the area.

Conclusion

The results clearly indicated that the area is rich in bee foraging plant species. These findings serve as a guide for the type of plantations to be promoted for establishment by different agencies based on their multiple uses natureincluding their value as bee forage. The floral diversity in the study area offers the possibility of diversification in bee keeping. In this context, pollen analysis studies are particularly relevant for indicating the nectar sources used by bees for honey production in each region and, consequently, for improving the use of bee flora in each locality. It is expected that our compilation of nectar, pollen, and flower records, pollen load data, and alternative forage plant recommendations will be used in conjunction with future field and laboratory studies to develop and help implement model resource management practices aimed at protecting and enhancing native bee populations.

Recommendations

There is need for pollen analysis studies to give an indication of nectar sources used by bees for honey production in the sub county and subsequently for improving the use of bee flora in each locality. There is also need to preserve the indigenous vegetation in an effort to slow down land degradation and thus ensure sustainability of beekeeping.

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The potential of essential oils in manipulation of rumen fermentation for improved feed utilization efficiency: a literature review

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Abstract
Ruminant digestion is inefficient andantibiotics have been used in the past to regulate the function of microorganisms in the rumen for improved feed efficiency. However, due to the increasing microbial resistance to antibiotics, the practice has been discouraged. Plants produce secondary metabolites called essential oils which have some antimicrobial activities. In the recent years, research on possible use of these essential oils to control rumen microbial populations has intensified. This review presents some of the common essential oils in this region that hold promise for use as feed additives to improve the efficiency of digestion in the rumen. Most of the work presented here is from in vitro studies. The results show promise in use of some of the essential oils singly or in combination to improve rumen efficiency. However, some of the results are contradictory, showing inconsistencies especially when dietary conditions are different. Non-the-less, some of the essential oil products are already being marketed in specially formulated combinations for use as feed additives.

Key words: Essential oils, rumen fermentation

Introduction

The inefficiency of energy and protein utilization in the rumen reduces productivity and contributes to the release of pollutants to the environment. It can be improved by the manipulation of several metabolic pathways, including volatile fatty acid formation and deamination (Tamminga, 1996) through manipulating the activity of specific rumen microbial populations involved in the pathways. The utilization of ionophores, a potent antibiotic against gram-positive bacteria, has proven effective in improving the efficiency of energy and protein utilization in the rumen (Van Nevel and Demeyer, 1988). However, the use of antibiotics in animal feeds is facing resistance due to the residues in the products leading to the development of resistant strains of bacteria, hence the search for alternatives, including yeast, organic acids, plant extracts, probiotics and antibodies (Calsamiglia *et al.*, 2006). Following the announcement of the ban on the use of antibiotics as feed additives in the European Union, there has been a renewed interest in the study of essential oils as rumen microbial modifiers.

Essential oils hold promise as feed additives in ruminant nutrition to improve feed efficiency in livestock. However, identification of essential oils, or their active components, that favourably alter fermentation without resulting in broad overall inhibition of rumen fermentation, continues to be a major challenge for researchers.

Essential oils are a mixture of plant secondary metabolites, isolated from the plant volatile fraction by steam distillation (Gershenzon and Croteau, 1991). Some essential oils have antimicrobial activities and are currently considered safe for human and animal consumption, categorized as Generally Recognized as Safe (GRAS) by the Food and Drug Administration of the USA (FDA, 2004). The antibacterial activity of essential oils is mainly related to their hydrophobicity, which enables them to accumulate in the lipid bilayer of the bacterial plasma membrane from where they exert their effects, which vary according to type of secondary metabolite. Some alter membrane permeability, some interact with membrane proteins, and others may interact directly with cytoplasmic components from within the plasma membrane or by diffusing into the cytoplasm itself. Their potential use in ruminants was reviewed by Calsamiglia *et al*., (2007) and Benchaar *et al*., (2007). There are two chemically distinct groups of essential oils. Each originates from different precursors of the primary metabolism and is synthesized through a different metabolic pathway:

1) Terpenoids are the most common and more diversified group of plant secondary metabolites. They are derived from an isoprenoid structure (C_5H_8). The most important terpenoids belong to the monoterpenoid and sesquiterpenoid families (Gershenzon and Croteau, 1991).
2) Phenylpropanoids are not common. They derive from a structure with a chain of three carbons bound to an aromatic ring of 6 carbons.

Mode of action

Essential oils act against bacteria through the interaction with the cell membrane, causing conformational changes in the membrane, resulting in the leakage of ions across the cell membrane and the loss of the transmembrane ionic gradient (Griffin *et al.*, 1999). Large amounts of energy are diverted to this function, resulting in reduced bacterial growth and, in some cases, microbial death occurs (Griffin *et al.*, 1999; Ultee *et al.*, 1999; Cox *et al.*, 2001). Thus essential oils are more effective against gram-positive bacteria, where the cell membrane can interact directly with hydrophobic compounds of essential oils (Smith-Palmer *et al.*, 1998; Chao and Young, 2000; Cimanga *et al.*, 2002). But the small molecular weight of most essential oils allows them to cross the external hydrophilic cell wall of gram-negative bacteria, being also active against them (Calsamiglia *et al.*, 2007; Griffin *et al.*, 1999; Dorman and Deans, 2000). This reduces the selectivity of these compounds against specific populations, making it difficult the manipulate rumen microbial fermentation.

Experiments with ruminant feeds

Studies have examined effects of essential oils, and their active components, on rumen microbial fermetation. However, many of these studies are *in vitro* and of a short-term nature. Nevertheless, results from *in vitro* batch culture studies provide evidence that essential oils and their components have the potential to improve nitrogen and/or energy utilization in ruminants. In most cases, a positive effect was

described as an increase in propionate and decrease in acetate, methane and ammonia-N production without reducing total VFA production.

Evidence on changes in microbial populations

Evans and Martin (2000) reported that thymol, an essential oil found in thyme (*Thymus ssp*.) affected energy metabolism of two relevant rumen bacteria grown in pure culture: *Streptococcus bovis* and *Selenomonas ruminantium.* Moderate doses resulted in an increase in the acetate to propionate ratio. *Selenomonas ruminantium* was more sensitive to thymol than *S. bovis* which may result in an increased accumulation of lactic acid because the production of lactate by *S. bovis* (a major lactic acid producer) may not be metabolized fast enough by *S. ruminantium* (a major lactic acid utilizer).

Cinnamaldehyde is the main active component of cinnamon (*Cinnamomum cassia*) oil, accounting for up to 75% of its composition. Ferme *et al*., (2004) reported that when cinnamaldehyde was added to an *in vitro* rumen simulation system there was a reduction in *Prevotella spp*., a group of bacteria known to be involved in deamination. On the other hand garlic reduced the population of *Prevotella ssp*. in a continuous culture experiment. *Prevotella ssp.* are mainly responsible for protein degradation and amino acid deamination (Ferme *et al.,* 2004). Busquet *et al*., (2005bc) suggested that the anti-methanogenic effect of garlic and its active components was the result of the direct inhibition of Archaea microorganisms in the rumen through the inhibition of HMG-CoA reductase (Gebhardt and Beck, 1996), and as a result, the reduction in the synthesis of the isoprenoid unit responsible for the cell membrane stability.

Evidence on changes in rumen VFA production

Work by Evans and Martin (2000) revealed that thymol reduced methane and lactate concentrations, although at higher doses also reduced overall nutrient digestion and total VFA production, a clear indication that microbial metabolism was inhibited. Castillejos *et al*., (2006) reported that low doses of thymol (50 mg/L) had no effects on *in vitro* rumen microbial fermentation, but at higher doses (500 mg/L) total VFA concentrations decreased, and the acetate to propionate ratio increased. Similar results were reported in a long-term continuous culture fermentation study (Castillejos *et al.,* 2006).

A continuous culture study demonstrated that cinnamon oil had negligible effects on rumen VFA concentration (Cardozo *et al*., (2004). Higher doses of cinnamon oil and cinnamaldehyde decreased total VFA concentrations, although cinnamaldehyde had stronger effects compared with cinnamon oil (Busquet *et al.,* 2006). However, cinnamon oil increased acetate without affecting propionate or butyrate molar proportions, while cinnamaldehyde increased propionate without affecting acetate and butyrate proportions. These results suggest that other components of cinnamon oil may interact with cinnamaldehyde to give less desirable results.

Busquet *et al.,* (2005ab) tested the effect of low doses of cinnamaldehyde in a long-term, dual flow, continuous culture fermentation study and reported similar trends, where cinnamaldehyde numerically decreased the molar proportion of acetate and numerically increased the proportion of butyrate, but differences were not significant. When higher doses (31.2 and 312 mg/L) were used (Busquet *et al.,* 2005b), cinnamaldehyde reduced the molar proportion of acetate and increased the molar proportions of propionate and butyrate.

Eugenol accounts for up to 85 and 8% of the clove bud (*Eugenia caryophyllus*) and cinnamon (*Cinnamomum cassia*) oils respectively (Davidson and Naidu, 2000). In a continuous culture study, low doses of clove bud oil resulted in lower molar proportions of acetate and branch-chained VFA (BCVFA) and higher molar proportion of propionate (Busquet *et al.,* 2005a).

In an in vitro batch culture dose response study, Busquet *et al*., (2006) confirmed that clove bud oil affected rumen fermentation, reducing total VFA and showing a linear increase in the molar proportion of propionate, and a quadratic effect on the molar proportions of acetate and butyrate. In general terms, the effects of eugenol were similar to those reported for clove bud oil. The fermentation profile observed suggests that, when used at optimal doses, efficiency of energy utilization in the rumen was improved.

Anethol is the main active component of anise (Pimpinella anisum) oil with antimicrobial activity (Davidson and Naidu, 2000). *In vitro* studies with rumen fluid showed that anethol and anise oil decreased total VFA and the proportions of acetate and propionate, and increased the proportion of butyrate, although anethol had stronger effects compared with anise oil (Busquet *et al.*, 2005a). Cardozo *et al.*, (2004) reported no effects on the VFA profile at lower doses of anise oil in continuous culture.
Capsaicin is tetraterpenoid found in hot peppers (Capsicum annum ssp.) and is the main component of capsicum oil (10 to 15%; Cichewicz and Thorpe, 1996). When ruminally cannulated beef cattle fed a high concentrate diet were fed capsicum oil, total VFA concentration was not affected, but the molar proportion of acetate decreased (Cardozo *et al.*, 2006).

Garlic oil is a mix of a large number of different molecules that are found in the plant or are the result of changes occurring during oil extraction and processing (Lawson, 1996). Although garlic oil is known for its therapeutic properties its antimicrobial activity against a wide spectrum of gram-positive and negative bacteria is its most prominent activity and has been thoroughly studied (Reuter *et al.*, 1996). Busquet *et al.*, (2005abc and 2006) have consistently shown that garlic oil reduced the proportions of acetate and BCVFA, and increased the proportions of propionate and butyrate. *In vitro* studies demonstrated that garlic reduced the CH4: VFA ratio from 0.20 to 0.05 (Busquet *et al.*, 2005). Methane is the main hydrogen sink in the metabolic pathway of rumen fermentation, and the inhibition of its synthesis results in the synthesis of propionate and butyrate being the main alternatives (Van Nevel and Demeyer, 1988).

The four purified active components (allicin, diallyl sulphide, diallyl disulphide and allyl mercaptan) thought to play a major role in its antimicrobial activity were tested *in vitro* to determine their effect on rumen microbial fermentation (Busquet *et al.*, 2005c). Garlic oil, diallyl disulphide and allyl mercaptan reduced acetate and methane, and increased propionate and butyrate proportions to the same extent, suggesting that diallyl disulphide and allyl mercaptan were responsible for most of garlic oil effects. In contrast, allicin and diallyl sulphide had minor effects on rumen microbial fermentation. Similar results have also been reported by Kamel *et al.*, 2007.

Evidence of changes in rumen nitrogen metabolism
The effect of essential oils on ruminal nitrogen metabolism likely results from their impact on hyper-ammonia producing bacteria, which affects deamination of amino acids and production of ammonia nitrogen. However, these responses are only observed with high doses of essential oils, which also can inhibit the process of ruminal fermentation as reflected by a decline in total volatile fatty acid production. Busquet *et al.*, (2005a) reported that *in vitro*, carvacrol, an essential oil found in oregano (Origanum spp.), used at 2.2 mg/L decreased large peptide and increased ammonia-N concentrations at 2 hours after feeding, suggesting that it either inhibited proteolysis or stimulated peptide lyses. High doses (500 mg/L) of thymol reduced total ammonia-N concentrations (Castillejos *et al.*, 2006). A continuous culture study suggested that cinnamon oil modified nitrogen metabolism of rumen microorganisms by inhibiting peptidolysis (Cardozo *et al.*, (2004). Higher doses of cinnamon oil and cinnamaldehyde decreased ammonia-N concentrations, with cinnamaldehyde showing stronger effects than cinnamon oil (Busquet *et al.*, 2006).

Clove bud also affected nitrogen metabolism, increasing peptide nitrogen and numerically decreased amino acid nitrogen concentrations, suggesting that it decreased the peptidolytic activity in the rumen. In an *in vitro* batch culture dose response study, Busquet *et al.*, (2006) confirmed that clove bud oil reduced ammonia-N concentrations. The fermentation profile observed by Busquet *et al.*, (2006) suggests that, when clove bud oil was used at optimal doses, efficiency of protein utilization in the rumen was improved.

Anise oil and anethol did not affect ammonia-N concentration (Busquet *et al.*, 2005a). Cardozo *et al.*, (2004) however, showed that lower doses of anise oil in continuous culture stimulated protein degradation, increasing the concentration of peptides and ammonia-N. Capsicum oil reduced the ruminal concentration of large peptides and increased that of small peptides and amino acids, but had no effect on ammonia-N concentrations. These effects suggest that it stimulated peptidolysis, which may provide

more peptides and amino acids, and enhance microbial protein synthesis and flow to the small intestine. Similar results were reported from an *in vitro* study by Cardozo *et al.,* (2005). However, this effect was not always consistent (Cardozo *et al.,* 2004; Busquet *et al.,* 2005a). Capsicum oil increased DM and water intake. There is evidence that capsaicin increases DM and water intake in rats and humans (Zafra *et al.,* 2003; Calixto *et al.,* 2000). There seems to be potential for using capsaicin in beef cattle diets based on its effects increasing DM intake and potential effects on rumen microbial fermentation.

The effects of garlic oil and its main active components on N metabolism were more variable. While Cardozo *et al*., (2004) suggested that garlic oil inhibited deamination, others reported only small and variable effects (Busquet *et al.,* 2005bc).

Effects of rumen pH

The effects of essential oils on rumen fermentation seem to be dependent on rumen pH, which is a function of the diet. Castillejos *et al.,* (2006) reported that thymol increased the acetate to propionate ratio in 60:40 alfalfa hay : concentrate diets at a pH of 6.4; Cardozo *et al.,* (2005) observed a reduction in the acetate to propionate ratio when thymol was incubated in rumen fluid from cattle fed a 10:90 straw concentrate diet at pH 5.5.

Cardozo *et al.,* (2005) tested the effects of cinnamon oil and cinnamaldehyde in vitro using rumen fluid from beef cattle fed a 10:90 forage to concentrate diet. At pH 7.0, cinnamon oil and cinnamaldehyde resulted in higher acetate to propionate ratio and lower total VFA concentration, suggesting a lower efficiency of nutrient utilization in the rumen. In contrast, at pH 5.5, total VFA increased and ammonia-N concentration and the acetate:propionate ratio decreased with cinnamon oil and cinnamaldehyde. Juven *et al*., (1994) showed that the antimicrobial effect of cinnamon oil increased as pH decreased from 6.5 to 5.5. Results indicate that cinnamon oil and cinnamaldehyde have the potential to improve nutrient utilization in the rumen, but in beef production systems the effects may be more relevant in feeding conditions that favour low ruminal pH.

Castillejos *et al.,* (2006) tested the benefits eugenol on rumen microbial fermentation with two different types of diets. Data confirmed that in a 60:40 forage:concentrate dairy cattle diet based on alfalfa hay, corn grain, barley grain and soybean meal, eugenol reduced ammonia-N and branched chain volatile fatty acids (BCVFA) concentrations, suggesting that deamination was inhibited. In a 10:90 beef-type diet based on straw, corn grain, barley grain and soybean meal, eugenol reduced total VFA concentration and the proportion of propionate, and increased the proportion of acetate and the acetate to propionate ratio. This fermentation profile may not be desirable for beef production. Therefore, it appears that eugenol may improve VFA production and profile, and N utilization in the rumen of lactating animals, but the fermentation profile does not support its recommendation for beef cattle diets.

When anise oil was used in *in vitro* fermentation studies using rumen fluid from beef cattle fed a 10:90 forage to concentrate diet and pH 5.5, ammonia-N concentration and acetate proportion decreased, and propionate proportion increased without affecting total VFA production (Cardozo *et al.,* 2005). Cardozo *et al*., (2006) supplemented anise oil to growing heifers fed a 10:90 forage to concentrate diet and reported a trend to increase DM intake. Total VFA concentration was not affected, but the molar proportion of acetate decreased and the molar proportion of propionate increased, and the acetate to propionate ratio decreased. Anise oil also decreased ammonia-N concentration and protozoa counts. These results suggest that anise oil inhibited deamination of amino acids and reduced the acetate to propionate ratio in the rumen, and may be beneficial for beef production systems.

Cardozo *et al.,* (2005) demonstrated that in an *in vitro* system with rumen fluid from beef cattle fed a 10:90 straw:concentrate ratio diet, at pH 7.0, capsicum oil reduced total VFA and ammonia-N concentrations but increased the acetate to propionate ratio. At pH 5.5 capsicum oil reduced ammonia-N concentration, increased total VFA production and propionate proportion, and reduced acetate proportion and the acetate to propionate ratio. The effects of capsicum oil on high concentrate diets at low pH suggest that nutrient utilization in the rumen may be improved. The low pH appears to shift the molecule to a more hydrophobic status, being more active as antimicrobial.

Cardozo *et al.*, (2005) tested the effects of garlic oil using rumen fluid and a high concentrate diet typically found in feedlot beef at different pH (7.0 vs. 5.5). At pH 7.0 garlic oil lowered ammonia-N and total VFA concentrations, at pH 5.5 ammonia-N concentration was also reduced, but total VFA concentration and propionate proportion increased, and acetate proportion and the acetate to propionate ratio decreased compared with a control with no garlic, suggesting a shift in rumen microbial fermentation.

Effects on animal production

Few experiments on the effects of essential oils on production have been documented. Busquet *et al.*, (2003) reported that the addition of cinnamadehyde to lactating dairy cattle resulted in a slight reduction in feed intake (0.3 kg/d), but an increase of 1.0 L/d in milk production, although differences did not reach significance. Busquet *et al.*, (2003) also reported an increase of 1 L/animal/d in milk production compared to a control, but the difference was not significant. Yang *et al.*, (2006) reported no effect of garlic powder on milk production and composition, although the effect may be different if the extract instead of the powder would have been used, because main active components identified are the result of transformation during oil extraction (Lawson, 1996).

Effects of combined essential oils

The additive, synergistic and (or) antagonistic effects of combined essential oils have been reported (Burt, 2004). As a result, many commercial products on the market have combined one or more essential oils, but very limited research is available on the potential synergies among them.

Conclusion

Essential oils and their active components may have a strong antimicrobial activity against gram positive and negative bacteria. At doses between 50 and 500 mg/L, some essential oils and their active components were able to modify rumen fermentation by changing VFA production and protein metabolism. In general terms, the fermentation profile suggests that the main mechanism of action is the inhibition of deamination. However, these effects may be diet and pH dependent. Based on the mechanisms of action of different additives on nutrient degradation and fermentation in the rumen, it is possible to identify potential synergies. A clear definition of the effects and target activities to modify, and a careful selection and combination of essential oils or their active components to modify these activities may provide a useful tool to improve the efficiency of nutrient utilization in the rumen. However, the limited scientific information published on the ruminal effects of many of the commonly used essential oils may result in confusion and inappropriate use of products and doses. Furthermore, there is an urgent need to conduct in vivo studies to determine the optimal dose and effects on animal performance.

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