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The Animal Production Society of Kenya (APSK) 2023 Annual Scientific Symposium

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Resilient and Sustainable Food Systems Transformation Agenda: Making Climate Smart Livestock Production Future-Compliant

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Ministry of Agriculture and Livestock Development

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PREFACE

The annual scientific symposium is the main mechanism through which the APSK objectives are met, that is, providing a forum for stakeholders – professionals and practitioners - to get together and share views on issues germane to livestock production. 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. An aging farming community, climate change and its complex relationships with livestock production systems, and low investments in agriculture are other emerging trends for consideration. Without urgent socio-economic responses, the human population suffering will escalate, jeopardizing lives and livelihoods for years to come.

Development trajectories in the long-term will be affected by the choices Kenya make now. Investment in the productivity of the livestock sub sector to feed our people is urgent, more than ever. 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 Bottom-up Economic Transformation Agenda (BETA).

However, unmanaged increases in livestock production could also result 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 genetic resources, feeds, and animal health services - as well as markets.

The APSK 2023 scientific symposium provided an 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 "Resilient and Sustainable Food Systems Transformation Agenda: Making Livestock Production Future-Compliant". The symposium platform opened an excellent opportunity for budding scientists and practitioners, and established inclusivity paths. It provided options and new opportunities for early-career scientists to engage, network, form research collaborations, exchange cutting-edge ideas and share results.

We would like to express our gratitude and special thanks to the sponsors of the symposium. 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 symposium participants.

After the symposium, presenters were asked to submit or revise their papers, considering 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 contents rests entirely with the authors. It is our hope that the APSK 2023 scientific symposium proceedings will provide useful reference material for those interested in understanding the major trends and associated issues covered during the scientific symposium.

Samuel M. Mbuku, PhD
Editor in Chief, APSK 2023 Symposium Proceedings

OPENING SPEECH BY HON JONATHAN MUEKE, PRINCIPAL SECRETARY, STATE DEPARTMENT FOR LIVESTOCK DEVELOPMENT, MINISTRY OF AGRICULTURE AND LIVESTOCK DEVELOPMENT DURING OFFICIAL OPENING OF THE ANIMAL PRODUCTION SOCIETY OF KENYA 2023 SCIENTIFIC SYMPOSIUM

[DATE: OCTOBER 24-27, 2023], KISUMU, KENYA

Director Livestock Production, Mr. Bishar Elmi

Director Livestock Policy Research and Regulations, Dr. Christopher Wanga

The Deputy Director General KALRO, Dr. Evans Ilatsia

The Chairperson Animal Production Society of Kenya, Dr. Samuel Mbuku

Distinguished Participants

Ladies and Gentlemen

It gives me great pleasure to be with you today, to officiate this special occasion of the Animal Production Society of Kenya (APSK) Annual Scientific Symposium 2023. You are meeting here this week to deliberate on a very important subject for Kenya today – that is, "Resilient and Sustainable Food Systems Transformation Agenda: Making Livestock Production Future-Compliant". The configuration of Food Systems is integrated in nature. Last week, we celebrated World Food Day 2023 under the theme - Water is Life, Water is Food. Leave No One Behind!

In Kenya, the livestock sector will contribute significantly to the food security and nutrition agenda. We must feed our people. We cannot allow Kenyan citizens to die needlessly because of hunger. I have no doubt, the animal production professionals and technical officers gathered here today will address this subject effectively.

Ladies and Gentlemen

Over the next four days, you will discuss the best ways of building sustainable food systems together. To secure sustainable food systems, we must work with intelligence and innovation. I am aware, our researchers are pushing forward new technologies, innovations, and digital solutions to help our farmers work more precisely, efficiently, and sustainably. We thank our research institutions and will continue to support them.

As you all know, the Ministry is undertaking farmer registration and profiling which aims to establish a national central farmers' database through the Kenya Integrated Agriculture Management Information System (KIAMIS). In the same breadth, we are currently developing a Livestock Master Plan (LMP), which aims to identify investment options in the livestock value chains through evidence-based sector analysis. Data is critical in decision making as well as developing sustainable financing and investment mechanisms in the livestock sector. Please participate, actively, in these initiatives.

Mr. Chairman,

We need these professionals to intensify livestock research, production and development across a broad range of livestock breeds, feed choices and livestock marketing options. Well thought and implemented extension services including capacity building will effectively encourage adoption of

innovations by farmers. This symposium is critical in addressing the nexus between research and extension services – working collaboratively and in partnerships with county governments.

While livestock farming faces multiple challenges, I am optimistic. Why? We enjoy many potential advantages. We have relatively abundant land – can support livestock farming. We have industrious workforce with impressive entrepreneurial skills, and a deep reservoir of traditional knowledge in the management of livestock. We stand high in science and technology advances. If we are able to utilize effectively our natural, human and technological resources, we can produce enough to feed our people and have surplus for domestic and export markets. It is possible!

Ladies and Gentlemen

Recognizing the challenges and the opportunities, the Ministry developed Sessional Paper No. 03 of 2020 on The Livestock Policy through an inclusive and consultative process. It is expected that the Policy changes envisioned will revitalize the livestock sector and guarantee sustainability of livestock farming as a major economic thrust in the country. The Livestock Bill 2021 which is under development will provide enabling environment for the development and regulation of the livestock sector. Let us ALL support it. We must work together!

Mr. Chairman,

I am aware your members are patiently waiting for the Enactment of the Animal Production Professionals and Technicians Bill, 2023. The Bill, once enacted into Law, will provide for the training, registration and licensing of animal production professionals, technicians and specialists; provide for the regulation of animal production training institutions; and provide for the regulation of the standards and practice of the animal production profession. The appointed Task Force completed development of the draft Bill including regional and national validation workshops in July 2023. Some members of the Task Force are in this room. We thank you very much!

Today, I want to assure Animal Production Professionals of my commitment to engage Parliament and complete this process within the shortest time possible. Establishment of the Animal Production Professionals and Technicians Board is long overdue. Mr. Chairman APSK, I want to sincerely thank you for your tireless efforts and energies over the years championing the enactment of this Law. We will continue to work together and your team in the remaining stages. The dream will turn to a reality very soon. We need a regulated livestock sub-sector. I want to assure APSK members that the Government through the State Department for Livestock Development will continue to support the Society, as well.

Ladies and Gentlemen

I trust you will have stimulating discussions over these coming four days. I hope that, by the end of the day Friday, you will have identified and endorsed ambitious priorities for action aligned to the Bottom-up Economic Transformation Agenda to advance the sustainable development of livestock sector in Kenya. I look forward to receive a copy of proceedings from this symposium.

It is now my pleasure to declare the Animal Production Society of Kenya 2023 Scientific Symposium officially open.

Thank you

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

The Draft Animal Production Professionals and Technicians Bill 2023

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Abstract

The draft Animal Production Professionals and Technicians Bill 2022 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.

Review of Basic Poultry Farm Biosecurity Practices

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Abstract

The Kenyan poultry industry continues to be one of the most economically significant sectors in the livestock industry contributing up to 30% of the Agricultural Gross Domestic Product. Numerous households especially those near urban centers earn a living from poultry production and with the projected population growth and increase in the middle-class population, poultry consumption is expected to rise and so will the production. Apart from the economic importance of poultry production, it also influences human health security. As farmers intensify their production to meet the growing demand, disease challenges that force them to use antimicrobials to control and treat infections also increase. Improper or overuse of antimicrobials can result in Anti-Microbial Resistance (AMR) which occurs when bacteria, viruses, fungi, and parasites adapt and no longer respond to medicines, making infections harder to treat and increasing the risk of disease spread, severe illness, and death. AMR is one of the greatest threats not only to animal production but also to human health. There is need to employ measures that will prevent or reduce disease incidences, consequently reducing use of antimicrobials in farms. Biosecurity is one of the infection prevention measures which refers to the prevention of introduction, establishment or spread of infection or disease. Critical control points in farms such as source of products and inputs, entry to sites and sheds as well as movement within the site must be closely monitored to prevent introduction and spread of diseases. Some of the biosecurity measures that should be implemented in farms include, installing fences, lockable gates and doors, footbaths with disinfectants and proper cleaning and disinfection. Training farmers and livestock production professionals on these biosecurity practices could encourage adoption resulting in reduction of disease incidences and AMR.

Keywords: *Biosecurity, Animal health, Disease prevention, Training*

Towards Ending Drought Emergencies in Kenya (Twende) Project

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TWENDE - Towards Ending Drought Emergencies an Ecosystem Based Adaptation for Restoration of Kenyan Rangelands

TWENDE - Towards Ending Drought Emergencies in Kenya (TWENDE) Project is an Ecosystem Based Adaptation for Restoration of Kenyan Rangelands whose objective is to reduce the cost of climate change induced drought on Kenya's national economy by increasing resilience of the livestock and other land use sectors in restored and effectively governed rangeland ecosystems. The project focuses on eleven of Kenya's Arid and Semi-Arid (ASAL) counties including *Garissa, Tana River, Isiolo, Marsabit, Samburu, Kajiado, Kitui, Makueni, Tharaka-Nithi, Meru and Taita Taveta.*

The project is implemented by the Ministry of Agriculture, Livestock, Fisheries and Cooperatives (MoALFC), National Drought and Management Authority (NDMA), and Conservation International (CI) as executing entities in partnership with respective County Governments and other specifies service providers. TWENDE project, will be implemented with financial support from the Green Climate Fund through the International Union Conservation of Nature (IUCN) as the Accredited Entity. The project will contribute to improved adaptation to climate change of Kenya's national policy of "Ending Drought Emergencies", as outlined in "Kenya Vision 2030".

The project will be implemented in 3 landscapes encompassing 11 counties, which have devolved powers under Kenya's new constitution. The project will benefit 620,000 people in 104,000 households and will protect or restore 500,000 hectares of rangelands in a landscape of 2.5 million hectares**.**

Keywords: *Rangelands; Pastoralism; Sustainable livelihoods; Adaptation; Restoration*

The Kenya Livestock Commercialization Project - KeLCoP

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Kenya Livestock Commercialization Project (KeLCoP) is a six year project that is jointly funded by; Government of Kenya (GOK), International Fund for Agricultural Development (IFAD), Heifer International, Participating Financial Institutions (PFI) and Beneficiary communities. The Kenya Livestock Commercialization Project (KeLCoP) is a project launched by the Kenyan government in partnership with the International Fund for Agricultural Development (IFAD). The project was established with the aim of enhancing the commercialization of the country's livestock sector and improving the livelihoods of small-scale livestock farmers.

The KeLCoP project is being implemented in 10 counties in Kenya, which are predominantly arid and semi-arid regions. The project focuses on increasing the productivity and profitability of small-scale livestock farmers through various interventions such as improving access to animal health services, strengthening market linkages, and promoting better livestock management practices.

Some of the key components of the KeLCoP project include the establishment of community-based animal health workers, the provision of veterinary drugs and vaccines, the construction of livestock markets, and the development of value chains for livestock products such as milk, meat, and hides.

LIVESTOCK NUTRITION FOR SUSTAINABLE FOOD SYSTEMS

Animal Feed Balance Assessment: Implications for Policy and Investment Planning in Kenya

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Abstract

A feed inventory and balance assessment study was conducted in the 47 Counties of Kenya falling under the Arid and Semi-Arid land (ASAL) and high and medium rainfall areas (HMRA) from 2018 to 2019 for phase 1 and 2019 to 2022 for phase 2 respectively. The objective of the assessment was to determine the national feed requirements, feed production and availability; competitive feed uses as well as feed balance annually. Several tools were employed in the development and implementation of the study thus; an excel-based model for 'estimation of dry matter (DM), Metabolizable Energy (ME) and crude protein (CP) requirements of different Livestock type'; 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'. Using the tools stated above, trainings on the methodologies for feed assessment and feed balance including Predictive Livestock Early Warning System (PLEWS) were conducted to the county representatives, State Department for Livestock (SDL), and Data Analysts in both phases. The assessment results showed that the total annual feed requirement for ruminants is 55 million metric tons (MT) as DM. The annual feed production is 46 million MT indicating a deficit of 9 million MT on potential basis. The competitive feed uses (alternative uses, wastages and losses) accounted for 46.3 percent of the land feed production potential (equivalent to 21.3 million MT of DM). Therefore, on actual basis, the amount of feed available to the animals is 24.7 million MT against the national feed requirement of 55 million MT resulting in a 55 percent negative feed balance. The land carrying capacity in terms of potential and actual as DM is 19.9 and 10.7 Million Tropical Livestock Units (TLUs) respectively compared to the current TLUs of 24.07 Million. Demonstrating that, Kenya can only support 44.5 percent of the current livestock population on actual basis. It can therefore be concluded that the national annual livestock feed requirements surpass the actual feed resources production and availability. The study findings revealed the potential for overstocking, overgrazing and eminent land degradation if the situation persists and suggesting the need for increased off-take, de-stocking and increasing fodder production and utilization. The total annual feed gap was equivalent to 21,058,000 tons of DM lost which is enough to feed 9,155,652 TLUs per year valued at Kshs 275 Billion. Similarly, the lost DM per year is equivalent to 1.7 Billion hay bales weighing 15 Kgs each of 80 to 90 percent on DM basis valued at Kshs 825 Billion. The estimated loss as equivalent TLUs and hay bales can employ 9.2 and 27.5 Million millennium farm workers respectively. Various technical, institutional and policy interventions options for bridging the identified feed shortages and losses were explored. In response to the study findings, the Ministry of Agriculture and Livestock Development in collaboration with partners has since formulated the national feed strategy. The strategy proposes to drive 11 livestock enterprises and promote the farming of 10 key feed resources covering 5.4 million acres to meet the national feed requirements at an investment cost of Kshs 47 Billion; while generating 145, 000 jobs annually for the next 10 years. Consequently, focused investments in feed inputs, storage and conservation, value addition and

mechanization as well as transportation guided by policy and investment planning for Kenya becomes necessary.

Keywords: *feed inventory, feed requirements, feed supply, feed gaps, feed strategy, investment planning*

Assessing the Potential and Utilization of Insects as Alternative Non-conventional Protein Source for Fish Among Farming Communities in Nyandarua, Nakuru and Nyeri Counties

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Abstract

In Kenya, many farmers have embraced fish farming to curb food shortages, poverty and creation of employment. However, they face a challenge of high cost of quality fish feeds. Most depend on feeds like fish and soybean meals as major ingredients for fish and other aquaculture species. Such feeds are very expensive and not readily available thus discouraging their use by many farmers. This is a major challenge to the growth of fish industry in the country. In the recent years, BSF fly has been recruited to address nutritional challenges in livestock. The Black Soldier Fly Larvae (BSFL) has been incorporated as a protein and fat source in animal feeds instead of the more expensive protein sources such as silver fish, sunflower and cotton seed cake among others. In addition, BSF larvae have also been harvested and fed directly to livestock animals. Black Soldier Fly farming is a low capital venture owing to the fact that the main ingredients are organic waste from kitchens, horticultural wastes like vegetables and fruits (market waste), waste cereals, abattoir waste, municipal market waste and even faecal matter among other organic wastes. Large scale production of BSF larvae can be optimally used to manage the organic waste efficiently in the surrounding environments, and more important, the larvae obtained will be used to address the ever-elusive livestock protein needs by processing them into various products. The study results indicate that fish farming was predominantly an activity for men in all counties (Nyeri, 86%, Nakuru, 75%, and Nyandarua, 63%). Farmers in the age bracket of 30 to 49 years engaged more in fish farming (47.0%) as compared to the age group 20 to 29 years (17.6%) and 50 to 59 years (14.7%). Most farmers showed higher preferences for producing table size fish which they deemed would fetch better market prices at the end of the production cycle with fewer farmers engaging in fingerling production. The cost of production of fish diets per Kilogram indicates that omena based diets were the most expensive at Kes. 163.21 and 153.58 respectively for cold (Trout) and warm water species (Tilapia and catfish) respectively. Soya based feeds followed in terms of cost at Kes. 89.97 and 86.29 respectively for cold and warm water species respectively. The least cost feeds were the BSF based ones at Kes. 80.03 and 67.66 respectively for cold and warm water species respectively. The majority (81%) of the farmers were not aware of the use of BSF as fish feed. However, majority of them (97%) were willing to use

BSF to feed their fish. This results show the potential of BSFL as one of the highly nutritive, affordable and safe feed ingredient for compounding fish feed rations.

Keywords: *Fish farming, Black soldier fly larvae (BSFL), Non-conventional protein source, cross sectional survey*.

Introduction

Fisheries and aquaculture support the livelihoods of 10 – 12% of the world's population, and it remains a vital source of essential nutrients, which accounts for over 17% of animal protein that is consumed globally (FAO, 2018). In Africa, the potential for aquaculture expansion is enormous but currently, it contributes only 2% of the total global aquaculture production. Egypt is a major African producer while sub-Saharan Africa produces only 0.6% of the world production (FAO, 2018). In Kenya, aquaculture farming is practiced by small-scale farmers under semi-intensive system using earthen ponds and is largely characterized by low inputs and diverse farming conditions in terms of income level and market objective (Omasaki *et al.,* 2016). The main species that are cultured for food include Nile tilapia (*Oreochromis niloticus*), Common carp (*Cyprinus carpio*), African catfish (*Clarias gariepinus*) and the Rainbow trout (*Oncorhynchus mykiss)* (Opiyo *et al.,* 2017). Aquaculture farming has been on a continual increase in the country since the Government initiated the National Fish Farming Enterprise Productivity Program in 2009. The program provided farm subsidies to farmers, established new hatcheries, revived and upscaled existing ones. Consequently, the number of farmers engaged in fish farming increased to 49,050 from 4,742 (Nyandat & Owiti, 2013). Land size under aquaculture farming expanded to 3,500 Hectares in 2018 from 722 in 2008 (Opiyo *et al.,* 2018). Production levels shot from 4,452 metric tonnes in 2008 to 24,096 in 2014. In 2020, fish outputs increased by 7.6% from 18.5 thousand tonnes in 2019 to 19.9 thousand tons in 2020. The economic survey (2021) reports that fish farming contributes 16.1% to the total fish production.

Despite the milestone in the sector, aquaculture farming is facing significant challenges and bottlenecks. Among other reasons, lack of fish feeds leading to increased cost of production (Omasaki *et al.,* 2017). Limited supplies of feeds mainly proteins have led to competition between farm animals and humans for these products, thus limiting the intensification of fish farming. Commercial feed formulation has heavily depended on proteins from plant sources and silver fish as the main protein supplement, which are also used to address the dietary needs for man. This has led to over fishing of silver fish, high market prices and subsequently low protein supply to animals and competition with man triggering malnutrition to both. For protein deficient countries like Kenya, the solution may lie with the exploitation of non-convectional protein sources such as insect feeds. Insects such as Black Soldier Fly (BSF) larvae are of similar or slightly higher quality than these conventional protein-rich feed ingredients and may serve as an alternative and economically viable protein source for aquaculture. BSF larvae has been found to have between 42 - 50% protein (Van Huis *et al.,* 2013; Diener *et al.,* 2011).

Methodology

Study area

This study was conducted in three counties (Nyandarua, Nyeri, and Nakuru) in Kenya. In each county, sub-counties and wards were sampled as indicated in Table 1.

Table 1: Sampled counties, sub-counties and wards

County	Sub-counties	Wards
Nakuru	Gilgil	Gilgil
	Naivasha	Hells gate, Maeilla
	Nakuru Town East	Menengai
	Kinangop	Gathara, Githioro, North kinangop
Nyandarua	Kipipiri	Kipipiri
	Ndaragwa	Kiriita, Shamata
	Oljoroorok	Weru
	Olkalou	Rurii
Nyeri	Kieni East	Kabaru, Naromoru

Data collection

Baseline primary data and information were sourced from fish farmers through direct interviews using a semi-structured questionnaire and frontline extension workers using a key informant interview guide. Secondary data was from county fisheries reports, ration formulation modelling, literature, and desk reviews. The data included information on the farmer's socio-demography, the status of fish production, and the potential use of insects, including BFSL, in fish feeds.

Survey design

The study applied a cross-sectional design involving a total of 34 fish farms selected through snowball sampling procedure. KCSAP county coordinators and county livestock officers identified the initial farmers in the sampling process. Through a snowball sampling, initial farmers identified other farmers. Farmers had to meet defined criteria of keeping fish; Tilapia, Catfish or Trout. Statistical Package for Social Science (SPSS, version 20) was used to enter and analyze the coded data.

Results

Socio-demographic characteristics

Fish farming was predominantly an activity for men in all counties (Nyeri, 86%, Nakuru, 75%, and Nyandarua, 63%). Farmers in the age bracket of 30 to 49 years engaged more in fish farming (47.0%) as compared to the age group 20 to 29 years (17.6%) and 50 to 59 years (14.7%). The finding agrees with the studies conducted by Ole-Moiyoi (2017) as well as Obiero *et al.,* (2019). The male dominance in fish farming can be attributed to decision making, benefits sharing and power relations within the households (Kruijssen *et al.,* 2018). On the other hand, a majority (82.4%) of the farmers had a secondary and above level of education, with few (17.6%) educated up to the primary level. A higher percentage of fish farmers (57.6%) were doing semi-intensive production system using earthen ponds compared to intensive production system (42.4%).

Type of fish reared and purpose of fish farming

Table 2 shows the type of fish farmed and the reasons for engaging into fish farming. Majority of the farmers ran their fish commercially (71.9%) with the intention of commercialising their entreprises to generate income. Type of fish kept in the studied areas was limited to three species, Nile tilapia, trout and catfish. This mirrors the lack of diversity of aquaculture species in the three counties, which could be associated with low production of fish harvests and income (Opiyo *et al.,* 2018). This provides a clear indication that there is need for introduction of more fish species for culture in the country to diversify and enhanced the overall output. Nile tilapia farmers mostly produced table size fish unlike trout and catfish who targeted fingerling, brooders, table size and fillet production.

Table 2: Purpose and type of fish species reared

Purpose of rearing	Frequency	Percent
Commercial	23	71.9
Subsistence	2	6.2
Commercial and subsistence	7	21.9
Total	***32***	***100.0***

Fish marketing

Farm-gate prices for fingerlings, table size fish and value-added fish product

Aquaculture sector plays a vital role in the national economy. Fish farming is an avenue for economic empowerment and food security as it boosts household subsistence requirements and enhances cash income thus reducing poverty levels. The respondents were asked about farm-gate prices of fingerlings, table size fish and their value-added product (Table 3). Average prices (KES) for tilapia, catfish and trout fingerlings were 9.7, 15 and 28.3 respectively. Farmers were selling mature table size fish at an average of 335, 540 and 650 KES for tilapia, catfish and trout respectively. The price for value-added tilapia, catfish and trout were 700, 700 and 1200 in that order.

Rearing period and harvest weights

The rearing period for tilapia, catfish and trout fish were approximately 10.4, 10.2 and 12 months whereas the harvested average weights were 326.76, 1357.14 and 555 grams respectively (Table 3). Growth, size and feed conversion efficiency are as the most important traits in the choice of species kept. Fish with high efficiency in these traits will attain harvest weight early.

Averagely, the prices (Table 3) for fingerlings, raw and processed (value-added) fish ranged from 9.7 to 28, 335 to 650 and 700 to 1200 Kenya shillings (KES) respectively. The price of table size fish depends on the fish species, weight of the fish, height and thickness. Generally, price for trout species were higher compared to the other species. On average, heavy fish fetches better prices because it is believed that they have more flesh. Heavy fish at harvest will fetch better market prices. This therefore, is clearly seen in the current study as farmers were tempted to prolong their rearing period in order to achieve heavier weights.

Table 3: Rearing period, harvesting size and prices for raw and value-added tilapia, catfish and trout across the three counties

Rearing period in months				
Fish species	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Tilapia	6.00	12.00	10.4	2.16
Catfish	6.00	12.00	10.25	2.49
Trout	8.00	16.00	12.0	3.27
Harvesting size in grams				
Tilapia	250.00	400.00	326.76	55.87
Catfish	700.00	2500.00	1357.14	789.21
Trout	250.00	1000.00	555.0	406.36
Fingerling prices in Kenya shillings (KES)				
Tilapia	4.00	15.00	9.7	3.19
Catfish	15.00	15.00	15.0	0.00
Trout	13.00	45.00	28.25	16.60
Prices for raw table size fish in Kenya shillings (KES)				
Tilapia	200.00	600.00	335.0	149.16
Catfish	250.00	800.00	540.0	277.04
Trout	300.00	1000.00	650.0	404.15
Price of value-added fish in Kenya shillings (KES)				
Tilapia	700.00	700.00	700.0	0.00

Rearing period in months				
Fish species	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Catfish	700.00	700.00	700.0	0.00
Trout	1000.00	1400.00	1200.0	282.84

Use of insects as feed

Table 4 presents the various sources of locally available insects used in fish farms, information, awareness and willingness to use insects (BSF) as fish feed. Over 46% of the farmers indicated to have access to information on locally available insects. Predominantly, insects were not used (91%) in fish farms as feeds. About 6% of the respondents captured insects from the wild whereas 3% reared specifically crickets, Daphnia and red worms. Majority (80%) of the sampled farmers indicated that they were not aware of BSF usage in the fish ration. However, the majority (97%) revealed that they are willing and ready to adopt and utilize the BSF larvae in their fish farms.

Table 4: Information of locally available insect used as fish feeds

Availability of information	**Frequency**	**Percent**
Yes	15	46.9
No	17	53.1
Total	***32***	***100***
Source of insect		
Reared	1	2.9
Collected from wild	2	5.9
Not using	31	91.2
Total	***34***	***100.0***
Awareness of BSF as fish feed		
Yes	6	19.4
No	25	80.6
Total	***31***	***100***
Willingness to use BSF in fish feeds		
Yes	32	97.0
No	1	3.0
Total	***33***	***100.0***

Cost analysis of fish feeds

The cost of BSF was arrived at after computing all variable costs associated with production of 1 kg of BSF based feeds, Omena- based feeds and soya based feeds for both the warm (tilapia and catfish) and cold (Trout) species (Table 5). Some of the variable inputs that were costed include the cost of ingredients, electricity, labour, packaging material among others.

From the computations, feed ingredients across rations accounted for the highest percentage of costs. Further, quality protein sources are the most challenging to acquire. The cost of production per Kilogram indicates that omena based diets were the most expensive at Kes. 163.21 and 153.58 respectively for cold (Trout) and warm water species (Tilapia and catfish) respectively. Soya based feeds followed in terms of cost at Kes. 89.97 and 86.29 respectively for cold and warm water species respectively. The least cost feeds were the BSF based ones at Kes. 80.03 and 67.66 respectively for cold and warm water species respectively. This empirical evidence further proves that BSF feeds are favourable to farmers as far as costs are concerned.

Table 5: Cost analysis summary of assorted fish feeds

Type of feed	Cost / Kg (Ksh)
Omena based feeds (Trout)	163.21
Omena based feeds (Tilapia & Catfish)	153.58
Soya based feeds (Trout)	89.97
Soya based feeds (Tilapia & Catfish)	86.29
BSF based feeds (Trout)	80.03
BSF based feeds (Tilapia & Catfish)	67.66

Discussion

Socio-demographic characteristics

The dominance of men in fish farming in our study agrees with the report by Ole-Moiyoi (2017) and Obiero *et al.,* (2019). Also, our finding concurs with farm Africa (2016) report, which indicated that men do most fish farming in Kenya. The male dominance in fish farming is attributed to decision-making, benefits sharing and power relations within the households (Kruijssen *et al.,* 2018), which may lead to limited participation of women in fish farming. Although men dominate the fish industry, women play a vital role in fish farming, especially in routine fish management and cultural activities, cleaning ponds and providing security to the ponds during day time. With the high literacy level and interest among farmers, particularly those middle-aged (30-49 years), both public and private service providers can impart basic technical and entrepreneurial skills in fish farming quickly.

Dominancy of semi-intensive system is attributed to lower input costs arising from mainly the use of available natural feeds that are cheaper. Farmers mainly use livestock manure to fertilize ponds to encourage growth of natural feeds and supplement with available feeds such as bran combined with formulated rations. The findings collaborate well with Omasaki *et al.,* (2017) who reported that, in Kenya, aquaculture farming is practiced by small-scale farmers under semi-intensive system using earthen ponds characterized by low inputs and diverse farming conditions in terms of income level and market objective. Contrary, intensive farmers in the studied counties have capitalised heavily on infrastructure and fish husbandry technologies including use of concrete ponds and re - circulating culture techniques as in the case of trout farmers.

Across all the surveyed households, fish farming played an important role as a source of income and nutrition. Such income enabled households to access other foods and to improve their overall living standards. However, the commercial orientation varied among the fish species. The relevance of harvest weight in marketing fish is often important to both consumers and producers (Blonk *et al.,* 2010; Trong *et al.,* 2013). Most farmers emphasized on producing table size fish. Heavy fish at harvest will fetch better market prices at the end of the production cycle for these farmers, which explains why most farmers showed higher preferences for table size fish. Few farmers showed the preference to fingerling production. From the observation, this group of farmers were more knowledgeable and more resource endowed. Sevilleja (2001) reported that the production and management of fingerlings generally requires more resources, skills and technology than rearing grow out fish, which is in agreement with the findings from this study. Taken together, our results showed that farmers have a different market orientation, which translates to different management strategies and different preferences for breeding goal traits.

The culture period is influenced by factors such as timing of harvest towards festive period and lack of fish feeds, which subsequently affect the quantity and value of fish harvested (Raufu *et al.,* 2009). The optimum size of fish harvested is commonly 300 grams under standard aquaculture husbandry practices (Okechi, 2004). Some farmers preferred to harvest fish of higher weight between 500 - 700g which take a longer time to attain than standard table sizes, but this was done based on market

demands. This was reflected in the sizes of fish harvested which ranged from 250g to 1000g. For example, farmers who harvested at 500g sold at higher average prices than those who harvested at 300g. This is in agreement with Kawarazuka (2010), who observed that large sized fish were sold as a strategy to meet the daily market needs while small sized fish are consumed at home.

Potential use of BSFL meal in fish feeds and cost implication

The high cost of trout fish feed is because of the high nutrient requirements compared to tilapia and catfish (NRC, 1993). It needs a high percentage of protein in feed to supply the required amino acids and hence the high cost of protein source among the feed ingredients. Conventional protein sources are expensive; therefore, fish feed prices represent up to 60-70% of operational expenses in fish production (Alfiko *et al.*, 2022). Therefore, most (75%) of the available commercial fish feeds contain crude protein values of less than 30% (Shitote et al.,2013), which is lower than the recommendations in Kenya by the Kenya Bureau of Statistics (KEBS). The cost of production indicates that Fish meal (FM)-based feeds were the most expensive, followed by Soya Based meals (SBM)-based feed, mainly because of the high price of their protein content. However, the Black soldier fly larvae (BSFL) meal-based feed cost was significantly lower than those formulated using SBM and FM, respectively. The low cost was because of the lower price of BSFL meal compared to the other protein sources. Besides the feed ingredients, reducing the cost of labour, packaging, and electricity will reduce the cost and hence enhance the affordability of fish feeds to farmers.

Different types of feeds including mash, home-made pellets, commercial pressed pellets, and extruded floating feeds are used by farmers in the country. Commercial fish feed processors are Unga Feeds, Sigma, Food Tech Africa, Jewlet Enterprises and Lenalia Feeds Ltd (Opiyo *et al.*, 2018). These Commercial feeds are far much expensive for majority of smallholder fish farmers. Consequently, these financially constrained farmers have opted to utilize other livestock feeds such as chicken and swine feeds or formulate their own rations. This practice has resulted in stunted growth and nutritional diseases as the feed do not match fish dietary requirements (NRC, 1993) for optimum growth. The conventional protein sources used in formulating diets are expensive and have become scarce. Utilization of BSF insect as feeds is favourable and sustainable alternative protein source. This is because it is cheap and consumer acceptability is over 70% (Smith and Barnes, 2015).

Conclusion

The results from the current study indicated that fish farming is an activity that generate cash income, create employment opportunities, ensure food and nutrition security, and enhance societal empowerment to the community. This happened as farmers exploited the potential of tilapia, catfish and trout fish species. Utilization of insects and access of information by farmers on the available market opportunities locally and nearest urban cities are imperative for future planning and development of successful aquaculture farming. Developing alternative feed sources initiatives based on the locally available materials such Black Soldier Fly to address feed challenge is an overriding priority as it would lead to increased productivity in both short and long term.

Recommendations

More participation of women and youth in fish farming is encouraged to improve their livelihoods. Appropriate technologies and management practices (TIMPs) should be developed through research to promote other fish species and alternative protein sources, including insect meals, for a sustainable blue economy. Additionally, capacity building of the fishing community is necessary to address the challenges they face and to enhance their skills and knowledge of fish farming for improved production and income.

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Entomophagus Response of Indigenous Chicken to Diets Enriched with German Cockroach (Blattela germanica) Meal in Kenya

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Abstract

Feeding accounts for 65-70% of cost production in a chicken enterprise. Fishmeal has primarily been used as a source of protein in chicken feed owingto its excellent nutritional value. However, due to its unstable supply and variation in quality, recent studies have focused on finding alternative protein feedstuff, such as edible insects. A study was carried out to evaluate the effectsof substituting fishmeal (FM) with *Blattela germanica* meal (BGM) on the growth of chicks. KALRO improved indigenous chickens (KC),at the grower stage, eight weeks old, comprising an equal number of males and females were used as sampling units in a completely randomized design (CRD) feeding trial. Each of the four treatments was replicated three times. Birds were fed on dietary treatments that were isocaloric and isonitrogenous and comprised - treatments TA (87.5 %FM, 12.5% BGM), TB (62.5 % FM, 37.5 % BGM), and TC (50% FM, 50% BGM) TD (100 %FM, 0% FM)-Control. Data on daily feed intake and weekly live weight was taken for eight weeks and used to calculate the feed conversion ratio (FCR) and average dailygain (ADG). Data were subjected to a one-way analysis of variance (ANOVA). The feed intake, average daily gain, final weight gain, and feed conversion ratio was not significantly different from the control (P> 0.05). Thus, indigenous chicken fed diet with BGM and fishmeal performed similarly. As such, farmers should be encouraged to incorporate cockroachesas their on-farm feed to reduce the feed cost and increase chicken productivity.

Keywords: *Cockroach Meal, Chicken, Feed, Intake,Kenya*

Introduction

The supply of quality feeds has been one of the major constraints to increased chicken production in developing countries such as Kenya (Omondi, 2019). Even in areas where feeds are available, the high cost of compounded feeds has made theminaccessible to local smallholder farmers (Atela,2016). Poultry feed production relies on ingredientssuch as soya beans and fishmeal to supply proteins (Parisi *et al.*, 2020). The poultry feed industry utilizes 85% and 10 % of the world's soya meal and fishmeal, respectively (Zegeye, 2020). Ingredients that supply protein accounts for over 15% of the cost of chicken feed production (Khan *et al.*, 2018). The availability of fishmeal has been diminishing in thelast decade due to increased demand for human consumption. It has necessitated research on alternative protein supplies, such as edible insects.

Numerous edible insects have a crude protein content of 20-80 % of dry weight and a considerable proportion of fats, carbohydrates, minerals, and vitamins (Allegretti *et al.*, 2018; Rumpold and Schlüter, 2013). Scavenging chicken has co- evolved to feed on insects as part of their daily diets. Current avian research focuses on including edible insects in conventional chicken diets as a replacement for fishmeal to lower the feed costpartially. Strategies to increase poultry production through non-conventional feeds such as edible insects as a replacement for fishmeal are gaining popularity among smallholder farmers. Most evaluation tests have been done in broiler feeds with

minimumconsideration for indigenous chicken, yet themajority (>80%) of chicken produced in Sub-Saharan Africa (SSA) are indigenous. An insect such as oxya replaced 50% of fishmeal in poultry feeds with positive results. Feeding *Acheta domesticus* larvae to poultry increased feed conversion efficiency and weight gain (Oibiokpa *et al.*, 2018). Oyegoke *et al.*, (2006), while replacing fishmeal (4 % of the diet) with larvae of *C. forda*, revealed that there were no significant differences between the growth performance of broiler chicks that were fed the compounded larval diets and thosefed the conventional fishmeal. Scanty information is available where cockroach has been used as an ingredient in chicken feed thus limiting use as chicken feed. Ayssiwede *et al.*, (2011) reported that *Blattela orientalis*, - a cockroach species - had no negative effects when fed to indigenous chickensin Senegal. German cockroach is rich in protein (56-58%) and therefore suitable for chicken feeding (Ngaira *et al.*, 2022).

The current study investigated the effects of replacing fishmeal with *Blattela germanica* meal onthe growth performance and survival of KALRO- improved indigenous chicken. The findings will be useful for the farmer, feed manufacturers and policymakers who wish to consider adopting the use of cockroach meal as feed ingredient to optimize chicken productivity.

Materials and Method

Study Site and Design

A study was conducted at Kenya Agricultural and Livestock Research Organization at Non-RuminantResearch Institute, Kakamega. According to Jaetzold *et al.*, (2011), this area lies within Kakamega town at an altitude of 1585 m above sea level, a latitude of $00^0$16'N, and a longitude of $34^0$45'E. The mean annual rainfall is 1883.96 mm, the mean temperature is 21.00 C, the average maximum temperature is 27.0 ^{0}C, the average minimum temperature is 14.0 ^{0}C, the average evaporation is 120 mm, and the average daylength is 12 hours. This agroecology is suitable for crop and livestock production (Jaetzold *et al.*, 2011).

Experimental birds and design

Seventy-two birds, aged 49 -day's old mixed-sex KALRO Improved Kienyeji (KC) chicks were randomly allocated to four (4) treatment diets and replicated thrice (3). The number of chicks per replicate was six (6) and eighteen per (n = 18) per treatment. The recommended minimum birds per replicate is five (5). Each of the three replicates consisted of six birds (three males and three females) to make eighteen birds per treatment diet in a completely randomized design (CRD). The design was suitable for the current study because thesampling units (chicks) were similar, homogenous and in a controlled environment.

Experimental Diets

Four experimental treatment diets that were isocaloric and isonitrogenous were formulatedusing maize grain, wheat bran, soya beans, fishmeal(FM), and processed *Blatella germanica* meal (PBGM) as main ingredients (*Table 1*). Whereas omena (Silver Cyprinid fish) was used as fishmeal, soya beans were roasted using dry heat to remove anti-nutritional factors such as anti-trypsin, but bothwere ground using a hammer mill (*Figure 1*). Thesepercentage composition and proximate analyses were determined by (AOAC, 1990) and are shown in *Table 1*. The diets were formulated to meet the nutrient requirements for energy (ME = >2600 Kcal/Kg), crude protein (CP = 16 %), and crude fat (<7 %) based on standard guidelines (*Table 2*) adopted from NRC (1994). Metabolizable energy (ME) was estimated using the following formulae:

ME (kcal/Kg) = 37 x %CP + 81 x %fat + 35.5x %NFE

Management of Birds under Experiment

Chickens were allocated to 12 cages within a standard deep–litter system house, naturally well ventilated, with a daily photoperiod of 12 hours of light. The house, feeders, and drinkers were washedin clean water and disinfectant; it was fumigated before the arrival of the chicks. Each of the 12 penswas an experimental unit and measured one metre by two metres on a floor covered with dry wood shavings.

Each experimental unit had a drinker, and a round feeder was assigned from weeks 8 to 12 after hatching; after that, a feeder was replaced withNaivasha long feeder from week 13 to week 16. Birds were also provided with clean water and freshfeeds at *adlibitum*. Fresh feed was weighed before being added into the feeding trough, and remnants were removed and weighed the next day before thefresh feed was added. Before the feeding trial, birds were subjected to standard routine management and vaccinated according to recommended indigenous chicken schedule. On occasions when there was morbidity, the sick birds were isolated and treated with conventional medications and then returned to the flock. The bedding material (wood shaving) was changed weekly, and the experiment lasted eight weeks. Any mortality was removed from cages, and a post mortem conducted to rule out feed-related death.

Growth Performance

The birds in each cage were put in a tarred carton box and weighed on weekly basis at 0900 hrs. The weight of individual bird was obtained by dividing the total weight by number of birds in each cage. The average daily gain (ADG) was calculated.

Feed Intake

Feed intake was monitored daily and weekly by weighing feed remnants, then emptying the feeders before adding fresh feed (1kg). The Naivasha long feeders used measured (10 cm by 23 cm by 100 cm)and was placed in each cage. The weight of feed consumed by each bird was calculated by obtainingthe difference (initial weight + weight of feed remnants). The total feed intake and average daily feed intake per bird was calculated.

Statistical Analysis

The following statistical model guided analysis:$Yij = \mu + \alpha i + \varepsilon ij$,

Where; **Yij** = Feed intake (g day-1)/ Initial weight/Total Weight gain/Average Daily Weight gain/Final weight/Feed conversion ratio (g/bird/ day); **μ**= is the overall mean; **αi** = is effect of the treatment diet (i = TA…TD); **εij** = is the error term. All quantitative data was analysed in R 4.1.2 for analysis of variance to determine difference between treatments. Least square means were obtained using the Bonferroni test and the significance was calculated at a 5% confidence level. Data on weight gain, feed intake and feed conversion ratio were analysed using one way analysis of variance (ANOVA) with the four BGMsubstitution levels (0 %, 12.5 %, 37 % and 50 % of Composition of Diets.

Results

Ingredients used in formulating the diets were similar except for variation in the fishmeal and *B. germanica* meal level, as shown in ***Table 1***. The nutrients of the treatment diets were in tandem with nutrient standards for chicken in the grower phase (National Research Council (NRC), 1994).

Table 1: Composition of diets with 0 %(TD), 12.5 %(TA), 37 %(TB) and 50 %(TC) substitution of fishmeal with *B. germanica* in growers' diet.

Ingredients (%)	Treatment Diets			
	Diet TA	Diet TB	Diet TC	Diet TD
Maize grain	59	59	59	59
Wheat bran	17	17	17	17
Fishmeal	3.5	2.5	2	4
Cockroach meal	0.5	1.5	2	0
Soya beans	18	18	18	18
Limestone	1.3	1.3	1.3	1.3
DCP	0.3	0.3	0.3	0.3
Vitamin Premix	0.2	0.2	0.2	0.2
NaCl	0.2	0.2	0.2	0.2
MycoBinder	0.1	0.1	0.1	0.1
Calculated Analysis				
Dry Matter (%)	90.53	90.55	90.54	90.53
ME(Kcal/Kg)	2907	2912	2909	2909
Crude Protein %	16.0	15.9	15.91	16.0
Crude Fibre (%)	4.69	4.7	4.71	4.7
Crude Fat (%)	7.3	7.3	7.3	7.31
Methionine	0.77	0.77	0.78	0.78
Lysine	0.80	0.8	0.81	0.81
Determined Analysis				
Dry Matter (%)	89.64	89.89	90.04	90.04
ME(Kcal/Kg)	3255	3329	3356	3298
Crude Protein %	17.71	17.31	17.7	17.7
Crude Fibre (%)	4.99	5.37	5.38	5.38
Crude Fat (%)	6.49	7.24	7.58	7.24
Ash	10.81	10.47	9.81	11.61
Nitrogen Free Extracts (Carbohydrates)	49.64	49.15	49.91	48.47

Vitamin premix to provide the following per kg of diet: Vitamin A, 10,000 IU; Vitamin D3, 2000 IU, Vitamin E, 5 mg; Vitamin K, 2 mg; Riboflavin, 4.2 mg; Nicotinic acid, 20 mg; Vitamin B12, 0.01mg; Pantothenic acid, 5 mg; Folic acid, 0.5 mg; Choline, 3 mg; Mg, 56 mg; Fe, 20 mg; Cu, 10 mg; Zn, 50 mg; Co, 125 mg; Iodine, 0.08 mg.

Treatment diets were formulated to meet the minimum nutrient requirement of KALRO Improved chicken (KIC) of > 2900 Kcal/kg ME anda crude protein of 16-17 %, as indicated in ***Table 1***.The treatment diets' analysis also shows no great variation between the calculated and analysed proximate composition. A great amount of crude protein was supplied by soya beans, fishmeal and cockroach meal as indicated in *Table 1*. The numerical difference observed for various values were minor. Feed Intake and Feed Conversion Ratio of Chicken Fed on Diets with *B. germanica* Meal (BGM)

During the fifty-five days of the feeding trial, therewas no significant difference in total feed intake, average daily feed intake, and feed conversion ratio($p > 0.05$) of every bird, as shown in *Table 2*. The highest total feed intake and average daily feedintake were recorded in diet TD (106.54g), while diet TC recorded the lowest value (99.56g).

Table 2: Feed intake, body weight gain, and feed conversion ratios of chickens fed with 0% (TD), 12.5 %(TA), 37 %(TB) and 50 %(TC) substitution of fishmeal with *B. germanica* in their grower diet.

Parameter	TA	TB	TC	TD	SEM	CoV	P-value
ADFI (g/ bird /day)	101.31[a]	104.93[a]	99.56[a]	106.54[a]	2.03	7.30	0.665
ATFI (g /bird)	5572.32[a]	5771.20[a]	5476.05[a]	5859.68[a]	111.76	7.29	0.665
FCR	6.74[a]	7.37[a]	7.10[a]	6.32[a]	0.22	10.62	0.384

SEM= standard error of mean, CoV= coefficient of variation, ADFI=average daily feed intake, ATFI= average total feed intake, FCR=Feed conversion ratios, abcd=figures within the same row with different superscripts differ significantly p<0.05

Feed conversion ratio (FCR) was not different among the four diets (p>0.05), the highest FCR was 7.37 for diet TB. FCR in diets TA, TB, and TC wasonly numerically different.

Final Weight and Average Daily Weight Gain ofChicken Fed on Diets with Blattela germanica meal (BGM)

There was a gradual increase in weight of birds for all treatment diets during the whole period of the feeding trial. There was no significant difference (p>0.05) in average weekly weight gain between thediets with BGM and the control.

Table 3: Initial body weight, total weight, and average daily gain of chickens fed with 0 %(TD), 12.5 %(TA), 37 %(TB) and 50 %(TC) substitution of fishmeal with *B. germanica* in their grower diet.

Parameter	Diet TA	Diet TB	Diet TC	Diet TD	SEM	CoV	P-value
MILW (g)	539.72[a]	531.17[a]	543.61[a]	531.94[a]	8.13	5.25	0.9537
MFLW(g)	1368.78[a]	1322.19[a]	1325.11[a]	1458.44[a]	79.62	7.91	0.423
ALWG (g)	829.05[a]	791.19[a]	781.49[a]	926.5[a]	29.62	11.74	0.3178
ADWG (g)	15.0[a]	14.39[a]	14.21[a]	16.85[a]	0.53	12	0.318

ADWG=Average Daily Weight Gain, MILW=Mean Initial Live Weight, MFLW=Mean Final Live Weight, ALWG=Average Live Weight Gain. abcd=figures within the same row with different superscripts differsignificantly p<0.05

Initial live weight, total weight gain, and average daily gain of the chicken growers fed on diets with replacement of fishmeal with cockroach meal at 12%, 37%, and 50% of 4 % inclusion of fishmeal did not differ significantly (p>0.05) from the controlduring the growth phase (weeks 8-16) as indicated in *Table 3*.

Discussion

Composition of Diets

Feed ingredients are vital parameters in determiningthe nutritional value of a diet and physical characteristics such as colour, smell, and palatability. The treatment diets' analysis also showed no great variation between the calculated and analyzed proximate composition. The results imply that the values used in determining the appropriate formula for mixing the ingredients werea true reflection of the nutrient concentration in thefeedstuffs.

Effects of Diets with B. germanica Meal (BGM) on Feed Intake and Feed Conversion Ratio of Indigenous Chicken

Feed intake is one of the parameter used to gauge feed palatability in chicken. Birds will take less feedwhen the diet is not palatable, has poor texture or when they do not like it (Khan *et al.*, 2008; Teguia *et al.*, 2002). Increased feed intake is observed whenthe birds either like the feed or it is nutritionalimbalanced. Higher values for feed conversion ratios (FCR) are associated with high feed intake and vice versa (Warren and Emmert, 2000). In the current study, there was no significant difference intotal feed intake, average daily feed intake, and feed conversion ratio (p > 0.05) as shown

in *Table 2*. The highest average daily feed intake was recorded in diet TD (106.54g) while diet TC recorded the lowestvalue (99.56g) with average of 103.05g, which is similar to standard average daily intake of 100g. The average daily feed intake for the current study was higher than reported for same species in the similar growth phase (Wanjohi, 2019). In the study,Wanjohi *et al.*, (2019) reported lower value of 82.3gthat was attributed to inclusion of fibrous *Propis julifora* pods in the diet.

The feed conversion ratio (FCR) was not different among the four diets ($p>0.05$); the highest FCR was 7.37 for diet TB. Despite replacing up to 50 % of fishmeal in the diets, this did not affect daily feed conversion ratio. This could be attributed to the factthat nutritional analysis showed that all diets had similar nutritional values regarding protein and energy. These results are contrary to those of Téguia *et al.*, (2002) and Bovera *et al.*, (2016) who reported reduced FCR for growers fed on diets withinsect meals. Feed intake in chicken has usually been affected by feed factors such as palatability (taste and smell), nutritional composition, and texture. The latter were uniform for treatment diets, but replacing fishmeal was expected to affect the diet's smell and taste. Regarding the results in this study, replacing up to 50 % fishmeal in growers' diets did not significantly alter the physicochemical properties of feed, thus resulting in similar feed intake across the diets.

Effects of Diets with B. germanica meal (BGM) on Total Weight and Final Weight

Weight is an important parameter that is used as anindicator of the nutritional status of birds. For birdsin the grower phase, it is expected that birds will have a progressive increase in weight when fed on abalanced diet but stagnate or retard in weight whenthe diets are not providing the required daily nutrient intake. In the current study, the birds had similar initial live weights at the start of an experiment. At the end of the feeding trial, the totalweight gain and average daily gain of the chick growers fed on diets with replacement of fishmeal with cockroach meal at 12 %, 37 %, and 50 % of 4% substitution of fishmeal did not differsignificantly ($p>0.05$) from the control during the growth phase. There is limited information on studies that involved the replacement of fishmeal with the cockroach. The finding of the current studyare contrary to the findings of Khan *et al.*, (2018) who reported a significantly higher body weight forbirds fed on insect meal compared to the control. Current study findings on average daily gain are similar to those reported by Wanjohi *et al.*, (2018) for the same bird species.

Parameters such as feed intake, weight gain, and feed conversion ratio are interrelated and mostly used to assess growth performance in animals suchas chickens. The similarity in these parameters for chicken fed on diets where fishmeal was replaced with BGM confirms similar nutritional benefits.According to Okello *et al.*, (2021), farmers are willing to accept the incorporation of IBF as there isno longer credible information indicating thebenefits of a given insect meal. The current study has found utilizing BGM in chicken diets is as goodas using conventional fishmeal.

Conclusion and Recommendation

Based on the finding from this study, *Blattella germanica* meal has the potential to replace 50% of fishmeal in chicken growers' diets. The study recommends adoption and use of *B. germanica* meal in conventional chicken feeds to minimize dependence on fishmeal in Kenya. There is, however, a need for further studies with higher levels of cockroach meal inclusion to determine optimum inclusion levels in poultry- based diets.

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Ethical Approval

National Commission on Science and Technology (NACOSTI) authorized the research under license No. NACOST/II/P/22/20771. The research was conducted with approval from Jaramogi Oginga Odinga University of Science and Technology ethical committee approval No. 7/19/ERC/10/01/22-07 and following principles and guidelines of KALRO Animal Handling and Care,

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Diversifying Energy and Protein Sources for Poultry Feeds in Kenya

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Abstract

This study explores the utilization of alternative and locally available energy and protein sources in laying chicken feed formulations, aiming to reduce costs, enhance availability, and promote climate-smart approaches. The experiment included five dietary groups, each with specific energy and protein sources. Significant results emerged: average live weights displayed statistical significance ($p<0.0001$), with hens on diet A3 containing fish meal (omena) exhibiting a moderate weight increase. Weekly egg collection demonstrated significance ($p<0.0002$), with diet A3 yielding the highest collection, while diet A5 (positive control) produced the lowest. These trends mirrored the percentage lay, emphasizing diet's role in egg production. The incorporation of fish meal in diet A3 stood out, influencing growth rates and egg production due to its nutrient density and balanced amino acids. The impact of diets on egg weights was significant ($p<0.0001$), and feed consumption varied ($p<0.0001$), influenced by factors such as palatability and nutritional balance. The Feed Conversion Ratio (FCR) analysis highlighted diet differences in feed utilization. Overall, the study highlights the intricate interplay between dietary compositions, poultry performance, and production metrics, emphasizing the importance of well-balanced, diverse, and climate-smart feed formulations in achieving sustainable and efficient chicken production.

Keywords: *Feed sources, Climate-smart feed formulations; Feed efficiency; Egg production*

Introduction

Fishmeal and maize are conventional feed ingredients utilized as the main components in poultry feeding due to their excellent nutrient profiles. However, these essential feed sources face significant demand from other livestock (fishmeal) and human consumption (maize). Predictions suggest that by the year 2050, the global population could reach 9.1 billion, resulting in an escalated demand for food resources (FAO, 2009: HLEF2050 Global Agriculture). Developing nations are experiencing a notable surge in the consumption of poultry products such as eggs and meat. This surge necessitates a corresponding increase in the demand for poultry feed. This escalating demand for poultry feed introduces an element of competition in terms of availability. Consequently, the existing balance of feed resources may be disrupted, thereby potentially compromising national food security. Currently, there are concerted efforts to investigate alternative feed options that can effectively replace maize in poultry diets (Teguia and Beynen, 2005). The push behind this phenomenon arises from the escalated costs associated with conventional raw materials, compelling the search for substitutes aimed at cost reduction. In this framework, sorghum and cassava are highly considered due to their high energy profiles and substituting omena with soybeans as a source of protein.

These non-conventional energy ingredients (cassava and sorghum) show the potential to entirely supplement maize as the primary energy source in poultry diets (Thirumalaisamy et al.,2016). After maize, wheat, and rice, sorghum stands as the fourth most notable cereal crop in the world (Awika J.M, 2011). Sorghum farming constitutes a significant agricultural endeavor in Kenya, with cultivation spanning across the 41western, northern, eastern, and central provinces in an area covering

197,403-ha. The crop's popularity in Kenya's arid areas stems from its impressive drought tolerance. In 2022, the nation had produced 135,000 metric tons of sorghum (Safiorganics Guide: Sorghum Farming Guide, 2023). This is low compared to other nations' output, such as Nigeria and Ethiopia. Nigeria is Africa's top sorghum producer, with a total output of 6,725,000 metric tons.

Concurrently, cassava *(Manihot esculenta Crantz*) is a drought-tolerant root crop grown in the Western, Coast, and Eastern zones of Kenya. Cassava is grown on approximately 61,201 ha, with a production rate of 11 metric tons per hectare (FAO, 2021; Kidasi *et al.*, 2021). Cassava root is a valuable energy source for chicken; however, it comes with constraints such as inadequate protein and amino acid balance. Despite this, its energy content remains notably high, comparable to conventional sources like maize, with a range of 3000 to 3200 Kcal/kg.

In regard to protein sources, the sun-dried and ground product of the silver cyprinid, locally known as *Omena*, produces fish meal, a highly digestible protein source extensively used in chicken feeds across Kenya (Maina *et al.*, 2007). Omena fishmeal contains elevated levels of crude protein, omega-3 fatty acids, calcium, and phosphorus. However, integrating fishmeal into chicken diets poses a challenge due to the conflict between human consumption and animal feed production. Moreover, the relentless exploitation of marine resources leads to a decline in the population of small pelagic forage fish essential for fish meal production. Additional limitations stem from its restricted incorporation, which is capped at a maximum level of 10% in both egg and meat production chicken feeds. With the mentioned complexities, relying solely on fishmeal or omena as the primary protein source in feed production is no longer a sustainable option.

The possibility of wholly replacing fishmeal with soybeans as a protein source presents an intriguing opportunity in Kenyan poultry nutrition. Soybean meal holds a central role as the primary protein supplement in chicken diets globally, serving as the standard against which alternative protein sources are evaluated. Chicken have the option of being nourished with whole or full-fat soybeans, as well as soybean meal—a by-product of oil extraction (Lourenco, 2019).

The protein contents, specifically the amino acid profile, of soybeans make them a preferred choice for balancing dietary amino acids in cereal grains for chicken feeds. Although the global availability of suitable land for soybean cultivation is diminishing, soybean cultivation is widely underexploited in Kenya (Nyongesa *et al.,* 2017). Therefore, soybean could be one of the cheapest and most readily available source of protein, an alternative substitute to animal protein

This scarcity of conventional resources such as maize and fishmeal has driven a significant increase in chicken feed prices, with these ingredients constituting 70% of total feed production costs (Thirumalaisamy *et al.,* 2016). In light of the above, this study sought to investigate the utilization of alternative and locally available energy and protein sources while reducing costs, increasing availability, and also promoting climate-smart feed formulations for laying chicken.

Materials and Methods

Study Location

The research took place at the Kenya Agricultural & Livestock Research Organization (KALRO), Non-Ruminant Research Institute, Kakamega. This institute is situated in Kakamega County, in the western region of Kenya, with geographical coordinates of 0.2777 N and 34.76 E. The climate of Kakamega features an annual average rainfall of 1395 mm, and the daily temperature ranges from a minimum of 16°C to a maximum of 28°C during the day. The humidity level remains around 74% throughout the year.

Experimental Design

The study utilized the KALRO Improved Indigenous Chicken KC1 breed, recognized for its dual-purpose attributes of meat and egg production. A total of one hundred and fifty (150) laying hens, aged 25 weeks, were randomly assigned to five distinct treatment diets: A1, A2, A3, A4, and a positive control diet denoted as A5. To ensure their optimal performance, the birds were placed in an open house with appropriate lighting, temperature, and ventilation. The study adherence to standard management protocols with unrestricted access to both feed and clean water.

The study employed a Completely Randomized Design, wherein each of the five test diets was assigned randomly to three separate pens, for a total of 15 pens, each housing 10 layers. Average feed intake, live weight, and egg numbers per pen were taken for a period of 10-week experimental period, data was collected on a weekly basis, covering a variety of parameters such as feed intake, live weight, and egg numbers, all relevant to hen performance and feed conversion ratio.

Table 1: Experimental Diet composition

Ingredients	**% inclusion level**			
	A1	**A2**	**A3**	**A4**
Maize	-	-	51.00	47.00
Cassava	51.00	-	-	-
Sorghum	-	55.00	-	-
Threonine	2.00	2.00	1.50	3.00
DL Methionine	2.00	2.00	1.50	3.00
Lysine	2.00	2.00	1.50	3.00
Omena/ fishmeal	9.00	5.00	10.00	-
Sunflower SC	7.00	6.00	7.00	9.00
Soya Full fat	11.00	8.00	-	12.00
W. bran	6.00	10.00	16.00	12.00
Lime	7.00	7.00	8.00	8.00
DCP	3.00	2.00	2.00	2.00
Premix	1.00	1.00	1.00	1.00
Salt	0.30	0.30	0.30	0.30
Enzyme	0.03	0.03	0.03	0.03

The study used five distinct dietary groups, with each formulation designed to maintain consistent levels of nitrogen and energy. Furthermore, all diets adhered to a minimum energy requirement of 2300 kcal/kg and a crude protein content of 16%, specifically tailored for the KALRO-improved indigenous layers. These diets used diverse sources of energy and protein: A1 had cassava as the primary energy source; A2 contained sorghum as the key energy source; A3 had omena as the main protein source up to the maximum inclusion level of 10%; A4 integrated soybean as the principal

protein component up to an inclusion level of 12%; and lastly, A5 was standard commercial feed, designed as the positive control, against which others were compared. **Table 1** below gives the composition of experimental diets.

Measured Experimental Variables

The following experimental variables were measured to investigate the utilization of alternative and locally available energy and protein sources. These included: feed consumption, egg production, live body weight, egg weight, and food conversion ratio.

i. *Feed consumption*: The feed consumption of each pen was measured on a weekly basis using an electronic weighing scale, which involved measuring both the feed provided and the leftovers and then dividing by the number of birds in a pen.
ii. *Egg production:* The number of eggs laid in each pen per day was recorded. This will be used to assess how dietary interventions influenced egg production and, subsequently, the laying percentage.
iii. *Egg weight:* Egg weight was measured by calculating the average weight of eggs laid per pen per week to provide potential variations in egg weight attributed to the dietary treatments.
iv. *Body weight:* Live bird weight was calculated by average live bird weight per pen per week to facilitate the tracking of weight changes throughout the study duration.
v. *Feed conversion ratio (FCR):* it is the feed consumption divided by the number of eggs laid per week to compare feed utilization efficiency.

Statistical analysis

Data was analyzed using SAS® software. A one-way analysis of variance (ANOVA) was employed to assess the significance of differences among the dietary treatment groups on repeated measures through the 10-week trial period. Post hoc tests, including Tukey's least significant difference (LSD) test, were used to identify specific differences between the treatments and the coefficients of their variations.

Results and discussion

The composition of the diets was shown to have a significant impact on live bird weight, with a least significant difference (LSD) of 35.951g (F value (12,92) = 22.62, p-value <0.0001). Among the diets, hens fed diet A3 exhibited an average weight of 1909.79g, reflecting a moderate increase from their initial weight of 1790.83g. Conversely, no significant differences in the live weights were observed among birds fed diets A1, A2, and A4. Diet A5 which was the control had the smallest weight gain compared to the initial weight over the course of the 10-week period. (See Table 2 Below). Bird weight is an important attribute in poultry trade in both structured and unstructured markets. Birds with higher weights fetch more price compared to low-weight birds.

Table 2: Effects of energy and protein sources on chicken performance

Diet	Weight of Bird	Eggs Collected	Egg Weight	% Lay	Consumption	FCR
A1 Cassava-1	1874.12 ab	60.095 ab	50.0265 ab	85.850 ab	125.562 b	14.6790 b
A2 Sorghum-2	1850.67 b	58.143 ab	51.1588 a	83.061 ab	126.086 b	15.2810 b
A3 Omena-3	1909.79 a	60.905 a	50.9391 a	87.007 a	126.590 ab	14.6079 b
A4 Soya 4	1875.40 ab	57.190 b	48.5145 b	81.701 bc	124.629 b	15.4299 b
A5 Control	1732.64 c	53.238 c	50.1281 ab	78.216 c	129.446 a	17.2508 a
F value (12,92)	22.62	3.67	4.62	2.76	40.06	9.45
P- value	<.0001	0.0002	<.0001	0.0030	<.0001	<.0001
Mean	1848.5230	57.9143	50.1534	83.1670	126.4626	15.4497
LSD	35.951	3.0934	1.7001	4.2884	2.9855	0.9688
CV %	3.1731	8.7145	5.5307	8.4128	3.8517	10.2310

Note: Means with the same letter in a column are not significantly different at 5% level using Tukey /LSD mean separation test

The proposed diets had varying effects on egg production. Layers consuming diets A1, A2, and A3 exhibited no significant differences in egg production. For instance, diet A3 yielded a weekly collection of 61 eggs, while A1 and A2 achieved collections of 60 and 58 eggs, respectively. Diet A4 resulted in 57 eggs, differing significantly from A3. Birds on diet A5, the positive control, produced the lowest egg collection at 53 eggs. The minimum egg collection was 3 eggs. The egg collection data mirrored the percentage lay, with hens on diet A3 displaying the highest collection, thereby reflecting the most significant laying percentage. This trend extended across diets A1, A2, A4, and A5, showcasing a minimum variance of 4.3% (F value (12,92) = 2.76, p-value <0.003). Diet A3 had the highest egg collection per day. The egg production level of a chicken is economically important to any poultry enterprise hence a feed composition that gives higher egg production is the best option.

The A3 diet incorporated fish meal as its primary protein source, differentiating it from the remaining diets. Fish meal is characterized by its rich nutrient density and a well-balanced composition of crucial amino acids, some of which might be deficient in alternative protein sources (Nguyen *et al.*, 2009). The availability of these amino acids from fish meal can support optimal growth rates and egg production. Furthermore, fish meal boasts high digestibility, ensuring optimal absorption of its nutrient content within the chicken's digestive system. This attribute results in heightened utilization of protein and other essential nutrients, translating to improved growth, weight gain, and egg production (R. D. M. Miles & Chapman, 2021).

The diets were also shown to influence egg weight. Among these diets, A2 exhibited the most substantial weight at 51.2g, representing the least significant difference of 1.7g, which is within the established standard range of between 50 to 55g. This weight was not statistically different from birds feeding on diets A1, A3, and A5; however, A4 deviated slightly with a weight of 48.5g. The weight of eggs is subject to various influences, encompassing genetic factors, environmental conditions, age, management practices, and nutritional factors. The insignificant variations in egg weight may be attributed to environmental and genetic factors since the diets were formulated to meet identical minimal nutrient compositional standards. Consequently, these results have no economic implication on the poultry industry since currently, the Kenyan market does not grade eggs.

The composition of the feeds was shown to have a significant effect on the amount of feed intake. Layers feeding on diet A5 were feeding the highest amount of 129.5g per day. Conversely, diets A1, A2, A3, and A4 exhibited no substantial differences in consumption between them, with a least

significant difference of 3.0 g. The quantity of feed consumed by birds is influenced by a range of factors, including their physiological requirements, management practices, health status, and environmental conditions. Birds tend to consume more when their nutritional needs are not adequately met (Barzegar *et al.*, 2020). The palatability and nutritional balance of the diet play a vital role in promoting increased consumption. Diets rich in dense energy content might lead to reduced feed intake as birds fulfill their energy requirements with smaller amounts of feed. Diet-rich feed therefore leads to reduced cost on feed intake per bird hence reduced cost on feed. Consequently, ensuring sufficient protein levels is crucial for optimal growth and production. Insufficient protein in diets can lead to heightened feed consumption as birds attempt to compensate for the deficiency (Ravindran, 2013).

The Feed Conversion Ratio (FCR) was calculated to assess the quantity of feed consumed by a bird to produce a single egg. The feed conversion ratio (FCR) is subject to a range of influences, including genetics, age, health conditions, and nutrition. A lack of proper nutritional balance, which could involve an increase in protein content or energy levels, can profoundly impact efficiency and FCR (Barzegar *et al.*, 2020). Among the diets, A5 displayed the highest FCR value at 17.3, while A3 showcased the lowest ratio at 14.6. This conveys that a layer fed with A5 required 17.2508 grams of feed to produce an egg, whereas a layer on A3 needed only 14.6079 grams for the same purpose. With a least significant difference of 0.9688, diets A1, A2, A3, and A4 did not exhibit significant discrepancies in FCR values, whereas A5 stood out distinctly.

The overall mean FCR, calculated at 15.4 grams, indicated that on average, a layer consumes 15 grams of feed to produce one egg. The A3 diet, containing fish meal, demonstrated lower efficiency in feed conversion, aligning closely with other diets that employed soybean meal as the protein source. The control diet A5 displayed the lowest feed efficiency. Therefore, diet A3 was more economically viable since it had lower FCR compared to the other diets.

Conclusion

The study's multifaceted implications span the economic, environmental, and nutritional realms. It underscores the feasibility of transitioning towards climate-smart crops in poultry feed while acknowledging the competition between human and animal feed for key ingredients. The results of this study have provided empirical evidence that embracing alternative feed sources such as cassava and sorghum as alternative ingredients to maize in the poultry feed could boost the poultry industry hence contributing to sustainable food systems, mitigating climate impacts, and alleviating resource pressures, all of which are crucial in navigating the complexities of a changing world.

In the context of climate change and the imperative to embrace climate-smart practices, the study's outcomes offer a promising pathway forward. The results suggest that maize can be replaced with climate-smart crops like cassava or sorghum in chicken feed formulations without compromising the feed conversion ratio. This realization is not only a significant stride towards sustainable chicken production but also aligns with the pressing need to adapt to changing agricultural landscapes and address the challenges posed by climate change.

Cassava and sorghum, both considered climate-smart crops, emerge as compelling alternatives to maize due to their adaptability to various regional contexts. These crops, prominently available in western Kenya and arid regions such as Lower Eastern and the Coast, present an opportunity to diversify feed ingredient sources and reduce the ecological footprint of feed production. By incorporating these locally available crops, the poultry industry can actively contribute to climate resilience and sustainable resource utilization, thereby aligning with broader environmental goals.

However, in the face of increasing population growth, the competition for essential resources, notably maize and *Omena*, has intensified. Maize's status as a staple crop renders it an essential dietary component for millions, amplifying demand due to population increase. This dual demand for maize, both for human consumption and animal feed, creates a complex web of challenges surrounding availability, affordability, and sustainability. Similarly, *Omena* is also a crucial source of proteins for humans, therefore, there is a high demand for both human consumption and as an animal feed ingredient. Amidst this intricate landscape, the study's innovative approach offered a potential resolution. Validating the efficacy of cassava and sorghum in poultry feed increases diversity for poultry feed ingredients. These alternative ingredients not only offer feed efficiency but also contribute to reducing the demand for maize and *Omena*. This finding aligns with the need for holistic and sustainable solutions in the face of population growth, competition for resources, and climate challenges.

Against the backdrop of mounting challenges due to population growth and resource competition, the study's implications extend beyond the realm of poultry production. By promoting alternatives to maize and omena, which face dual demands for human and animal consumption, the research embodies a crucial step towards reconciling the needs of both sectors. This is particularly pertinent as the global population continues to expand, intensifying the competition for essential resources. The study's findings, rooted in economic, environmental, and nutritional considerations, spotlight a pathway that promises a harmonious coexistence between poultry and human food systems.

As a whole, this study encapsulates the interplay of economic viability, sustainable practices, and climate resilience within the poultry industry. By embracing alternative feed ingredients, considering changing market dynamics, and factoring in climate-smart principles, the research not only paves the way for a more efficient and profitable poultry sector but also serves as a blueprint for a more adaptable and sustainable agricultural landscape in the face of evolving challenges. Ultimately, the study's outcomes underscore the imperative of marrying innovation, sustainability, and economic prosperity in shaping the future trajectory of poultry production in the context of a changing world.

The research therefore serves as a clarion call for the poultry industry to adopt innovative strategies that not only enhance economic viability but also contribute to resilience in the face of climate-induced uncertainties. The confirmation of cassava and sorghum as effective feed ingredients not only augments resource efficiency but also positions poultry production as a driver of sustainable agricultural practices. Furthermore, the study's insights on feed efficiency, egg production, and weight gain provide a robust foundation for evidence-based decision-making in feed formulation, thereby contributing to improved poultry management practices.

Recommendations

Several actionable recommendations emerge that can guide the chicken industry, policymakers, and stakeholders towards more sustainable, efficient, and resilient poultry production practices:

1. *Diversify feed ingredients:* Encourage the incorporation of locally available and climate-smart crops like cassava and sorghum into poultry feed formulations. This diversification not only reduces dependency on resource-intensive crops like maize but also contributes to climate resilience by promoting crops adapted to changing weather patterns.

2. *Promote feed efficiency:* Emphasize the importance of feed efficiency in poultry management practices. Provide education and resources to chicken farmers on balanced feed formulations that optimize feed conversion ratios, enabling better utilization of resources and lowering production costs.

3. *Support research and innovation:* Foster ongoing research initiatives focused on identifying alternative feed sources and their impact on performance. Investment in innovation can lead to the discovery of more cost-effective, sustainable, and nutritionally balanced feed options.

4. *Enhance climate adaptation*: Recognize the role of climate-smart crops in enhancing climate adaptation strategies. Encourage breeding and cultivation of crops that withstand environmental stresses, contributing to a more resilient agricultural system.

5. *Financial literacy for poultry farmers*: Provide farmers with financial education and tools to better understand profit margins, break-even points, and cost-benefit analyses. This knowledge equips them to make informed decisions on the choice of feeds that enhance profitability while considering resource constraints.

6. *National and county government policy support*: Collaborate with policymakers to develop supportive regulations and incentives that encourage the adoption of alternative feed ingredients. Tax incentives, subsidies, or grants for research and development of climate-smart crops can incentivize sustainable practices.

7. *Capacity building:* Offer training and workshops to chicken farmers on sustainable practices and efficient resource utilization. Equipping farmers with the skills to manage their operations more effectively can lead to better overall performance and reduced environmental impacts.

8. *Industry collaboration:* Foster partnerships between the poultry industry, research institutions, and government agencies. This collaboration can facilitate knowledge exchange, technology transfer, and the implementation of best practices across the sector.

9. Market diversification: Explore opportunities to diversify product offerings beyond conventional chicken products, such as organic or specialty eggs, which may command premium prices in niche markets.

10. *Long-term planning:* Encourage long-term planning that considers market trends, resource availability, and climate impacts. By adopting a forward-thinking approach, poultry producers can anticipate challenges and adjust their strategies accordingly.

In essence, the study's outcomes emphasize a paradigm shift towards sustainability, efficiency, and adaptability in chicken production. By embracing alternative feed sources, optimizing resource utilization, and aligning practices with climate-smart principles, the industry can navigate the complex web of challenges posed by population growth, resource competition, and climate change. Through concerted efforts across stakeholders, the recommendations outlined above can drive a more resilient, profitable, and sustainable future for chicken production.

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Nutritional Value of Feed Ingredients and Compounded Feeds for Dairy Cattle Production in Kiambu County, Kenya

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Abstract

Nutrition and feeding of dairy cattle is a key component in the determination of the lactation performance of dairy cows. The quality of feeds fed to the animals is as much important as the quantity offered. The objective of this study was therefore to assess the nutritional quality of feed ingredients used as protein and energy sources for compounded feeds (dairy meal) as well as commercial dairy meals utilized for feeding dairy cattle in Kiambu County, Kenya. Samples of 5 energy-source feed ingredients and 5 protein sources were collected and analysed for proximate composition. A further 6 samples of commercial compounded dairy meals sold in Thika and Juja sub-counties were also analysed for their proximate composition. Results showed that the feedstuffs were generally dry with dry matter (DM) content of more than 88.00% for both ingredients and compounded feeds. The ash content was within the expected range for such feedstuffs except fishmeal (27.99%) and rice polishings (18.18%), which were unusually high and an indication of some adulteration. Fishmeal had the highest crude protein (CP) at 56.03%. For the plant-based protein sources, the CP content ranged from 14.57% in Copra meal to 46.78% in soybean meal. Copra exhibited the highest content of neutral detergent fibre (NDF) and acid detergent fibre (ADF) with 63.45% and 37.80% respectively with soybean meal having the lowest levels NDF and ADF at 13.60% and 8.35% respectively. While the DM content of the compounded commercial feeds did not vary much, the CP content varied widely (12.95% - 18.19%) across the different brands. The ash content ranged from 3.97% to 9.18% while the NDF and ADF ranged from 26.40% to34.20% and 10.80% to 14.20% respectively. The compounded feed with the lowest CP content had the highest fibre contents. These results show the importance of the farms carrying our nutritional analysis of the feed ingredients as well as the compounded feeds so as to feed their animals with quality feeds for improved and efficient lactation performance.

Adoption and Utilization Levels of Liquid Brewers' Yeast in Dairy Production: Githunguri Sub-county, Kenya

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Abstract

Dairy production plays an integral part in supporting smallholder farmers' livelihoods. The desire to increase the number of dairy cattle is not feasible due to the reduced output of feed resources occasioned by climate change. Consequently, the need to increase productivity per cow is inevitable. Conventional protein supplements are costly; hence, the need to explore affordable nutrient-dense alternative feed resources. Liquid brewers' yeast (LBY), a by-product of the brewing industry, is a rich protein supplement in dairy production. This study aimed to investigate adoption and utilization levels of LBY as a feed supplement in Githunguri Sub-county, Kenya. Semi-structured questionnaires were administered to 457 dairy farmers in a cross-sectional survey. It was revealed that even though 53.1% of the respondents were aware of the use of LBY, only 30.6% utilized it to supplement dairy cows, most of whom (96.0%) used it fresh without preservation. Membership in farmers' organizations increased awareness of LBY (r=0.732). The benefits of using LBY outweigh the challenges involved with a loading matrix of 0.891- 0.954 and 0.681- 0.807, respectively. The limited adoption and usage of LBY as a protein supplement were attributed to a lack of awareness. There is a need for concerted efforts by stakeholders in the industry to increase farmers' knowledge base on the utilization and effectiveness of LBY in dairy production.

Keywords: *Dairy production; Liquid Brewers' Yeast; Supplementation; Protein Source, Kenya*

Introduction

Dairy farming in Kenya is concentrated in the high-altitude agro-ecological zones of the central highlands and Rift Valley regions. The areas have high bimodal rainfall and relatively low temperatures of 15-24 ºC (Kashangaki and Ericksen, 2018). The continual dependence on conventional sources of feed ingredients may not be the solution to the challenges facing the livestock sector in Kenya. Production of feed ingredients from crops such as grains and legumes by local farmers remains inadequate for human and animal nutrition. The alternative is to utilize unconventional supplements such as LBY, which do not directly impact human on nutrition (Chollom *et al.*, 2017). One solution would be to use a relatively high amount of commercial concentrates. However, these concentrates are costly, highlighting the need for affordable alternative by-products and waste products sourced from local food processing factories near farmers. (Kamphayae *et al.*, 2017).

Liquid brewers' yeast is the second most abundant by-product from the brewery and distillery industries. It also has a rich nutritional composition, making it a valuable feed for cattle (Killerby *et al.*, 2022). The by-product is usually discarded into the environment as a waste product, causing pollution of water bodies' and increasing the biological oxygen demand (BOD). Liquid brewer's yeast

is a cheap source of protein obtained in areas where breweries are situated (Chollom *et al.*, 2017). The production of LBY in Kenya is at 20,000 litres per day, but only 10% undergo drying due to the high costs involved, and the rest is sold in liquid form. The LBY supply chain originates from producers to distributors and farmers (Alaru *et al.*, 2019). Despite its benefits, limited information is available on the extent of its utilization as an alternative protein source by farmers. The objective of this study was to assess the adoption and utilization levels of LBY as a feed supplement for dairy production in Githunguri

Methodology

Study area

The study was conducted in Githunguri sub-county within Kiambu County, Kenya. The area is 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 area is a tea and dairy zone characterized by hills, plateaus and high-elevation plains. The sub-county has high-level upland fertile soils from volcanic rocks, making it suitable for agriculture, including dairy farming (Aguda 2019).

Study design and data collection procedures

Data was collected using a semi-structured questionnaire, and 457 respondents were interviewed. The questionnaire assessed the utilization of LBY vis-a-vis other supplements and associated benefits and challenges. The questionnaire was pre-tested to determine its validity. The study households used multistage and purposive sampling to capture all the desired information. This study set a standard for the reliability correlation coefficient to be 0.7 and higher. A reliability correlation coefficient above 0.7 shows a high internal consistency.

Data analysis

Data collected from the cross-sectional survey was analyzed using SPSS statistics software version 26 at a 95% confidence level. Both descriptive and inferential statistics were used to analyze data. Principal Component analysis (PCA) was used to cluster benefits and challenges associated with using LBY in the order of priority. Linear regression models were used to identify the determinants of farmers' awareness of LBY as a feed supplement. The regression model used is as indicated in equation 1:

$$y_i = \beta_0 + \beta_i x_i + \cdots + \beta_n x_n + \in i \qquad \textit{(Equation 1)}$$

Where y_i is the farm-level indicator for farmers' i awareness of LBY, β_o is the intercept, $\beta i \ldots . \beta n$ are coefficients to be estimated and $Xi \ldots Xn$ is a vector of farm practices, $\in i$ is the error term.

Results and Discussion

General characteristics of Githunguri dairy farms

The average dairy herd on the farms was six cows, four of which were in lactation, two dry cows and two heifers. It takes 6.18 ±2.88 years before the disposal of cows from the herd (Table 1).

Table 1: Dairy herd structure and longevity in Githunguri

Parameter	Mean	Min.	Max.	Std.
Total herd (No.)	6	1	57.0	7.33
Milking cows (No.)	4	0	32.0	3.88
Dry cows (No.)	2	0	16.0	1.72
Heifers (No.)	2	0	15.0	1.92
Longevity (Yrs.)	6.18	1	15.0	2.88

Key: Min. = Minimum; Max. = Maximum; Std. = Standard deviation

The findings demonstrated that farmers in the study area have slightly larger average herd sizes. This is contrary to Kashangaki and Ericksen (2018), who reported that a smallholder dairy farmer in Kenya typically owns between one and five herds of cattle.

Level of awareness on the use of Liquid Brewers' Yeast (LBY)

The adoption and handling practices of spent liquid brewers' yeast by Githunguri farmers are in Figure 1. Whereas 53.1% of the farmers know LBY as an animal feed, only 30.6% use it. Of the farmers that have adopted LBY use, 96.0% do not preserve it, and only 17.2% received training on handling practices. Most of the farmers have experience of more than five years in dairy farming. According to Svensson *et al.*, (2018), a dairy farmer's experience is essential in implementing farm management practices, for enhanced profitability. The level of education, herd size, and access to credit facilities determine the adoption of improved technologies (Ilatsia & Murage, 2011). The high literacy level and more years of experience by farmers in the area have enabled them to develop innovative management strategies that have significantly improved dairy production.

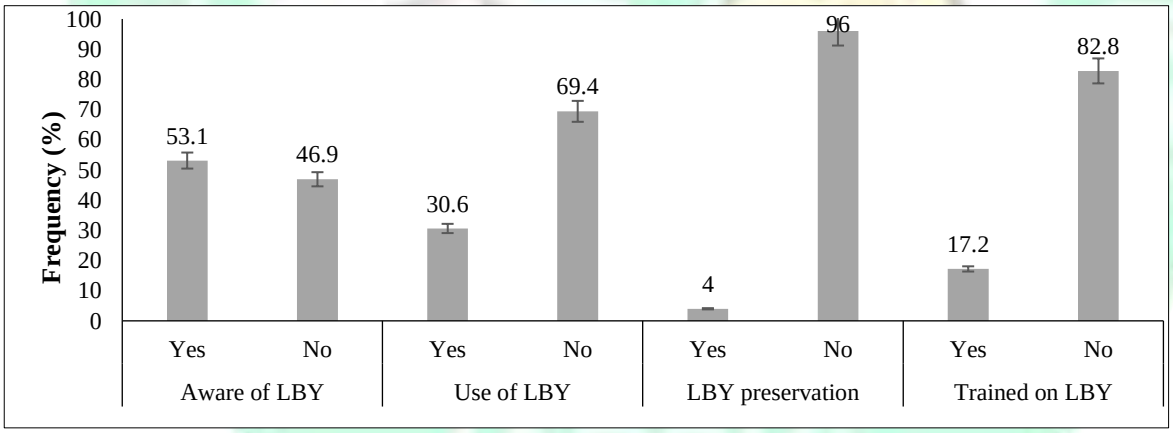

Figure 1: Githunguri dairy farmers' adoption and handling practices of Liquid brewers' yeast

The regression model of practices that significantly influenced Githunguri farmers' awareness of LBY is in Table 2. Findings demonstrated that farmers who feed cattle on industrial fruits by-products and those who apply fertilizers to forages/fodders had significantly less awareness of LBY as a feed supplement at r= -0.071 and r= -0.388, respectively. However, farmers who were members of the organization and those who practised steaming up to cattle before calving had a significantly higher awareness of LBY use at r=0.732 and r= 0.344, respectively. Membership in a farmers' organization and the practice of steaming up cows before calving positively influenced the adoption of LBY as a feed supplement (Table 2). This observation can be due to information-sharing strategies available at farmers' organizations such as the Githunguri Dairy Farmers' Cooperative Society (GDFCS). Members of farmers' cooperative societies gain more benefits through knowledge sharing on market stability, services, and opportunities for decision-making, social interaction and civic engagement (Liang *et al.*, 2021). The ability to generate, disseminate, and share critical information with

communities participating in farming activities is the solution to enhanced agricultural productivity (Danso-Abbeam *et al.*, 2018). The respondents acknowledged elaborate knowledge-sharing mechanisms employed by the cooperative society to enable information on good farming practices to reach farmers through its more comprehensive extension network. It is important to note that most farmers who were unaware of LBY utilization are not members of GDFCS.

Table 2: Regression analysis of LBY handling practices and adoption

Model	R	Std. Error	t	Sig.
Intercept	0.963	0.319	3.023	0.004
Do you feed industrial fruits by-products to animals?	-0.071	0.018	-3.958	0.000
Do you steam up your in-calf cows before calving?	0.344	0.124	2.765	0.008
Do you apply fertilizer to your forages?	-0.388	0.114	-3.421	0.001
Membership in farmer organization	0.732	0.228	3.208	0.002

a. Dependent Variable: Are you aware of liquid brewers' yeast?

LBY Handling and Utilization Practices

Liquid brewers' yeast utilization and management by Githunguri dairy farmers are in Table 3. Farmers daily use an average of 12.6 litres on milking cows; consumption per heifer is 2.22 litres and 1 litre per weaned calves. Farmers procure a litre/kg LBY at an average price of Ksh. 10.6, store it at 22.3°C, and it takes 7.57 days for it to spoil. The findings on LBY shelf life is consistent with previous study by Alaru *et al.*, (2019).

Table 3: Utilization and management of liquid brewers' yeast by Githunguri dairy farmers

Utilization and management practices	Mean	Min.	Max.	Std.
Cost of liquid brewers' yeast (Ksh./litre or Kg)	10.57	6	30	7.57
Milking cows daily quantities fed	12.64	1	80	21.19
Heifers daily quantities fed	2.22	1	5	1.30
Weaned calves daily quantities fed	1.00	1	1	0.26
The temperature at which LBY is stored	22.25	18	25	2.89
Days to spoilage of LBY	7.57	3	14	3.95

Key: LBY= Liquid Brewers' Yeast; Min. = Minimum; Max. = Maximum; Std. = Standard deviation

The handling and management practices for LBY are in Table 4. Among the farmers who were aware of the LBY use as an animal feed, 76.7% received the information from other farmers, 2.3% from the media and 21% from several sources that included extension officers, cooperative dairy society, research institutions, agro-vets and agricultural shows. Among the farmers who use LBY, the majority (81.3%) purchase it from distributors, 12.5% buy it from both distributors and middlemen, and 6.3% obtain it solely from middlemen.. The majority (92.0%) of the farmers that utilize LBY for cattle feed it in fresh form, while (4.0%) use it after preservation and (4.0%) utilize it in either fresh form or after preservation. Liquid brewers' yeast quality was rated as spoilt by farmers on observation of visible mould growth (15.4%), change in smell (23.1%), change in texture (23.1%) and remaining (38.4%) used a combination of the attributes and decreased uptake by dairy animals. During the purchase of LBY from distributors, a farmer needs to gather information on the last replenishment date of the by-product at a distribution point. They would then estimate the feeding duration for the procured LBY before spoilage. Again, hygienic handling of the by-product is important to avert contamination along the supply chain. Westendorf and Wohlt, (2002) pointed out that the chief concern about the use of LBY relates to spoilage, which results in a less palatable product that may cause health concerns to animals. The application of cost-effective preservatives may be a viable approach to preventing nutrient losses (Killerby *et al.*, 2022). However, more precaution is necessary regarding food preservatives to avoid residual effects on animal by-products. It was observed that

farmers who were aware of LBY as a feed supplement obtained this information mainly from their fellow farmers. Even though farmers shared the idea, the adoption rate was low. The study revealed that crucial stakeholders in the dairy sector had not educated farmers *en masse* on the benefits of using LBY in dairy production. Hence, this could be a contributing factor to the low adoption of the use of LBY in the area despite being near brewing industries.

Table 4: Handling and management practices for liquid brewers' yeast by Githunguri dairy farmers

Practice	Level	Frequency (%)
Source of information on LBY	Other farmers	76.7
	Media	2.3
	Both extensions officers and other farmers	4.7
	Both extension workers and dairy cooperative	2.3
	Both agricultural shows and other farmers	2.3
	Both research institutions and media	2.3
	All the above channels	4.7
	Both agro-vets and other farmers	2.3
	Both agricultural shows and research institutions	2.3
LBY source	Distributors	81.3
	Both distributors and middlemen	12.5
	Middlemen	6.3
LBY feeding	Fresh	92.0
	After preservation	4.0
	Both fresh and after preservation	4.0
Quality deterioration	Visible mould growth	15.4
	Change in smell	23.1
	Change in texture	23.1
	Visible mould growth, change in smell, change in texture and decreased uptake by the animal	38.4

The loading matrix of benefits and challenges associated with using LBY on principal components is in Table 5. It was determined that there were three principal components, where benefits associated with using LBY had a very strong positive loading on principal component 1. Challenges associated with using LBY had a very strong positive loading on principal component 2. Principal component 3 had a slightly strong positive loading of one benefit (improves growth= 0.534) and a slightly strong negative loading of one challenge (bulky and cumbersome to transport= -0.596).

Table 5: Loading matrix of benefits and challenges of using LBY on principal components

Category	Factor	Principal Component		
		1	2	3
Benefits	Improves milk yields	**0.954**	-	-
	Inexpensive	**0.940**	-	-
	Purchase required quantities any time	**0.940**		
	Better quality	**0.926**	-	-
	Dairy cattle like the taste	**0.891**	-	
	Improve growth	**0.654**	-	0.534-
Challenges	High transport cost	-	**0.807**	-
	Dairy cattle do not like the taste	-	**0.796**	-
	Do not know appropriate feeding quantities	-	**0.789**	-
	Can not purchase required quantities	-	**0.777**	-
	Not readily available protein	-	**0.733**	-
	Bulky and cumbersome to transport	-	**0.771**	-0.596-
	Short shelf life	-	**0.681**	-

The main challenge associated with using LBY is the high transport cost due to its bulkiness. Nonetheless, it was established that the benefits of its use in dairy production outweigh the limitations based on the experience of the farmers. The perishable and bulky nature of LBY calls for developing

strategies and techniques to standardize it for long-term storage under tropical conditions; preferably, using solar energy to dehydrate and reduce its bulkiness is inevitable.

Conclusion and Recommendation

The study established that more than half of the farmers know LBY as a dairy cattle feed supplement, the adoption rate is low. Hence, the need for concerted efforts by stakeholders in the industry to increase farmers' knowledge base on the utilization and effectiveness of LBY as an affordable alternative protein source for sustainable and economically viable dairy production.

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LIVESTOCK PRODUCTION AND MANAGEMENT FOR SUSTAINABLE FOOD SYSTEMS

Calf Survival Rates upto Two Years for Improved Boran Cattle and their Crosses

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Abstract

The aim of this study was to evaluate calf survival rates before weaning and upto two years since it has an effect on herd growth, economic returns, genetic progress. Data was collected for calves that were born between 2014 and 2021. A total number of 133 calf deaths and their cause were recorded within this period. Descriptive statistical analysis was done using excel while effect of sex, birth weight and breed of calf was determined by logistic regression using SAS v. 20 software. From the results, the pre-weaning mortality rates, mortality rates after weaning upto 1 year and between 1 and 2 years were 6.3, 2.7 and 2.0% respectively. Most of the mortalities occurred between February and May while the lowest number of deaths occurred in November and December. Generally, more males died as compared to females. Birth weight, breed and sex of the calf non-genetic factors were found to have a significant effect on mortality of the calf. It is concluded that the post-weaning mortality rates are within the recommended levels, with slightly higher than recommended levels for pre-weaning mortalities. Since pre-weaning mortality rates are slightly above the recommended levels, strengthening of calf management strategies will enhance attainement of the recommended survival rates.

Key words: *calf management, genetic progress, post-weaning mortality rates*

Introduction

Calves provide the heifers and bulls for replacement in the herd which facilitates growth of beef cattle herds. These animals also provide stock for sale especially in commercial farms and in smallholder farms. Achievement of high pre-weaning and post-weaning survival rates of calves is therefore important for availability of replacement animals. The survivability of calves can be affected by high calf mortality rates which could limit the growth of the beef cattle herds (Reimus *et al.,* 2020). Incidences of calf mortalities have been reported in beef cattle herds in Santos *et al.,* (2019) and Motus *et al.,* (2019). High calf mortalities contribute to high economic losses in beef farms (Ferede *et al.,* 2014). According to Radostits *et al.,* (1989), calf mortalities for ages below one year can go upto 50% due to factors such as endemic diseases and poor adaptability of exotic breeds to prevailing climatic conditions. According to Hossain and Farhad, (2009), mortality rates should maintained at levels between 3-5%. In addition to economic losses, loss of favourable genetic material can happen which could otherwise be used for genetic improvement of beef cattle herds.

Mandal *et al.,* (2019) has classified causes of calf mortality as infectious or non-infectious. The infectious causes include diseases such as pneumonia while the non-infectious factors include low birth weight and management practices. Some non-genetic factors associated with calf mortalities include sex, birth weight and season of birth of the calf (Mandal *et al.,* 2019) while the genetic factors include sires for the different calves. Since calf survival rates is one of the traits in the breeding objective of beef research institute and the rates affect herd growth and economic returns in a beef cattle production system, the aim of this study was to assess pre- and post weaning calf survival rates upto two years, and identify possible factors that could be associated with calf mortalities.

Methodology

Study area

The study was conducted in Kenya Agricultural and Livestock Research Organization - Beef Research Institute in Lanet, Nakuru County, Kenya which is situated in Agro-Ecological zones 3 and 4. The mean annual rainfall in the institute is 800mm and diurnal temperatures between 14-26ºC.

Animal management and study animals

The animals are reared under ranching conditions whereby grasses such as *Chloris gayana*, *Pennisetum clandestinum* and *Themeda triandra* are dorminant. The calves are born throughout the year and stay with the dams until 7 months when they are weaned. Details that are recorded immediately the calves are born include date of birth, breed, sire, dam, coat colour and birth weight. Disease management practices include dipping once per week, deworming after every three months and vaccination against diseases such as East Coast Fever, Foot and Mouth Disease, Lumpy Skin Disease, Black Quarter and Anthrax. The main cattle breed reared in this institute is Boran. The breeds that were considered in this study were straight bred improved Boran and its crosses with Sahiwal, Redpoll, Orma Boran and (Dairy) Ayrshire and Fresian breeds. The improved Boran reared in the institute are registered with Kenya Stud Book.

Data source and statistical analysis

Data recorded between 2014 and 2021 was used to evaluate the pre and post-weaning calf survival rates. Veterinary investigation laboratory results were used to collect information on identification, age of the animal, sex, breed, date and cause of death. The data was initially recorded in MS Excel. A total of 133 deaths were recorded for animals from a total of 1344 births between 2014 to 2021. Descriptives statistics were performed using MS Excel whereas effects of birth weight, breed and sex on mortality was evaluated using Logistic procedure in SAS v.20 software. A significance level of $P<0.05$ was used in evaluation of significant factors affecting mortality rates.

Results

The mortality rates before and after weaning are shown in Table 1. The highest death rates occurred before weaning (6.3%), after weaning upto one year (2.7%) and between one year and two years (2.0%).

Table 1. Mortality rates before and after weaning upto two years (2014 - 2021)

Factors	N	Percentage (%)
Dead before weaning	76	6.3%
Dead after weaning up to 1 year	33	2.7%
Dead after weaning between 1- 2 years	24	2.0%
Survived	1211	89.0%
Total	1344	100

The distribution of animal mortalities between January and December are shown in Figure 1. The highest number of deaths occurred in February and March. Lower rates of mortalities occurred in November, December and January. For the sexes, generally, more males than females died between January and May and also in August and September.

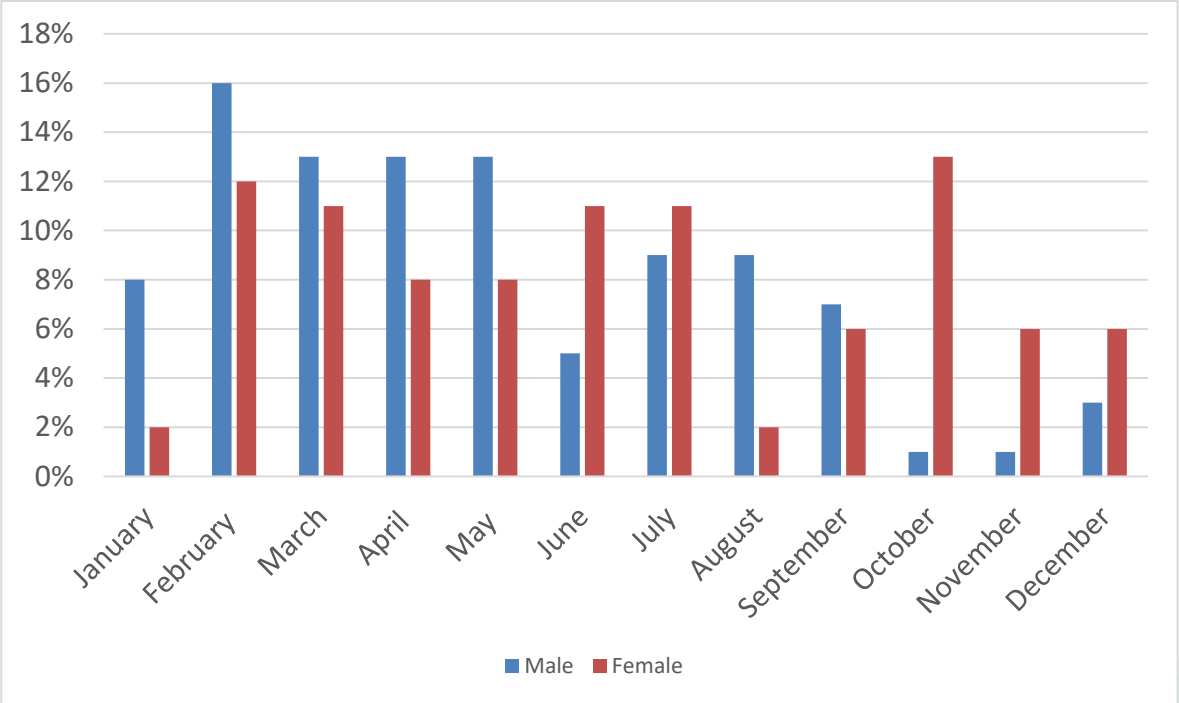

Figure 1. Occurrence of calf deaths for males and females between January and December

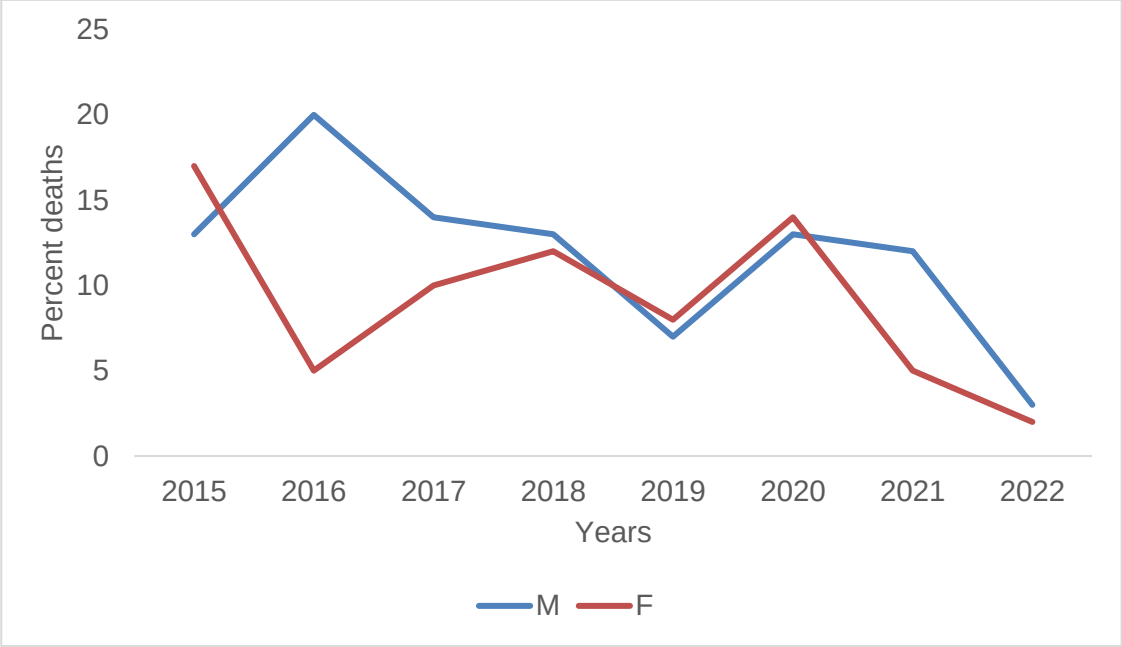

Figure 2. Mortality trends between 2015 to 2022 (M-Males, F-Females)

Mortality rates trends for males and females is shown in Figure 2. Generally, there has been a decrease in calf mortalities since the year 2018 although there was an increance in 2020 for both males and females. Effect of sex, breed and birth weight of the calf are shown in Table 2. Sex, breed and birth weight of calf significantly affected mortalities with P values at 0.0147, 0.0112 and 0.0383, respectively.

Table 2. Factors associated with mortalities based on logistic regression analysis

Variable	Categories	Frequency	Percentage	P value
Sex	Male	579	49	0.0147
	Female	609	51	
Breed	Improved Boran	661	56	0.0112
	Sahiwal X improved Boran	249	14	
	Redpoll X improved Boran	111	9	
	Dairy crosses	167	21	
Birth weight (kgs)	≤20	39	3	0.0383
	21-25	596	50	
	>25	553	47	

Discussion

The pre-weaned calves had higher mortality rates as compared to post-weaned ones. A similar trend was reported in Kebamo *et al.*, (2016), where pre-weaning and post weaning mortality rates of 13.1% and 11.2% respectively, was reported. High pre-weaning mortalities are associated with the fact that the immunity of the calf is still developing and also it depends on the extent of transfer of antibodies to the calf which requires that for optimal antibodies transfer, the young one should be fed within 24 hours from birth (Kebamo *et al.*, 2016; Santos *et al.*, 2019; Godden 2008). The pre-weaning mortality rate in this study (6.3%) was lower as compared to 13.3% reported in Kebamo *et al.*, (2016). The pre-weaning mortality rate in this study was slightly above the value of 3-5% as recommended by Wold and Yehualashet, (1987). This implies that there is a need to improve on health and feeding management strategies for the calves from birth to weaning. The post weaning mortality rates are within the recommended values of 3-5% by Radostits *et al.*, (1994). This means that the post-weaning feeding and health amanagement levels are within the desirable levels for beef production.

The highest number of mortalities occurring in February and March is an indication that availability of quality feeds affects survival of the calf as a result of sufficient nutrition to the dams which in turn provide enough milk for the calves especially for the pre-weaned calves. Therefore, although, supplementation is done at the institute during the dry seasons of the year, it might not be sufficient. According to Uza and Adee , (2005), unavailability of quality feeds and reduced feed intake during dry months of the year could be the cause of high rates of mortalities during dry periods in February and March. During dry periods, the pastures are mostly fibrous and have reduced protein levels (Valente *et al.*, 2014; Branco *et al.*, 2010). This can lead to lowered immunity of the animals and make them more susceptible to diseases. Higher death rates experienced in May, June and July is also an implication of how some diseases could have high prevalences due to cold environmental temperatures for pre and post-weaned calves. According to Kumar *et al.*, (2002), Hordofa *et al.*, (2014) and Mellado *et al.*, (2014), factors that are related to weather such as extreme cold leads to an increase in pathogens loads and makes the environment conducive for multiplication of microorganisms.

Mortalities were high in males than in females. This was similar to results reported by Debnath (1990). This was contrary to what was reported by Hordofa *et al.*, (2014) and Ngugi *et al.*, (2006) whereby there were high number of female deaths as compared to males. According to Azzam *et al.*, (2020), males have a tendency to have high mortalities in comparison to females even when factors such as dystocia and the birth weight have been accounted for. The decrease in calf mortality trend over the years implies that there has been an improvement in calf management strategies in terms of health and nutrition. Calf survival rates are affected by many factors and improvement of these aspects enhance calf survivability especially for young calves (Mandal *et al.*, 2019). This will in turn

improve profitability as a result of availability of animals for replacement and sale. This trend was similar to Assefa *et al.,* (2014) whereby the mortality rates for females decreased with years.

The sex of the calf had a significant effect on death occurrence of the animals (P=0.01). This was similar to Pathak *et al.,* (2018) and Mellado *et al.,* (2014), where sex of the calf was reported to influence the mortality of the animal. A possible explanation to this has been given in Staley *et al.,* (1985) and Khan and Khan (1991), whereby it was recorded that there is less absorption of serum immunoglobulins in males as compared to females which are required for protection against diseases. Since there is competition between immunoglobulins and microorganisms for a common intestinal receptor, males become more immunodeficient than females making them more prone to bacterial diseases. Contrary to the results in the current study however, Geses *et al.,* (2021), Asefa *et al.,* (2014) and Ferede *et al.,* (2014) reported that sex doesn't influence death occurrence in calves.

Birth weight of the calves did not have a significant effect on mortality rates of the calves with P=0.083. Higher calf mortalities are associated with higher birth weights due to dystocia or low birth weights which reduces survivability due to low colostrum intake (Mandal *et al.,* 2019. Improved Boran and its crosses are not as large as compared to exotic breeds due to its medium body size which could be the reason why the birth weights did not significantly affect survival. Kebamo *et al.,* (2019) however reported a significant effect on calf mortlaities stating that calves with lower birth weights have low survivability and vitality. The breed of the calf had a significant effect on calf mortality (P=0.01) which was in harmony with Debnath *et al.,* (1990). The significant effect of the breed is as a result of the indigenous improved breeds such as improved Boran and Sahiwal which have been developed for tropical conditions having better adaptability to environmental and climatic conditions tof tropics in comparison to exotic breeds and their crosses (Debanth *et al.,* 1990). In Pathak *et al.,* (2018), however, non-significance of genetic groups on mortality rates on Jersey crossbred calves of different ages was reported. Higher mortality rates were reported for crossbred calves at 75% exotic and 25 % local as compared to crossbreds at 50% local breeds. The differences however could be as a result of small sample sizes for some breeds especially Redpoll and Dairy crosses.

Conclusion

It is concluded that the post-weaning mortality rates are within the recommended levels, with slightly higher pre-weaning mortalities above the recommended levels. The current reduced pre-weaning mortality levels within the ranch are almost reaching the recommended survival rates for growth of the herds and genetic progress.

Recommendation

Since pre-weaning mortality rates are slightly above the recommended levels, strengthening of calf management strategies will enhance attainement of the recommended survival rates.

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Determining the Effects of Cow Characteristics and Calf Gender on Dam Milk Yield in Dairy Breeds; Case Study of Kiambu County Dairy herds, Kenya

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Abstract

Dairy production and achieving high milk yield have far-reaching implications for human nutrition, economic development, and agricultural sustainability. Ensuring the efficient and sustainable production of dairy products is crucial for meeting the needs of current and future times. This study was carried out to determine the effect of cow characteristics and calf gender on dams milk yield. It analysed factors affecting milk production in Jersey and Friesian cattle breeds where it shows distinct characteristics and responses to various variables. Statistical analysis using ANOVA techniques was conducted to show the relationship between breed, calf gender, age of the dam, and seasonal influences on milk yield. The study showed a statistically significant difference in milk production between Jersey and Friesian breeds. The F-value of 14.28 and a low p-value of 0.001 emphasized the substantial distinction in milk production levels between these two prominent dairy breeds. The study also examined the breed's effect on milk production at different stages of lactation. Holstein Friesian cows demonstrated significant milk production influence at day 100, 200, and 300 of lactation, while Jersey breed exerted a significant impact at day 200 and 300, emphasizing breed-specific variations in milk yield. The research also showed the effect of calf gender on milk yield, demonstrating a significant difference in both Jersey and Friesian breeds, with female calves exhibiting higher milk

production. This gender-based difference remained consistent across breeds. The analysis also considered both calf gender and age of the dam, confirming the significance of calf gender and the age of the dam as a crucial factor, with older dams yielding more, the study also analysed the relationship of calf gender, age of the dam, and seasonal influences on milk yield. The results underscored the seasonal effect on milk production in both breeds, even when accounting for calf gender and maternal age. This research was aimed at the ongoing discourse surrounding cattle breeding and management practices.

Key words*; Animal characteristics, milk performance, dairy cattle, calf gender*

Introduction

Dairy production is vital to Kenya's economy, with Kiambu County being a major contributor. In 2019, Kiambu County produced 275 million liters of milk, primarily from smallholder farmers owning a few cows (KNBS, 2019). Factors like breed, management, and calf gender impact milk production (FAO, 2020).Research also has shown that calf gender affects milk yield, with female calves often leading to higher yields (Hinde *et al.*, 2014). This insight could upscale dairy management and genetic selection. However, data on exotic breeds' impact on milk yield at different lactation stages and calf gender's effects are limited (Lukuyu *et al.*, 2019). The objective of the study was to assess how cow characteristics, including calf gender, influence milk yield and profitability. It also explored the potential of using sexed semen to manage these effects (Norman *et al.*, 2010). Such research can refine breeding strategies and deepen our understanding of milk production in dairy cattle (De Vries & Kemp, 2017).

Materials and Methods

Study Area

The research was conducted in Kiambu County between December 2019 and April 2020. Kiambu County, with its capital in Kiambu and the largest town being Thika, is located adjacent to the northern border of Nairobi County. It has a population of 1,623,282 and is 40% rural and 60% urban due to Nairobi's growth. The county's coordinates are between latitudes 00°25' and 10°20' south of the Equator and longitudes 36°31' and 37°15' east.

Study Design

The survey involved structured questionnaires and focused on dairy farmers meeting specific criteria: they had to rear dairy cattle under zero grazing, have exotic breeds, and maintain reliable milk records. Data on lactation and calving from the last three parities were collected from 16 dairy farmers who raised Friesian and Jersey dairy cows. Sexed semen was not used during this study. The data used was obtained from an existing database and was exempt from ethics approval. Only cows with single, unassisted live births were considered. Lactation records with exceptionally short (<100 days) or long (>305 days) durations were excluded. Data from cows with recorded calf genders for the first three parities were analyzed.

Data Collection and Data Analysis

Data collected included the number of dairy animals, their breeds, dams' ages and parities, calf genders, and milk production. SPSS software was used for analysis. Descriptive statistics determined milk production means, linear regression assessed animal characteristics' impact on milk yield at different lactation days (day 100, 200, and 300), and analysis of variance tested the significance (at $\alpha = 0.05$) of calf gender, seasonal effects, and dam age on milk yield.

Results and Discussion

Table 1 shows the variation in milk production between Jersey and Friesian breeds is statistically significant. The F-value of 14.28 suggests that there is a significant difference in milk production levels between these two breeds. The low p-value of 0.001 indicates that this difference is statistically significant .Within each breed (Jersey and Friesian), there is variation in milk production among individual animals. The sum of squares (SS) and degrees of freedom (DF) within breeds represent this variation. The analysis confirms that there is a significant difference in milk production between Jersey and Friesian breeds.

Table 1: The Effects of Breeds on Milk Production

Source of variation	Sum of squares(SS)	Degree of freedom(df)	Mean squares (MS)	F value	P value
Between breeds	1,234,567	1	1,234,567	14.28	0.001*
Within breeds	8,764,432	90	8,764,432		
Total	10,000,000	91			

* indicates significant difference at 0.05% confidence level

Table 2 indicates the effect of cow/ animal breed on milk production at day 100, 200 and 300 of lactation. Holstein Friesians cows had a total of 22228.82±30.35 litres of milk at day 100 of lactation, 1463.39±19.82 litres of milk at day 200 of lactation and 495.24±6.75 litres at day 300 of lactation. The study also indicates that the Holstein Friesian breed had significant influence on milk production at day 100, 200 and 300 of lactation. It was also observed that Jersey breeds had a mean milk production of 5635.77±36.13 litres of milk at day 100, 4943.04±23.76 of milk at day 200 and 4943.04±23.76 litres of milk at day 300 of lactation. Jersey breed significantly influenced milk production at day 200 and 300 of lactation. Mean milk production at day 100 was not influenced by the Jersey breed.

Table 2: The effect of breeds on milk production at Day 100,200 and 300 of lactation

Breed	Mean Milk production at day 100 (Litres)	Mean Milk production at day 200 (Litres)	Mean Milk production at day 300 (Litres)
Holstein Friesian	2228.82±30.35*	1463.39±19.82*	495.24±6.75*
Jersey	5635.77±36.13	4943.04±23.76*	4943.04±23.76*

* Indicates significance at 0.05% confidence level

Table 3 indicates the effects of calf gender on milk yield in Friesian and jersey breeds, the data shows that, for Jersey breed, there is a statistically significant difference in milk production between male and female calves ($p < 0.05$). Female Jersey calves have a higher mean milk yield. For Friesian breed, there is also a statistically significant difference in milk production between male and female calves ($p < 0.05$). Female Friesian calves exhibit a higher mean milk yield. In both breeds the results showed that there was a higher milk yield in dams with females calves compared to the ones with male calves.

Table 3: Effect of Calf Gender on Dams Milk Yield in Friesian and Jersey Breed

Breed	Source Of Variation	F-Value	P-Value
Jersey	Calf gender	6.25	0.032*
Friesian	Calf gender	7.80	0.021*

Table 4 indicates the combined effect of dam age and calf gender on milk yield. After taking account of the age of the dam and the gender of the cow, gender-based differences in milk yield was still significant ($p<0.05$). Female calves consistently exhibited higher milk yield compared to their male

counterparts within both Jersey and Friesian breeds. Furthermore, the age of the dam emerged as a crucial factor influencing milk production. Older dams were associated with higher milk yields, suggesting that lactation performance tends to increase with maternal age.

Table 4: The Effect of Both Calf Gender and Age of the Dam on Milk Yield

Breed	Source Of Variation	F-Value	P-Value
Jersey	Calf gender	6.25	0.032*
Jersey	Age of the dam	8.14	0.015*
Friesian	Calf gender	7.80	0.021*
Friesian	Age of the dam	6.75	0.026*

* Indicates significance at 0.05% confidence level

Table 5 indicates the effect of seasons, age of the dam and calf gender on milk yield, a three way ANOVA was used to find the relationship among the three variables. The analysis showed the significant effect of each variable and indicate that the season has a significant influence on milk yield in both Jersey and Friesian breeds when still considering calf gender and age of the dam.

Table 5: The Effect of seasons of the year, age of dam and the calf gender on milk yield

Breeed	Source Of Varition	F –Value	P-Value
Jersey	Calf gender	6.25	0.032*
Jersey	Age of dam	8.14	0.015*
Jersey	Season of the year	4.46	0.049*
Friesian	Calf gender	7.80	0.021*
Friesian	Age of dam	6.80	0.026*
Friesian	Season of the year	5.62	0.036*

* Indicates significance at 0.05% confidence level

Discussion

A study by S.H. Evers *et al.*, (2023) emphasized the significant influence of breed on milk production, specifically noting variations between Holstein Friesian and Jersey cattle. Other research by Cole *et al.*, (2023) highlighted the role of management practices in milk production. Factors contributing to milk production differences in these breeds include genetics, body size, feed quality, milking practices, lactation curve, herd management, breeding goals, and health (S.H. Evers 2023).

The study also examined milk production at various stages of lactation, showing that Holstein Friesians had a consistent impact on milk production across days 100, 200, and 300, while Jerseys primarily affected days 200 and 300, not day 100. This aligns with findings by R. Prendiville, suggesting Jersey influence in later lactation stages. Kensinger (2022) reinforced this by highlighting a slower initial milk production rise in Jerseys, attributed to their smaller size and lower milk potential, offset by higher fat and protein content (National Dairy Development Board (NDDB) 2015).

Additionally, the study noted a significant difference in milk yield between dams with female and male calves in both Jersey and Friesian cows, which is consistent with Fabrice *et al.*, (1995). This gender effect may be due to hormonal differences, affecting mammary gland development and milk synthesis. Studies by Gaafar *et al.*, (2011) and Ghavi Hossein-Zadeh (2013) linked male calves to higher dystocia rates, impacting milk production. Bareille *et al.*, (2003) observed reduced dry matter intake postpartum in cows with dystocia, reinforcing the calf gender-milk production relationship. In Friesians, female calves contribute around 25% more milk than males, and in Jerseys, approximately 20% more.

In conclusion, breed choice significantly impacts milk production, with calf gender also playing a substantial role, affecting milk yields and warranting further investigation into hormonal and genetic factors.

Conclusion

The primary objective of dairy farming is to maximize profitability by optimizing milk production in each lactation cycle and extending a cow's productive lifespan. An assessment of factors influencing lactation efficiency has underscored the significant impact of breed on milk production. Hence, it's crucial to take these factors into account when making breeding decisions for a dairy operation. Moreover, the choice of animal breed can influence milk production across all phases of lactation (milk100, milk200, and milk300), making it a critical consideration when selecting breeds for a dairy enterprise. Additionally, calf gender plays a pivotal role for dairy farmers, as it directly affects the total milk production during a cow's lactation period. Cows giving birth to female calves tend to produce slightly more milk compared to those with male calves. This knowledge is essential for dairy farmers in managing their herds and optimizing milk yields.

Recommendation

In order to maximize profit a farmer might considered producing only female calf, not only because it is associated with high milk production of Dam but also, a heifer will be future herd replacement. The idea is 99% possible through use of sexed semen. This study was conducted under the assumption that variables such as feeding were held constant. Future research could investigate these factors in detail. The study also emphasizes on considering dairy animals characteristics when making breeding decisions to ensure, healthy productive herd while maximizing profits for the dairy enterprise.

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De-Risking, Inclusion and Value Enhancement (Drive) Project

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DRIVE is a regional project that is been implemented in four (4) Horn of Africa (HoA) countries i.e. Kenya, Ethiopia, Somalia and Djibouti as part of the Horn of Africa Initiative (HoAI) of building resilience to climatic shocks, facilitating trade and supporting value chains. The project has financial support from the World Bank with Kenya being supported by a credit of USD 140 million (KES 16.082 Billion @ exchange rate 114.87 per dollar as of April 2022).

The objective of the project is; to protect pastoral economies against drought risk, increase financial inclusion of pastoralists and better connect the pastoralist to markets; To facilitate livestock trade across the HoA countries and upgrade livestock value chain by mobilizing private investments.

The Project Development Objectives (PDO) are to enhance pastoralists' access to financial services for drought risk mitigation, include them in the value chains, and facilitate the livestock trade in the Horn of Africa. The project builds on the lessons learnt from the Kenya Livestock Insurance Program (KLIP). The Government of Kenya is implementing the project through the State Department for Livestock (SDL) in collaboration with ZEP-RE (PTA Reinsurance corporation, a COMESA reinsurance institution) and Kenya Development Corporation (KDC) as implementing partners. In Kenya, the project will target 21 ASAL counties of Turkana, Marsabit, Isiolo, Laikipia Mandera, Wajir, Garissa, Tana River, Taita Taveta, Kilifi, Kwale, Lamu, Meru (Meru North sub county), Tharaka Nithi, Samburu, Baringo, West Pokot, Narok, Kajiado, Makueni and Kitui where pastoralism type of farming is done and drought insurance products for livestock (Index based Livestock Insurance products) are viable.

Evaluation of Growth Performance of Sahiwal Crosses Calves During Pre-Weaning Period in Arid and Semi-arid Areas of Kenya

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Abstract:

The study was conducted at KALRO Mariakani, Kilifi County to assess the pre-weaning weights of different Sahiwal crosses. Sahiwal cattle is a dual-purpose breed native to Pakistan. It's a climate smart breed for the Kenyan Coastal ASALs. The breed has shown very good adaptability not only in Naivasha Kenya but also in the Kenyan Coastal ASALs.

Various Sires were used in the study and their calves' records taken since birth. The calves were weighed monthly and weights recorded in Excel spread sheet and latter analyzed using the SAS system (Statistical Analytical System). The heart girth tape was used to measure the weights. The calves suckle colostrum from their mother for 24 hours after birth and latter bucket fed twice in a day with mothers' milk (dam) at the rate of 10% of their body weights.

Among the key indicators recorded include, dams name, Sires name, calf name, calf date of birth, calf birth weight, sex of the calf (male or female), parity of the dam, monthly weight gain and the yearling weaning weight at seven months. These parameters used either had effect on the results obtained.

Key words: *Pre-weaning weight, Climate smart, adaptability, Coastal ASALs, Sire, Dam, Parameters*

Introduction

Livestock beef breeds reared on the Kenyan coast are mainly local breeds, such as the small East African Zebu, which produces small quantities of meat and milk. Beef farmers can increase productivity by adopting high yielding drought tolerant breeds such as the Sahiwal to enhance productivity and livelihood. As observed by the ASDSP (2014) report, the existing beef breeds need to be upgraded by crossbreeding to increase their genetic potential. Food insecurity, for example, in Kilifi County is rather high at 98%, and only less than 20% of the households ever experience food security during harvesting periods (ASDSP 2014). Through improved livestock production food security can be improved. The community can be encouraged to participate in breeding activities aimed at improving their local breeds for improved beef production both in terms of quality and quantity.

This study was aimed at determining the pre-weaning up to the weaning weights of given Sahiwal crosses, i.e., Sahiwal Aryshire crosses and Sahiwal improved Boran crosses. These weights also helped to deduce the Average Daily Gain (ADG) of the respective Sahiwal crosses. Sahiwal has higher growth rate and meat output compared to local coastal breeds reared. However, there is a need to have data on the same as proof to beef farmers to adopt superior genotypes in beef production.

There is a dire need to improve and disseminate climate-smart beef cattle for improved milk and milk output and livelihoods in the Kenyan coastal region. Due to the ongoing climate change, it is

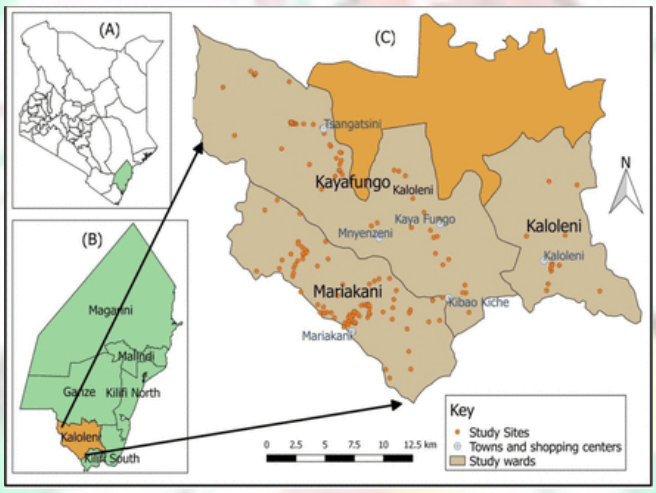
recommended and desirable to keep fast-growing and high-yielding breeds and cross-breed. Sahiwal breed is a dual-purpose breed adaptable to coastal arid and semi-arid lands (ASALs).

Pre-weaning weights for Sahiwal and crosses will be an essential tool to both the Kenya Agricultural and Livestock Research Organization (KALRO) Beef Research Centre as well as other beef actors and stakeholders in the Beef value chain. This forms the basis of a conversation on how adaptable, suitable, and climate-smart the breed is in relation to its environs.

Materials and Methods:

Site description

The study was conducted at Kenya Agricultural and Livestock Research Organization, Beef Research Centre Mariakani. The Centre is situated along the Mombasa-Nairobi highway adjoining Mariakani Township. The Centre is 37 km from Mombasa city. It lies at 3° 53´S 39° 28´ E. The Centre is in agro-ecological zone 5 (Lowland livestock-Millet Zone). It receives a mean annual rainfall of 800mm, bimodal in distribution, with long rains in April/May and short rains in October/December (Jaetzold and Schmidt 1983). 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, and lacking in organic matter.



Herd establishment and breeding programs:

A herd consisting of 102 Sahiwal Aryshire crosses dams were used for breeding. This was part of the herd at the Centre. Four bulls were used in breeding, namely 5F51 (improved Boran), a Sahiwal bull, Sahiwal Aryshire(S/A) crossbreed bull, and a Boran bull (MATUGA). The ages of the dam run from 3-17 years old with parities of 1-10.

Animals with superior characterists (highly heritable traits) were selected from a herd and allowed to mate at random. Selection of high quality breeding stock was done carefully and systematic. Among the traits observed include, the health of the animal, Age, temperament, fertility of the animal, body conformation. Animals with body deformities, stunted animals, old animals were not selected. Records to access the herd performance was obtained from the Centre's livestock records.

Natural mating method was used in breeding. Bulls were allowed to run with cows during breeding season. One bull was given a herd of twenty cows and ran with the females for three months.

Nutritional requirement/feeding:

Animals were fed on natural pastures, free-range grazing, and holistic grazing was adopted. Animals grazed for 8 hours a day. During scarcity of natural pastures, the animals were fed on molasses treated hay. To improve milk production, lactating cows were supplemented with 2 kilos of maize germ per day fed when milking. Water was provided *ad libitum*. The animals were well managed as all livestock routine management practices were strictly observed.

Calf rearing to weaning:

New borne calves suckled colostrum for 24 hours before being separated from their mothers. The bucket feeding method was used to feed calves with their mother's milk for7 months. Calves were fed at 0730hrs and 1600hrs, respectively. Calves were fed at the rate of 10% of the body weights.

Data recording, preparation and statistical analysis:

Details of both the Sire and Dam were recorded at Mating. This information was kept in a manual breeding record book and replicated in an excel spreadsheet. The expected date of delivery was indicated at the remarks section. Mated cows were observed to ascertain repeat estrus cycles.

Upon birth, the calf was identified by way of ear notching, where letters T and H were used to identify male and female calves, respectively; additionally, numbers 0 to 9 were used to represent individual calf identities. Following identification, the calf's birth weight wasrecorded.

Subsequently, the calves were fed with milk, and their weights were taken every month. A heart girth tape was used to take the weights. Calves were weighed in the morning before taking milk. Bucket feeding was preferred since it ensured that all calves were fed with the same amount of milk daily as per their requirements.

Results

Table 1: showing results for the pre-weaning weights, weaning weights, and average daily gain.

Factors	N	Birth weight	N	Weaning weight	N	ADG
Sex		**0.1143D**		**0.4094D**		**0.6301D**
Male		21.99±1.19		162.68±5.60		0.669±0.027
Female		21.23±1.15		160.81±5.45		0.664±0.0264
Overall	210	22.43	210	120.05	210	0.46
Parity of dam		**0.2131D**		**0.0002H**		**0.0001H**
1		21.29		168.20		0.6996
2		20.34		167.05		0.6986
3		21.31		159.11		0.6561
4		22.19		161.83		0.6617
5		21.31		161.15		0.6604
6		23.12		161.83		0.6603
7		22.62		158.23		0.6457
9		19.66		160.25		0.6692
10		22.73		159.88		0.6530
Sire		**0.3213D**		**0.0001H**		**0.0001H**
5F51(Improved Boran)		22.14		185.25		0.4436
MATUGA (Boran Bull)		23.77		122.25		0.4687
SAHIWAL Bull		20.47		125.04		0.4974
Sahiwal		22.15		120.41		0.4680
Ayrshire Bull						

Factors	N	Birth weight	N	Weaning weight	N	ADG
Year of birth		**0.0057H**		**0.0001H**		**0.0001H**
2018		21.54		165.17		0.6839
2019		22.81		173.92		0.7176
2020		21.60		159.27		0.6554
2021		20.52		148.63		0.6100

The sex of the calf did not affect the birth weight, weaning weights, or the ADG for Sahiwal Aryshire Boran crosses across the time frame observed. 2. The parity of the dam did not affect the birth weight of the calves; however, the parity of the dam affected the weaning weights as well as the ADG. Cows with a parity of 1 were observed to have the highest weaning weight of 168.2038kgs, while cows with a parity of 7 had the lowest weaning weight of 158.2270kgs.

The breed of the Sire did not have a significant effect on the birth weight of the calf born; however, it showed a significant effect on the weaning weight and the ADG. Sire 5F51 (improved Boran breed) had the highest weighing weight of 185.2534, while Sire S/A (Sahiwal Aryshire crossbreed) had the lowest weaning weight of 120.4067, respectively.

The year of birth had a significant effect on the birth weight, weaning weights, and on ADG. The y 2019 was observed to register the highest birth weights (22.8054) as well as the weaning weights (173.9172) and the ADG of 0.7176. The year 2021, as observed, had the least birth weights (20.5176), weaning weights (148.6278), and ADG of 0.6100.

Discussion

The parity of dam is an important factor to consider in the selection and breeding of Beef cattle, particularly in the ASAL Coastal regions of Kenya. Beef keepers should be advised to cull old breeding dams to achieve optimum birth weights of calves born. From the results, a cow with a parity of 1 had a competitive weaning weight of 168.2038 as compared to a cow with a parity of 10 with a weaning weight of 159.8840.

Improved Boran and Sahiwal Bulls are good candidates for breeding the KALRO Mariakani. This is because they recorded the highest weaning weights of 185.3 and 125.0, respectively. This will play a major role in increasing both meat output and milk production.

The environment was a direct determinant of the weaning weight and the ADG. There was enough rainfall in the year 2019, but the rains drastically reduced in the year 2020 through the year 2021. This had a significant effect on the weaning weights as shown above. Pasture growth and establishment require moisture in the soil. There is a need to consider feed reserves such as hay and silage for use during the dry season. Water harvesting methods should be adopted in ASAL areas to save situations during drought.

Conclusion and Recommendations:

To improve on both meat output and milk production in the ASALs areas of the Kenyan Coast, there is a need to adopt climate-smart breeds with increased productivity to maximize on the available feed resources. There is need to disseminate Technologies such as Improved breeds in this case, Improved Boran and Sahiwal breeds, to farmers and pastoralists in the Kenyan coast. This approach will enable us to upscale the productivity of precious local breeds, significantly improving the livelihoods of the people and combating food insecurity

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Identification of Indigenous Chickens' Egg Shell Colours in Kenya

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Abstract

Egg shell colour contributes to the visual appeal and attractiveness of eggs to consumers. Identification of shell colours by visual observation is inaccurate and application of spectrophotometer is constrained by availability and cost implications of the equipment. The objectives of this study were to explored use of a paint colour chart in identification and documentation of shell colours of indigenous chicken (IC) eggs in Kenya. Free-range IC chickens were sourced and clustered into three ecotypes. Eggshell colours were identified by comparison with a paint colour chart. The frequencies of each colour name were computed using excel and relationships between ecotypes and colours analysed using correspondence analysis. It was found that the Hex code, RGB code and colour shade descriptions could be determined and equivalent RGB colours established using the default computer colour display profile. A total of 34 different shell colours were observed and relationships with ecotypes established. It was concluded that a paint colour chart can be used to objectively identify and categorise egg shell colours. There exists a wide shell colour diversity that can be exploited for further development of IC.

Keywords: *ecotypes, egg shell colours, diversity, indigenous chicken, paint colour chart*

Intoduction

Eggshell colour contributes to the visual appeal and attractiveness of eggs to consumers (King`ori, 2012). The main pigments responsible for egg coloration in domestic birds are protoporphyrin IX, biliverdin IX, biliverdin zinc chelate and traces of coproporphyrin III (Lukanov *et al.,* 2015). Either independently or in combination, the pigments determine the different shell colours and shades within the same colour. Brown-shelled eggs are due to varying amounts of protoporphyrin, and uroporphyrin and traces of coproporphyrin. In blue-shelled eggs, biliverdin IX and biliverdin zinc chelate are the only pigments, while lack of pigmentation yields the white shelled eggs. The genetically determined shell colours affect not only the shell but also other egg quality parameters (Drabik *et al.,* 2021). Whereas commercial layers have been selected for either brown or white shelled eggs, unselected populations exhibit wide variations.

Both subjective and objective methods are used to assess egg shell colours. Subjective methods encompass visual observation (Gikunju *et al.,* 2018) or scoring by comparison with standards derived by the investigators (Lordelo *et al.,* 2017) while objective methods involve use of spectrophotometer. The application of objective methods in Kenya, and elsewhere in developing countries, is constrained

by availability and cost implications of spectrophotometer equipments thus leading to use of visual observations. Shell colours exhibit continuous variation whereas most visual observations generalize the colours into white, cream or brown. In order to classify all possible colours in a population, there is need to identify an accurate identification method. The objective of this study was to explored the use of commercial paint colour chart in egg shell colour identification and document the available colours of IC eggs in Kenya.

Materials and methods

Study site and egg source

The study was carried out at the poultry research unit (PRU) of the Kenya Agricultural and Livestock Research Organization (KALRO) situated at Naivasha. Free-range chickens were sourced from various counties clustered into three ecotypes. Ecotype 1 were from western counties of Bomet, Narok, Siaya, Homabay, Kakamega, Bungoma and Busia, ecotype 2 from arid and semi-arid lands (ASAL) counties of Turkana, West-Pokot, Mwingi, Isiolo and Laikipia and ecotype 3 from coast counties of Taita-Taveta, Kilifi, Kwale and Lamu. After 60 days of quarantined, each cock was allocated between 5 and 7 unrelated hens from the same county and placed randomly in deep litter mating pens. Each pen was labelled with the county of origin and the chickens provided about 130g per day of commercial layers' marsh and clean drinking water *ad libitum*. Eggs were collected daily for a period of 14 days and labelled to identify the source. The eggs were stored overnight at room temperature and on the following day, each egg's shell colour was compared to an ordinary colour paint chart (Dura coat, Kenya) and the matching colour code and name recorded. Using the chart colour code, the corresponding Hex code, RGB code and colour shade description were determined (Perfect Color Ventures, 2022). The equivalent RGB colours were established using the default computer colour display profile.

Data analysis

The frequencies of each colour name, general colour shade description and the number of colours per description were computed using excel software. The relationships between ecotypes and colour names were determined using correspondence analysis in SPSS (V 25).

Results

The eggshell colours are presented in Table 1 and relationships between ecotypes and shell colours in Figure 1. A total of 34 different colours corresponding to shades of light brown, very light brown, light orange, very light orange, very light yellow and very light green were observed. The most common colours (hex codes) were Inspiration (fae4c7), Soft Cashmere (fef0d8) and Chiffon (ffe7c4). There was a significant association between ecotype and shell colour (Figure 1). Amongst the colours, Marshmellow Snow (fbf0e0) and Golden Wheat (fbe5c4) were closely related, as were Afterglow (fad5af) and Kabuki (f8c693). Western ecotype was more associated with Inspiration (fae4c7), Carousel (fcd8af) and Elisa (faf0e1) shell colours, ASAL with Carotene (ffdaab) and Chiffon (ffe7c4), and coast with Honey Cream (fdf0d8).

Table 1. Eggshell colours and frequencies of indigenous chicken in Kenya

S/No.	Colour code	Colour name	Hex code	Colour shade description	RGB code	RGB colour	Frequency (%)
1	2058P	Inspiration	fae4c7	Very light brown	250 228 199		16.8
2	2064P	Soft Cashmere	fef0d8	Very light brown	254 240 216		12.3
3	2065P	Chiffon	ffe7c4	Very light brown	255 231 196		11.8
4	2059P	Carousel	fcd8af	Light brown	252 216 175		8.6
5	2072P	Flicker	fbe4ca	Very light brown	251 228 202		8.0
6	2057P	Elisa	faf0e1	Very light brown	250 240 225		7.5
7	2073P	Afterglow	fad5af	Light brown	250 213 175		5.2
8	2071P	Marshmellow Snow	fbf0e0	Very light brown	251 240 224		5.2
9	2066P	Carotene	ffdaab	Light brown	255 218 171		3.6
10	2036P	Honey Cream	fdf0d8	Very light brown	253 240 216		2.5
11	2086P	Peach Blossom	ffe3c9	Very light orange	255 227 201		2.0
12	2044P	Golden Wheat	fbe5c4	Very light brown	251 229 196		1.8
13	2015P	Wax Yellow	f8f3df	Very light yellow	248 243 223		1.8
14	2045P	Arcadia	f8d6a7	Light brown	248 214 167		1.6
15	2043P	Golden Glaze	fcebd0	Very light brown	252 235 208		1.6
16	2060T	Kabuki	f8c693	Light brown	248 198 147		1.1
17	2120P	Baby Pink	fbf0e8	Very light orange	251 240 232		0.9
18	2079P	Fantan	f7dec7	Very light orange	247 222 199		0.9
19	2344P	Sweet Thing	f1f2f1	Very light green	241 242 241		0.9
20	2078P	Mission Beige	f7e7d6	Very light brown	247 231 214		0.7
21	2134P	Pale Dogwood	faeee8	Very light orange	250 238 232		0.7
22	2074T	Festive	f0bb8f	Light orange	240 187 143		0.5
23	2085P	Lady Fingers	fdeddb	Very light brown	253 237 219		0.5
24	2050P	Navajo white	ffecca	Very light brown	255 236 202		0.5
25	2087P	Orange Ice	ffd6b4	Very light orange	255 214 180		0.5
26	2080P	Sunstone	f0c8ac	Light orange	240 200 172		0.5
27	2106P	Tender Touch	fcf0e3	Very light brown	252 240 227		0.5
28	2107P	Cameo Peach	ffe6d6	Very light orange	255 230 214		0.2
29	2687P	French Vanilla	f4ecd9	Very light yellow	244 236 217		0.2
30	2092P	Marble Peach	faede0	Very light brown	250 237 224		0.2
31	2939P	Mint Cream	eef1ea	Very light green	238 241 234		0.2
32	2897P	Pale Mushroom	efebe3	Very light brown	239 235 227		0.2
33	2029P	Paper Moon	fdf2da	Very light yellow	253 242 218		0.2
34	2093P	Peach Cascade	fcddc7	Very light orange	252 221 199		0.2

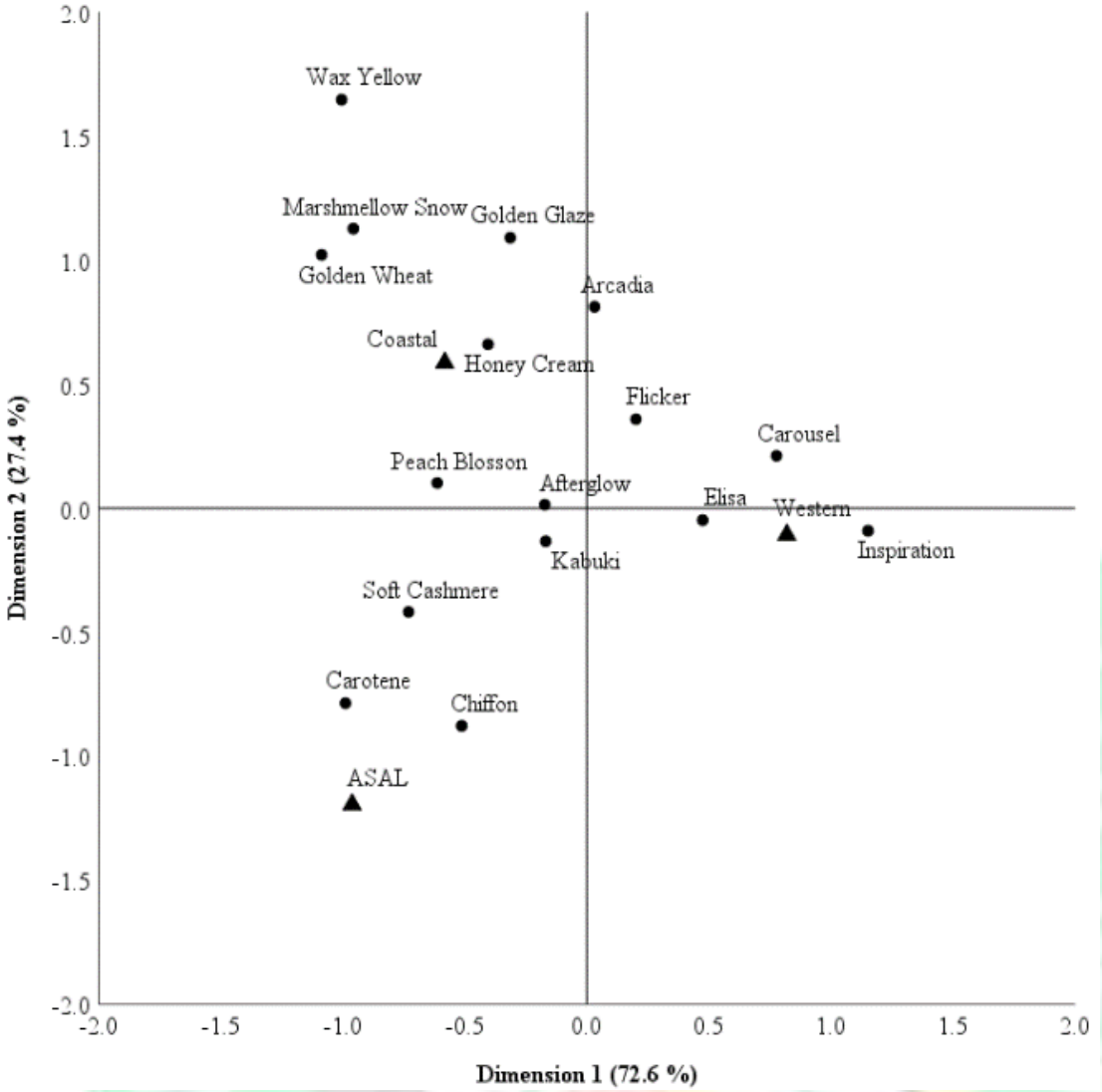

Figure 1: Relationship between cluster (▲) and shell colours (•) of indigenous chicken.

Discussion

The 34 different colours and 6 colour descriptions observed in the current study indicate suitability of the paint colour chart to objectively identify not only the individual egg shell colour but also its overall colour shade. Most visual observation methods have been able to categorise shell colours as white, cream and brown (Gikunju *et al.*, 2018; Gongolo & Tanganyika, 2018; Garamu, 2019). Spectrophotometer on the other hand has been shown to be reliable for colour identification only in brown and non-pigmented eggs (Lukanov *et al.*, 2015).

The 34 colours identified also imply existence of a wide diversity in the unselected Kenyan IC population. Although application of colour charts in chicken egg shell identification have been used (Shafey *et al.*, 2005; Isidahomen *et al.*, 2013), the current study was able to catalogue the corresponding Hex and RGB codes for each colour, thus revealing the different shell colours available. This could be used to develop IC that lay eggs of particular colours as preferred by different consumers. The most common colours were all shades of very light brown. This could be due to consumer preference for brown-shelled IC eggs in Kenya as demonstrated by Ndenga *et al.*, (2017). The close association between Marshmellow Snow and Golden Wheat colours (both very light shades of brown), on the one hand and, Afterglow and Kabuki (both light shade of brown) on the other could

be an indicator of such preferences. The association of ecotypes to particular colours could imply dominance of the colours in those regions or preferences by consumers.

Conclusions and recommendations

It has been demonstrated that a paint colour chart can be used to objectively identify and categorise egg shell colours of IC in Kenya. There exists wide diversity in IC shell colours with very light shade of brown being the most common. The IC genome need to be sequenced and genomic regions associated with shell colours identified for inclusion in breeding strategies and improvement programmes.

Acknowledgement

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Ethical approval

The research protocol was approved by Egerton University institutional scientific and ethics review committee (Approval No. EUISERC/APP/214/2023).

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LIVESTOCK FEED RESOURCES FOR SUSTAINABLE FOOD SYSTEMS

Preliminary Analysis of Morphological Diversity Among *Chloris roxburghiana* Accessions Conserved at KALRO-GeRRI Genebank

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Abstract

Characterization of germplasm is one of the main activities in genebanks aimed at acquiring information on variation among the accessions and identification of traits of importance that are useful in enhancing their utilization. Fifty-nine accessions of *Chloris roxburghiana* Schult, a grass species that has been widely promoted for rangeland rehabilitation, were planted for morphological characterization at KALRO-AMRI sub-station at Kiboko. The study aimed to characterize the accessions to provide more information about the conserved accessions as well as identifying accessions with high biomass and seed yield that could be selected for further evaluation studies. Data was collected on selected plant characters that included plant height, tillers, leaf and flower traits, germination capacity, among others. Hierarchical cluster analysis was then used generate dendrograms displaying different groupings of accessions as a result of the selected robustness related traits. Wide ranges of means were recorded for all measured traits across the accessions. The purple colored types were generally smaller in size with many tillers of thinnest stems, many nodes of up to 5 as compared to 3 for yellow green and lower seed yield ranging from 2.2 to 6.7 grams compared with 6.5 to 25.5grams for yellow green. Variations were further observed within the purple type due to node pigmentation and leaf intensity of hairiness. Two major groups were identified from the yellow green type with one cluster consisting of taller accessions with wide, longer leaves, more tillers and higher biomass and seed yield per plant. The results show that it is possible to select accessions with potential for higher seed and biomass production from *C. roxburghiana* accessions conserved at KALRO genebank. The identified accessions provide an opportunity for further performance evaluation studies that could lead to registration of new varieties for the species for improved forage production in the ASALs.

Introduction

Rangeland reseeding technologies using well-adapted indigenous grass species have been touted as a way of improving forage production and quality to support livestock production systems in the ASALs. Horsetail grass also known as *Chloris roxburghiana* Schult is one of the range grass species that have been promoted widely for rehabilitation of rangelands and to enhance forage production in the ASALs. It is a drought tolerant, persistent, indigenous, tufted perennial grass with a production potential of 11 t ha^{-1} (Keya, 1998). The species contains higher crude protein (CP) levels between 14.8-16 % compared to other forages like *Brachiaria* spp. cv. Mulato II (13.3%), *E. superba* (13%), *E. macrostachyus* (13.4%) and *C. ciliaris* (10.8%) (Machogu, 2013). *Chloris roxburghiana* variety CHROX_KBK was released and registered under KEPHIS variety list in December 2021. The variety is a selection from the ecotype mixtures currently being promoted for rangeland rehabilitation and natural pasture improvement. The variety registration process for the species had a problem of poor plant establishment partly attributed to high seed dormancy. Despite wide promotion, adoption of the species by farmers in the ASALs has been very low due to the poor plant establishment. Low seed germination, possibly due to high seed dormancy has in some cases resulted in low to total absence of plant establishment even in seasons with adequate rainfall. The current variety being promoted

also has low biomass yield compared to other three commonly grown grass species in the ASALs, *C. ciliaris*, *Eragrostis superba* and *Enteropogon macrostachyus* (Machogu 2013).

The National Genebank of Kenya that is hosted by KALRO Genetic Resources Research Institute (GeRRI) and has over 10,000 accessions of grass forages in conservation. *Chloris roxburghiana* is one of the grass species under conservation with 250 accession conserved. Despite the large number of accessions conserved, there was no comprehensive phenotypic characterization of the conserved germplasm. This information would help describe the accessions as identifying accessions with potential to address the current challenges of poor seed quality and low biomass yield. Thus, the project aimed at characterizing various accessions particularly for agronomic traits to help in selection of potentially superior types in biomass yield.

Materials and Methods

Planting of 59 accessions for phenotypic characterization was done in December 2020 in pots and managed in a glasshouse at KALRO-Muguga before transplanting to the field in February, 2021. Transplanting was done using single spaced plants in five by two meter plots with 50cm inter-rows spacing for each accession. The field trial was done at AMRI-Kiboko sub-station. The first crop was clipped in May 2021 as a standardization cut to allow for collection of characterization data. Data was collected from up to 10 plants per accession for two subsequent ratoon crops for at least 18 characters. The characters include plant height, stem thickness, nodes number, leaf length and width, flowering, number of tillers, flower pigmentation, dry matter yield, % flowering heads and various seed characters according to procedures by IBPGR (1985), Van de Wouw et al (1999) and Jorge et al (2008). Field data collection was completed in October 2021 and seed germination test was done for the second ratoon crop at KALRO GeRRI.

Data analysis was performed using Genstat 15th edition analysis tools (Payne *et al.*, 2012). Analysis of variance for the replicated morphological traits was done to assess variation among accessions. Means per trait were used to develop a similarity matrix that was then used to generate dendrograms using hierarchical cluster analysis. The dendrograms displayed different groupings or clusters of accessions as a result of selected robustness traits. The traits were plant height, leaf length, stem thickness and tiller numbers. Due to low number of established plants for some accessions, data analysis and selection was done using 29 accessions that had more than five plants per plot.

Plate 1: Images for field data collection and seed processing at Kiboko

Results

Wide ranges were recorded in all measured traits for *C. roxburghiana* accessions (Table 1). The purple coloured types that have distinctively purple coloured inflorescence at full bloom, recorded the thinnest stems with many nodes of up to five as compared to the yellow green type (YG) that had fewer nodes of up to three. The purple types recorded also the least seed yield (range 2.2-6.7g and mean of 4.3g) compared to the yellow green with a mean of 13.7 and range of 6.5 to 25.5grams. There was variation within the purple types in node colour and leaf hairiness intensity where some accessions had strong pigmentation on the node while others did not have.

Table 1. Mean range of morphological attributes of *C. roxburghiana*

Morphological characteristic	Range of ecotype means
1. Plant height	87.7 to 129 cm
2. Stem thickness	0.2 to 0.41mm
3. Number of nodes	2.8 to 5.5
4. Leaf length	7.45 to 28.1cm
5. Leaf breadth	4.5 to 16 mm
6. Days to full plot flowering	26.1 to 44.6 days
7. Days to start flowering	16 to 26 days
8. Total tiller number	25.4 to 103.6
9. Peduncle length	34.5 to 70.9
11. Fresh herbage yield	223 to 1225 gms
12.DM yield	162 to 890.5 gms
13. % Fertile tillers	5.5 to 31 % per plant
14. Inflorescence length	11.1 to 17.3 cm
15. Seed yield	2.15 to 25.5 g per plant
16. Germination capacity	3 to 97 %

Cluster analysis based on robustness related traits, namely, plant height, leaf length, leaf width and stem thickness resulted in various grouping (Figure 1). Two main clusters (Group one and two) were formed for the YG type while the two purple types (GBK 008417 and GBK 008835) grouped together. Cluster analysis was done for accessions with more than five plants per plot, thus only two accessions of purple were considered in the analysis.

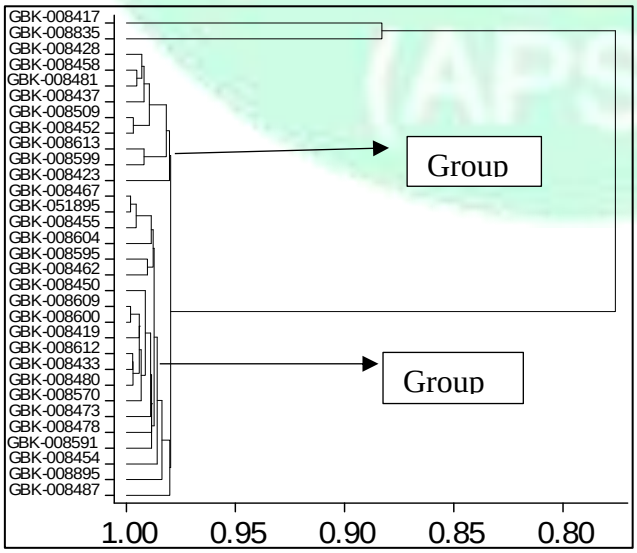

Figure 1. Dendrogram of Chloris roxburghiana accessions based on robustness related characteristics

From Figure 1, group one recorded significantly higher levels for selected traits that are important in herbage yield (Table 2). The group had higher mean biomass yield per plant (502g DM and 685g fresh weight), leaf length and number of tillers than group two indicating potential for higher biomass production. Group one consisted of nine accessions that were all taller with above 110cm height, long leaves (>20cm) and wider leaves (>12mm) with more tillers which was above the overall mean for these traits. Group one also recorded higher values for seed yield related traits, such as seed yield, productive tillers and inflorescence length, than group two. However, it had lower germination capacity due to very low percentage recorded by two accessions GBK 008423 (4%) and GBK 008509 (26%).

Table 2. Mean data for selected morphological attributes per cluster group

	Attribute	Group 1	Group 2	Mean	%CV	P_Value
		N = 9	N=20	N=29		
1.	DM Yield/plant (g)	502.1	330.5	383.7	24.4	***
2.	Fresh herbage yield/plant (g)	685.6	459.9	529.9	23.9	***
3.	Plant height (cm)	118.1	116.2	116.7	3.6	ns
4.	Leaf length (cm)	23.0	21.7	22.1	5.2	**
5.	Leaf width (mm	12.3	12.1	12.2	4.8	ns
6.	No. of tillers/plant (No.)	53.4	34.7	40.5	12.4	***
7.	Stem thickness (mm)	0.4	0.4	0.4	6.7	ns
8.	Nodes number	3.3	3.4	3.4	6.7	ns
9.	Days to full plot flowering (No.)	33.7	38.0	36.7	13.2	*
10.	Inflorescence length (cm)	14.7	14.1	14.3	6.8	ns
11.	Peduncle length (cm)	54.5	53.6	53.9	7.3	ns
12.	Productive tillers/plant (No.)	13.9	11.4	12.1	22.1	*
13.	Seed yield (g)	13.4	10.6	11.5	26.7	*
14.	Germination capacity (%)	50.3	63.4	59.2	30	ns

Discussion

Phenotypic characterization of *C. roxburghiana* resulted wide variation between the YG and the purple type as well as among the YG types variation among the YG type was mainly observed when cluster analysis was done using the biomass yield related traits. The observed phenotypic attributes such as taller plants, longer leaves, more tillers and high biomass yield per plant may have been influenced by the sites of accession collection for group one. Li *et al.*, (2015) observed reduced plant size in *Lymus chinensis* grass species size due to long term defoliation. Plants in areas with more resources such as rainfall and with minimum disturbance such as grazing have been observed to produce more herbage. Accessions in group one had more tiller numbers than group two which is an important character in influencing dry matter yield in grasses and increases chances of survival. The observed variation in tiller numbers is similar to results by Machogu (2013) who noted variability among different grass species.

While there was a wide range in time to start flowering (16 to 26 days) among the accessions, the character did not differ in the two main cluster groups. However, time to full plot flowering that ranged from 26 to 44 days among the accessions differed between the groups. The second group took longer (38 days) to reach full plot flowering compared to group one (34 days). The flowering results

from this study differed with other studies that found early flowering to correlate with smaller sized types (Kirwa et al 2016; Blum 2005; Boonman 1993).

The purple type was observed to be smaller in size compared to the YG type. This was noted from the significantly shorter and thinner leaves, thinner stems and shorter plants. The type is however less stemmy with higher leafiness score compared to the YG that gets stemmy particularly with maturity. The observed differences between the YG and purple could influence the nutritive content among the accessions thus there is need to carry out nutritive analyse between the two types.

Conclusion

There is wide diversity among the conserved accessions of *Chloris roxburghiana* that could be utilized to address the current challenge of poor plant establishment and low biomass yield. There were distinct morphological differences between the yellow green and purple types of *C. roxburghiana* particularly node number, leaf size and inflorescence colour. Nine accessions of *C. roxburghiana* grass species with potential for high yield in both seed and biomass were identified from the study.

Recommendations

- The selected accessions would need to be subjected to seed and biomass yield performance evaluation and nutritive value analysis studies.
- There is need to further analysis the difference between the YG and purple types for yield performance and probably adaptation differences that would allow for development of new varieties for each type.

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Evaluation of Nutritive Value and In-Vitro Degradation of Sorghum Silage and Rhodes Grass-Based Diets for Finishing Beef Cattle in Feedlot System in Kenya

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Abstract

The proximate analysis of sorghum silage and Rhodes grass *(Chloris gayana)* based diets were determined for their potential to finish different beef cattle breeds in a feedlot system in arid and semi-arid lands (ASALs) of Kenya. The chemical composition and *in-vitro* gas production characteristics of all feed ingredients were determined. The metabolizable energy (ME) content of locally available feed resources used as ingriedients from the ASALs ranged from 8.7 MJ/Kg DM in *Acacia tortilis* pods and 14.6 MJ/Kg DM in *Balanites aegyptiaca* nuts. *Balanites aegyptiaca* nuts were high in metabolized energy compared to *Prosopis juliflora* pods and *Acacia tortilis* Pods. The CP content ranged from the lowest of 84.6 gkg^{-1}DM in *Balanites aegyptiaca* nuts and the highest of 154gkg^{-1}DM in *Acacia tortilis* pods. The metabolizable energy content was 11.06 MJ/kg DM in Rhodes grass-based and 12.3 MJ/kg DM in sorghum silage-based diets. The *in-vitro* fermentation characteristics of sorghum silage-based and Rhodes grass-based rations DM widely varied between the two rations. The total gas production (ml/200mg DM) at 48hrs showed variations in the digestibility potential, with Rhodes grass-based ration (14.05) being the highest and sorghum silage-based ration (11.04) being the lowest at 48hrs. These results indicate that the two rations are potentially degradable for beef nutrition. The study concluded and recommended that the sorghum silage and Rhodes grass-based diets formulated using locally available rangelands feed resources have a potential for finishing beef cattle in the ASALs with minimal inclusion of commercial feed ingredients for increased and quality beef production.

Introduction

Beef cattle finishing in a feedlot production system requires sufficient amounts of quality feeds to ensure adequate feeding and good profitability from beef enterprises (Asimwe et al 2016; Neto et al 2018). Population growth for both human and livestock, as well as pressures on the available productive land for livestock production have necessitated for improved beef productivity per unit head in intensive system. In ASALs areas, however, there is usually a challenge in the availability of good quality and right quantities of livestock feeds. Seasonality of feeds due to erratic rains and climate variability have limited pasture and fodder production (Mudzengi *et al.*, 2020). In addition, there is competition for food and feed for ingredients like maize between humans and livestock (Wilkinson and Waldron, 2017; Manceron *et al.*, 2014). This necessitates the use of non-competitive

local feed resources such as sorghum and rangelands livestock feed resources to formulate feedlot rations (Kemboi *et al.*, 2017).

Beef cattle are finished in feedlot system 3-6 months before marketing, and this could assist in ensuring that cattle continue to receive required nutrients for gain when pasture is insufficient to meet their daily nutritional needs. For instance, during drought period when forages are of poor quality and insufficient in quantities (Greenwood, 2021). Utilization of locally available feed resources for making beef finishing rations have many advantages such as reduction of feeding cost through sourcing of local feed resources in the rangelands and propagation of drought-tolerant fodder sorghum varieties and adaptable grass species. In addition, the use of beef finishing technology in ASALs could be a solution for reduction of high mortalities of livestock during dry seasons and increase beef offtake in ASALs Counties of Kenya. Beef finishing technology using local rangelands feed resources has the potential to improve household income, nutrition, and reverse high trends of poverty index in ASALs of Kenya.
It is imperative always to conduct feed analysis for all the ingredients before ration formulation and it is equally important to analyze formulated rations before conducting animal performance trials. Thus, this study determined the nutritive values and digestibility of rangelands feed resources and formulated rations using the same ingredients for utilization in feedlot systems in ASALs.

Materials and methods

Forage Collection Site

Forage collection was conducted in ASALs sub-County of Marigat, Baringo County, Kenya, which lies at 1080 m above sea level. It receives 700 – 950 mm of rainfall per year with peaks in April/May and July/August, but it is generally very unreliable. The annual mean temperature is 23ºC.

Laboratory analysis: Proximate assay of samples

Proximate analysis of the feed ingredients preferred as livestock feed supplements used by pastoralists were analyzed to determine their dry matter (DM), crude protein (CP), ME (MJ/kg), and ether extract (EE) and ash according to the standard methods of AOAC (2006). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed according to the procedure described by Van Soest et al (1994).

In vitro gas production

In-vitro gas production was done by Menke and Steingass (1988) method. Samples (200mg DM) were incubated in triplicates in buffered rumen fluid (1:2 v/v) at 39°C for 96 hours. Gas production was recorded at intervals. Ørskov and McDonald (1979) model fitted gas values to determine degradability.

Results and discussion

Chemical composition of feed ingredients

Table 1 is the proximate analysis results of ingredients used in the formulation of the two beef finishing rations. The DM content of locally available feed resources from rangelands ranged from 890 gkg^{-1}DM in *Acacia tortilis* pods and 940 gkg^{-1}DM in *Balanites aegyptiaca* nuts. The CP content ranged from 84.6 gkg^{-1}DM in *Balanites aegyptiaca* nuts and 154gkg^{-1}DM in *Acacia tortilis* Pods. The relatively high CP content range (84.6- 154 gkg^{-1}DM) of *Balanites aegyptiaca* nuts, *Prosopis juliflora* pods, and *Acacia tortilis* pods showed their potential to be used as protein sources important for the formulation of locally formulated rations in beef cattle finishing in feedlot systems. These results are in tandem with previous studies by Ikanya *et al.*, (2022) and Sagala *et al.*, (2020) especially on *Acacia tortilis* Pods. To improve animal performance, animals consuming basal diets containing less than

7% crude protein (CP) will require supplementation to achieve maximum production, (Leo-Penu *et al.,* 2022; Ondiek *et al.,* 2000). According to NRC, 2000 growing beef cattle require a CP of more than 10% and energy above 9.5 (MJ/Kg). Therefore, both grass-based and silage-based rations required more ingredients for protein supply. Both grass-based and silage-based rations are relatively sufficient as energy sources.

Table 1: Chemical composition (gkg^{-1}DM) of ingredients used in ration formulation

Ingredients	DM	ME(MJ/Kg DM)	CP
Rhodes grass hay	918^{b}	10.63^{d}	53.4^{e}
Sorghum silage	917^{b}	9.9^{e}	46.8^{f}
***Prosopis juliflora* pods**	903^{c}	12.8^{c}	112.5^{c}
Balanites aegyptiaca Nuts	940^{a}	14.6^{b}	84.6^{d}
Acacia tortilis Pods	890^{d}	8.7^{g}	154^{b}
Sunflower Meal	891^{d}	9.1^{f}	300^{a}
Posho meal (Maize)	940^{a}	26.16^{a}	71.8^{e}
SEM	0.1279	0.0253	0.0645
P	<.0001	<.0001	<.0001

The relatively high crude protein content of the locally available local browses (150-249g/kg DM) provides enough nutrients for the utilization as a supplement to low quality natural pastures and crop residues (Amole et al 2022; Osuga et al 2006). The ME content of locally available feedstuff from the ASALs ranged from 8.7 MJ/Kg DM in *Acacia tortilis* pods and 14.6 MJ/Kg DM in *Balanites aegyptiaca* nuts. *Balanites aegyptiaca* nuts were high in metabolizable energy compared to *Prosopis juliflora* pods and *Acacia tortilis* Pods. Legume tree rangelands forages have high crude protein, organic matter, and mineral content and could be used as supplements to help offset the effects of low-quality feeds (Idan et al 2022; Ondiek et al 2013). The browse forages have high Crude Protein content, which makes them good protein supplements to poor quality roughages, particularly during the dry season (Deng et al 2017). To fill the daily nutrients gaps in terms of energy and protein that is not provided for by the local feed resources, use of commercial feed resources such as maize germ and sunflower meal is recommended because they are readily available.

Chemical composition of rations

Results of the nutrient composition of experimental diets/rations are presented in Table 2.

Table 2: Chemical composition (gkg^{-1} DM) of Experimental diets/Rations

Parameters	GRASS BASED	SILAGE BASED	SEM	P
CP(g/kgDM)	15.4^{a}	16^{a}	0.0667	<.0001
ME (MJ/kgDM)	11.06^{a}	12.30^{a}	0.0851	<.0001
ASH (%)	7.26^{b}	5.14^{a}	0.0033	>.0001
EE (gkg^{-1}DM)	17.16^{a}	15.93^{a}	0.0085	<.0001
DM (%)	89.23^{a}	87.93^{a}	0.0094	<.0001
NDF(g/kgDM)	65^{b}	81^{a}	0.3064	>.0001
ADF(g/kgDM)	41^{b}	47^{a}	0.2357	>.0001

T

he two rations were formulated according to the growing beef cattle daily requirements NRC, (2000) that states that well-finished beef cattle in feedlot system require a CP of about 14-15% and energy between 9.5-11.5 MJ/kg). The CP content was 15.4 g/kg DM in Rhodes based and 16 g/kg DM in Sorghum Based. The metabolizable energy content was 11.06 MJ/kg DM in ration one, which is Sorghum Based and 12.3 MJ/kg DM in ration two which is Sorghum based, the results suggest that

these rations formulated from locally available feedstuffs have a potential for finishing rangelands beef cattle in the ASALs of Kenya because they are adequate in energy and protein required by growing beef cattle to attain its daily growth.

Other previous studies have established that typical feedlot finishing diets should have a minimum ME of 10 MJ /kg DM and 11–15% CP/kg DM within diets with ratios fed at 2.5–3% of live weight (Gaughan and Sullivan, 2014). This was also similar to the results of Drouillard, (2018) on feedlot finishing diets containing metabolizable (ME) of 11MJ/Kg DM energy and crude protein of more than 11% CP/kg DM.

In vitro degradability for the rations

The *in-vitro* fermentation characteristics of silage and grass-based rations DM varied widely between the two rations. The total gas production (ml/200mg DM) at 24hr and 48hr shown in Table 3 and Figure 2 below show variations in the digestibility potential with grass-based ration (14.05) being the highest and silage-based ration (11.04) being the lowest at 48hrs.Sorghum-based ration and Rhodes-based ration were highly degraded at the 48 hours compared to the 24 hours. The ration's degradation improved from 24 to 48 hours, indicating that they need more time to degrade effectively. The differences in gas production between the two rations could be attributed to the amount of substrate fermented. Grass-based fermented faster as compared to silage based implying that it is low in fiber and lignin. Differences in gas production between feeding materials could be attributed to the amount of substrate fermented, which is in line with findings, by Garcia et al (2020).

Table 3: *In vitro* gas production (ml/200mg DM) of Sorghum and Rhodes-based rations

	Fermentation Characteristics						
Sample	**24**	**48**	**A**	**B**	**C**	**A+B**	**RSD**
Sorghum Based Ration	8.97	11.04	0.15	7.20	8.10	7.35	4.34
Rhodes Based Ration	9.20	14.05	1.18	4.46	6.94	5.64	3.52

A, B, C are constants (Ørskov and McDonald, 1979)

The higher digestibility in Sorghum and Rhodes-based rations could have been attributed to high nutritional quality as reported by Kidake et al (2016). This also indicates that these rations are potentially degradable and can become potential complete animal feeds especially in arid and semi-arid regions for beef animals where quality feeds are deficient.

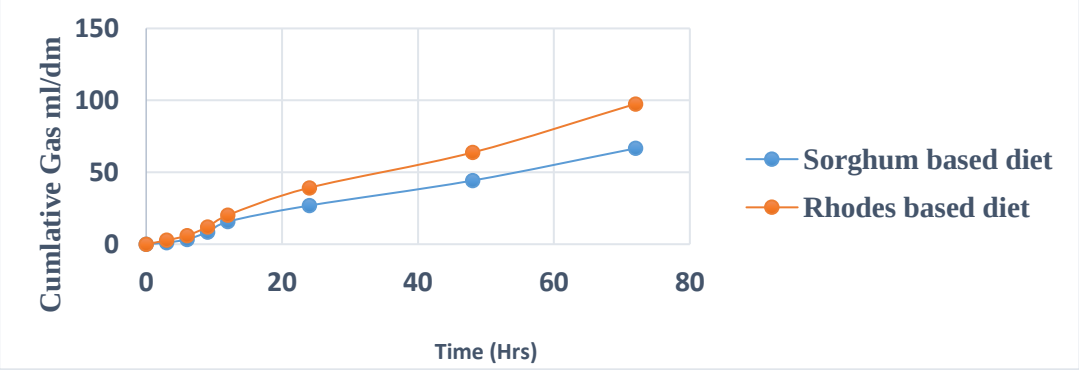

Figure 2: Patterns of *in vitro* cumulative gas production of Sorghum and Rhodes-based rations

Conclusion and recommendation

The analyzed rangelands feed resources offer great potential as feed ingredients for the provision of energy and protein sources with minimal inclusion of commercial feed ingredients and thus could be used in the formulation of feedlot rations. The study further concludes and recommends that the formulated rations are digestible and are also adequate in the provision of daily energy and protein requirements for finishing beef cattle and thus could be utilized by growing beef cattle for increased daily weight gain and higher quality meat output.

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Chemical Composition and In-vitro Dry Matter Digestibility of Dual Purpose Sweet Potato Vine Cultivars as Alternative Forage in Ruminant Diets

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Abstract

The sweet potato vines have desirable characteristics suitable for fodder production due to high protein and digestible energy content. The objective of this study was to evaluate the chemical composition and *in-vitro dry* matter digestibility of dual-purpose sweet potato vine cultivars as alternative forage in ruminant diets. The experimental design was randomized complete block design where six cultivars of sweet potato were established in three replicates. Six cultivars were used namely; Kenspot 1, 2, 3, 4, and 5. An improved forage type cultivar (Wagabolige) served as a control. The vines were harvested at 20 days and weighed to determine weight. Samples were taken for the determination chemical composition and gas production. Results showed that there was significant difference ($p<0.05$) in dry matter among the cultivars. Kenspot 4 having the highest (13.73%) and Kenspot 3 having the lowest (12.92%). Kenspot 1 had the highest CP (23.70%) compared with the other 5 cultivars. Kenspot 3 had the lowest CP content among the cultivars. Energy was highest in Kenspot 1 and lowest in Kenspot 2. Neutral detergent fibre and acid detergent fibre were highest in Kenspot 2 and lowest in Kenspot 4. Gas production kinetics, and ruminal digestibility and fermentation of the vines were determined *in vitro.* Kenspot 1 had the highest gas production of 42.1ml/200g DM and 69.9ml/200g DM after 24 and 48 hours respectively while Kenspot 3 had the lowest with (38.4ml/200g and 66.5ml/200 g) respectively. The organic matter digestibility ranged from 80 to more than 84%. Kenspot 1 had the highest (84.21%) whereas Kenspot 3 had the lowest (80.70%). This study concluded that the five dual purpose cultivars demonstrated excellent potential in terms of quality for forage use.

Keywords: *Digestible energy, fermentation, Gas, Kinetics, Protein*

Introduction

The area of land that can be utilized to cultivate pastures and forages has reduced significantly as a result of the growing population and shrinking land sizes, as the little available land is now being used to grow food crops (FAO, 2012). This has made it necessary to find crops with multiple uses that can be utilized for both human nourishment and cattle feed. Sweet potato *(Ipomoea batatas)* has attracted a lot of interest from many research groups in recent years. This is due to its adaptation to semi-arid environments and potential for use as both human food and livestock feed. However, there is no data on herbage yields and its effects on livestock output in sub-Saharan Africa, therefore its promise as a feed for livestock hasn't been fully realized (Peters, 2008).

According to research done at the International Potato Centre (C1P) in 2008, farmers preferred the dual-purpose cultivars since they produce enough tubers for human consumption and livestock feed due to the fact that harvesting can occur at any time during the growing season. A total of 12.8 t/ha of sweet potato tubers are produced in Kenya each year on roughly 59.2 thousand ha of land (FAO, 2012). However, the quantity of vines grown adjacently has not been recorded. In East Africa, sweet potato vines (SPVs) can provide a considerable supplement to other forages and pastures for dairy cows, goats, and pigs (Peters, 2008). A study conducted in Uganda to determine the potential of sweet

potato vine-based diets as partial milk substitute (PMS) for dairy calves reduced the amount of milk consumed per calf by 120 litres over the 70-day period (Taabu *et al.*, 2016).

In recent years several sweet potato varieties were released for various agro-ecological zones at Kenya Agricultural and Livestock Research Organization (KALRO), Foods Crop Research Institute in Njoro. These included cultivars; Kenspot 1, Kenspot 2, Kenspot 3, Kenspot 4, Kenspot 5 among others. However, studies on biomass and nutritional value for livestock are missing and this study is a step towards filling this knowledge gap.

Materials and Methods

This study was carried out at KALRO-Lanet situated in Nakuru County, Kenya. The center lies between longitude 36° 09' E and latitude 00° 18' S at an altitude of 1920 m above sea level.

Cultivation of Forage Sweet Potato

The land was prepared into a fine seed bed. The land was divided into 18 plots of 2.5m x2.5m with a 1-meter-wide pathway between the plots. A randomized complete block design (RCBD) was used to layout the experiment. Six cultivars of SPV namely Kenspot 1, Kenspot 2, Kenspot 3, Kenspot 4, Kenspot 5 and Wagabolige were planted randomly in three replicates. Wagabolige which is an improved forage type sweet potato cultivar (Ondabu *et al.*, 2007) was chosen as the control.

Chemical analysis

Feed samples were analyzed in accordance with the method outlined by Van Soest *et al.*, (1991). The proximate analysis was done using AOAC (2005) procedures.

In-vitro gas production

Samples of about 200 mg were incubated *in vitro* with rumen fluid in calibrated glass syringes in triplicate following the procedure of Menke and Steingass (1988). The syringes were pre-warmed at 39°C before addition of 30 mL of rumen liquor-buffer mixture (ratio 1:2) into each syringe and incubation in a water bath maintained at 39°C. Blanks with buffered rumen fluid only were also included. The gas production readings were recorded after 3, 6, 12, 24, 48, 72 and 96 h of incubation. The calculated values of gas production were fitted into the model developed by Ørskov *et al.*, (1979) to determine the degradability of the feed. *In-vitro* organic matter digestibility was calculated from the equation: OMD (%) = 18.53 + 0. 9239 (gas production at 48 hr) + 0.0540 CP (Menke (*et al.*, 1988). The metabolizable energy (ME) was estimated using the equation of the Australian Agricultural Council (AAC, 1990) for tropical forages as follows: ME MJ/Kg DM = DOM gKg^{-1} DM × 18.5 × 0.81. Where ME is the metabolizable energy (MJ/Kg DM), MJ is mega joules, DM is dry matter and DOM is digestible organic matter (gKg^{-1} DM)

Statistical analysis

The data was analysed by general linear model of ANOVA (SAS, 2002) software (version 9.0). Means were separated using LSD at ($P<0.05$).

Results

The yield and composition of the cultivars are shown in **Table 1**. Wagabolige, the control cultivar, produced the highest biomass quantity ($p<0.05$) followed by Kenspot 3, Kenspot 4, There was significant difference in energy among the cultivars where Kenspot 1 had the highest value while Kenspot 2 had the lowest. Fibre (NDF and ADF) was highest ($p<0.05$) in Kenspot 2 and lowest in Kenspot 1. Crude protein (CP) was highest ($p<0.05$) in Kenspot 1 and lowest in Kenspot 3. Kenspot 1 had the highest energy ($p<0.05$) followed by Kenspot4 while Kenspot 2 and Kenspot 5 had the

lowest respectively. Kenspot 1, Kenspot 5 and Kenspot 2 respectively. Kenspot 4 had the highest dry matter (DM) though not significant ($p<0.05$) from the other cultivars, while Kenspot 3 had the lowest.

Table 1 Yield and chemical composition of six cultivars of sweet potato vines on fresh basis

Cultivar	Yield t/ha	DM%	Crude Protein (%)	Energy (MJ)	NDF %	ADF %
Kenspot 1	29.4^{cb}	13.02^{d}	23.70^{a}	8.72^{a}	40.15^{c}	21.50^{e}
Kenspot 2	16.4^{d}	12.93^{e}	19.23^{c}	7.50^{ed}	42.28^{b}	24.96^{cb}
Kenspot 3	31.7^{b}	12.92^{e}	16.84^{d}	7.35^{f}	46.11^{a}	28.78^{a}
Kenspot 4	29.2^{cb}	13.73^{a}	21.82^{b}	8.00^{b}	42.85^{b}	23.29^{d}
Kenspot 5	19.5^{cd}	13.50^{b}	19.78^{c}	7.47^{d}	43.02^{b}	25.46^{b}
Wagabolige	64.5^{a}	13.12^{c}	19.60^{c}	7.72^{c}	42.94^{b}	24.40^{c}

^{abcd}*Means with different subscript in a column are significantly different at 5% ($p<0.05$)*

DM: Dry Matter; NDF: Neutral Detergent Fibre; ADF: Acid Detergent Fibre;

In vitro gas production

The different gas production levels are recorded in **Table 2**. Kenspot 1 had the highest gas production of 42.1ml/200 g DM and 69.9ml/200 g DM after 24 and 48 hr respectively while Kenspot 3 had the lowest with (38.4ml/200g and 66.5ml/200 g) respectively. The potential (a + b) and the rate (c) ranged between 68.2 to 78.2 ml and 0.21 to 0.52/hr. The rate of gas production (c) mostly explains the rate of passage of feed through the rumen, whereas the potential gas production (*a* + *b*), is associated with potential degradability of feed (Khazaal *et al.*, 1995). This indicates that the higher values obtained for the potential gas production in the Kenspot 1 might be due to its better nutrient profile available for rumen microorganisms. The calculated organic matter digestibility (OMD) ranged from 80 to more than 84%. Kenspot 1 had the highest (84.21%) whereas Kenspot 3 had the lowest (80.70%).

Table 2. *In-vitro* gas production (ml/200 g DM) of six cultivars of sweet potato vines

Cultivar	24	48	a + b	c(%h)	OMD 48(%)
Kenspot 1	42.1^{a}	69.9^{a}	78.2^{a}	0.33^{b}	84.21^{a}
Kenspot 2	39.2^{b}	68.3^{c}	68.4^{e}	0.52^{a}	82.49^{c}
Kenspot 3	38.4^{b}	66.5^{d}	68.2^{e}	0.28^{c}	80.70^{f}
Kenspot 4	34.0^{c}	68.5^{b}	75.3^{c}	0.25^{d}	82.82^{b}
Kenspot 5	33.2^{d}	68.2^{c}	72.5^{b}	0.23^{e}	82.43^{d}
Wagabolige	33.1^{d}	68.1^{c}	72.0^{d}	0.21^{f}	82.33^{e}

^{abcd}*Means with different subscript in a column are significantly different at 5% ($p<0.05$)*

OMD 48: In vitro organic matter digestibility calculated from the equation: OMD (%) = 18.53+0.9239 Gas production + 0.0540 Crude protein (Menke and Steingass, 1988). a, b, c are constants as described by Ørskov and McDonald (1979).

Discussion

All six varieties of sweet potatoes vines were quite nutritious. They all possessed a substantially greater CP than the 80 g CP/kg DM threshold that defines low quality forages (Leng, 1990). As a result, this has a positive effect on rumen microbial activity (van Soest, 1994). Additionally, the NDF was below the 600 g/kg DM level that is typically considered as the upper limit for good quality forage for ruminants (Meissner *et al.*, 1991). The low NDF was in line with the widespread finding that NDF is generally lower in non-grass forages than in grass (Minson, 1990). For rumination, saliva flow, rumen buffering, and the health of the rumen wall, the six cultivars contained sufficient fibre, assessed as NDF and defined as total cell wall content (Fox *et al.*, 1992). Additionally, the high OM digestibility and energy allows ruminant animals to get enough ME needed for integrating nitrogen

into microbial protein (Preston and Leng, 1987; Muia, 2000). However, Kenspot 3 had the lowest CP and the highest NDF, which could lead to lower DM intake and reduced nutritional digestion. The chemical composition of the six forage sweet potato cultivars matched that of forage sweet potato described in the literatures by (Snijders *et al.*, 1992; Kiragu & Tamminga, 1997; Larbi *et al.*, 2007). The DM matched the values published by Chhay *et al.*, (2007), Olorunnisomo (2007), and Kebede *et al.*, (2008). The OM values are in the same range as those reported for forage sweet potato by Farrell *et al.*, (2000), Iyeghe-Erakpotobor *et al.*, (2006) and Chhay *et al.*, (2007). As reported by Giang *et al.*, (2004), Lam and Ledin (2004) and Kiragu *et al.*, (2007), the CP values were also within these ranges. The NDF, ADF, and ADL levels of fibre were all within the range described by Olorunnisomo (2007) and Kebede *et al.*, (2008). All six sweet potato cultivars showed excellent nourishment for the sheep, as evidenced by the great nutritional digestibility observed. For instance, OM digestibility was higher than the typical range of 500–600 g/kg DM for tropical grasses (Minson, 1990; Kariuki, 1998; Muia, 2000). The OM digestibility contrasted favourably with the 678-831 g/kg DM for forage sweet potato reported by Snijders *et al.*, (1992). The highest OM digestibility was found in Kenspot 1, which also had the highest Energy, CP, and lowest NDF. This was consistent with findings by Minson (1990) which demonstrated that nutrient digestibility improved with higher ME and a decreased NDF. Additionally, Minson (1990) demonstrated that OM digestibility, which in turn was connected to the energy present in the forage, was positively correlated with nutritional digestibility. The amount of NDF affected how digestible the OM was. The amount of lignification, the activity of the rumen bacteria, and the length of time fodder is held in the rumen all affect how quickly NDF is digested (Minson, 1990). The six cultivars had essentially the same cellular structure and inherent characteristics for NDF and CP, and their OM digestibility was relatively similar. This result was in agreement with the studies of Kaitho (1997) and Hagerman *et al.*, (1992).

Conclusion

The six cultivars can provide suitable feed for sheep because they had higher levels of OM, and CP and less fibre compared with many tropical grasses. They also offered high ME and demonstrated high digestibility of OM, CP, and NDF, qualifying them as high-quality forage. The six cultivars may be able to give sheep the right nutrients, but their low dry matter content may prevent them from being used as a sole diet. It is therefore recommended to be fed as a forage supplement. All six cultivars have the potential to increase livestock productivity in Kenya.

Recommendations

This study therefore, recommends the use of Sweet potato vines as a suitable forage supplement. Additional research needs to be done on the performance of sheep and dairy goats fed on these sweet potato cultivars and their effects on animal products such as milk.

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Performance of Selected Grasses and Legumes in On-Farm Demos in Southern Kenya Rangelands

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Abstract

A study was carried out to evaluate 19 fodder varieties comprising 10 legumes and 9 grasses in an on-farm demo set in three counties of Kajiado, Narok and Taita Taveta which are part of the southern rangelands of Kenya. The sites were grouped into two groups based on agro-ecological zones. Parameters that were monitored included plant density, tiller numbers for grass, branching for legumes, disease incidence, pests infestation and yield. There were ten demo sites set in the upper zones (IV, III, & II) and 10 demo sites in the lower zones (V&VI). Theses demo sites were managed by facilitators trained by KALRO Scientists in collaboration with the counties livestock department officers. Sugargraze and Brachiaria cv. Cobra were the top performing grasses although they were also the most affected by disease and pests. Sweet potato vines were performers in the highlands while Cowpea. However, cowpea was also affected by pest and diseases compared to the other crops.

Introduction

The Arid and Semi-Arid Lands (ASALs) occupy 89% of the Kenya's landmass. The ASALs are home to about 14 million people of whom 4 million are pastoralists. Approximately 95% of ASAL households derive their income from the livestock sub-sector where 70% of livestock is produced. Livestock contributes more than 47% of the agriculture national gross domestic product (GDP) and, 12% of the GDP in Kenya. The livestock sector employs about 50% of the agricultural workforce and about 90% of the ASALs workforce. The ASALs have the lowest development indicators and the highest incidence of poverty. Over 60% of the ASAL inhabitants live below the poverty line (national average - 48%), subsisting on one dollar per day. Kenya has an estimated population of 14 million beef cattle, 17 million sheep, 24 million meat goats and 3 million camels (KNBS 2010) about 70% of which are in the ASALs. Under Vision 2030 (GoK, 2007) the agricultural sector is expected to grow at between 6-7% per annum for the country to realize the targeted 10% annual economic growth. Value chain analysis for red meat was done in 2012 and 2014 revealing that Kenya by then had beef supply deficit of about 100,000 MT (USAID 2012; KARI 2012; KMT 2014; MoALFD 2015) and mutton and chevon deficit of about 28,000 MT (Farmer and Mbwika, 2012; Behnke and Muthami 2012). Kenya was therefore importing about 20-25% of beef supply from the neighbouring countries including Ethiopia, Somalia, Tanzania and Uganda (KARI, 2012; Makokha, 2013; Yacob *et al.*, 2014). It is important and imperative to close this supply gap. An important cause of this beef supply deficit is feed shortage in terms of quantity and quality which limits livestock production and productivity in the ASALs. The shortfall in livestock feed supply is attributable to limited adoption of pasture production and rangeland rehabilitation technologies, frequent droughts, overstocking, land subdivisions especially in the semi-arid areas, changes in land use systems and lack of appropriate grazing plans. Capacity building was therefore carried out especially on pasture with a focus on existing technologies. The training of trainers' approach was adopted whereby 20 officers per county drawn from the county and Cooperatives/Ranches/Farmer group's extension service were trained on theory sessions combined with practical demonstrations. The research team then worked closely with trained extension service providers to train farmers in an on-farm demonstration set up.

Materials and Methods

Study Sites

The study was carried out in three counties of Kajiado, Narok and Taita Taveta located in the southern rangelands of Kenya. The counties are predominantly ASAL. However, within the counties, there are pockets of high rainfall receiving areas. The rainfall is bimodal in all three counties. Kajiado County receives as little as 300mm around the Amboseli basin to as high as 1250mm per annum in Ngong' hills and Mt. Kilimanjaro slopes (Kajiado County Integrated Development Plan, 2013-2017). Similarly, the rainfall in Narok County ranges from 500-2500mm per annum (County Government of Narok, 2020). On a similar trend with minimal rainfall per annum being 340mm and the highest 1200mm (GOTTC, 2018). The soils vary within the study area, with most being low in organic matter.

Fodder varieties

A total of 19 fodder varieties were used in the study. The fodder varieties were grouped into grasses and legumes. Further the fodders were sub-divided into two based on the agro-ecological zones (AEZ). These were upper zones (IV, III and I) and lower zones (V and VI). The legumes for the upper zones were Desmodium, Lucerne, Lupin, Mucuna, Purple Vetch and Sweet Potato vines while the grasses were Boma Rhodes, *Brachiaria sp.* Cv. Cayman, *Brachiaria sp.* Cv. Cobra and *Panicum* sp. Cv. Mombasa. On the other hand, legumes for the lower zones were Cowpea, Crotalaria and Dolichos while the grasses were African Foxtail, *Sorghum sp.* Cv. Sugargraze, *Brachiaria sp.* Cv. Camelo, Pearl Millet Cv. Nutrifeed and *Panicum* sp. Cv. Maasai.

Demo set up

The demonstration sites were also grouped into two based on the agro-ecological zones. In the upper zones (IV and above) there were 10 demo sites set up each with 10 fodder crops. The situation was replicated in the lower zones except that there were 9 fodder crops per demo instead of 10.

Crop Data Collection

The data collection was done using a $1m^2$ quadrant randomly placed 3 times in each plot. The data was recorded in prepared datasheets. Data on number of plants within the quadrant were counted to determine plant density, three plants were selected randomly for measurement of morphological parameters including plant height, tiller counts for grasses, branching for legumes. Material within each of the quadrat was cut and weighed in the field to estimate biomass yield. A sub-sample of each of the crop was taken, bagged, and taken to the laboratory for oven drying and subsequent estimation of dry matter. Pest infestation and disease challenge were scored on a scale between 0 (least) and 4 (most severe). This data was collected by the lead scientists from KALRO in collaboration with the county government livestock department staff and the trained demo facilitators.

Results

In the upper zones the best performing grass was Cobra although it was also slightly affected by pests as compared to the other grasses (Table 1). Although Bushrye was the poorest perform grass, overall it was however, not affected by any disease or pests.

Table1: Parameters for Grasses

Crop	Density plants/m2	Tillers numbers	Disease	Pests	Yield t/ha
Brachiaria sp. cv Cobra	7.0	25.5	-	0.3	24.9
Sugargraze	18.0	3.0	0.3	0.7	24.6
Brachiaria sp. cv Cayman	8.0	23.5	0.1	0.3	21.6
Nutrifeed	12.0	15.7	-	-	20.7
Boma Rhodes	12.3	85.0	-	-	16.6
Panicum cv Mombasa	39.3	20.3	0.1	-	14.5
Panicum spp. cv Maasai	15.5	22.0	-	-	10.0
Foxtail	11.0	77.7	-	-	8.6
Brachiaria sp. cv Camelo	8.0	38.3	-	-	8.5
Bushrye	18.0	48.0	-	-	3.4

The best performing protein fodder crop was sweet potato vines which like in the case of the grasses was affected slightly by pests (Table 2). Unlike the case of the grasses the poor performers were also affected by pest and diseases.

Table 2: Parameters for Legumes

Crop	Density	Branching	Disease	Pests	Yield t/ha
Sweet Potato vines	6.9	4.6	-	0.3	15.6
Mucuna	3.8	7.3	-	0.2	14.4
Purple Vetch	21.8	7.6	-	-	13.8
Desmodium	10.9	3.9	0.2	-	13.3
Lupin	7.2	4.8	0.3	0.2	13.3
Crotalaria	21.4	3.2	0.2	0.3	6.0
Cowpea	11.7	5.2	0.2	0.3	6.0
Dolichos	4.4	14.7	0.8	0.5	5.0
Lucerne	102.3	5.3	0.6	0.3	3.4

General Discussion

There is a positive relationship between branching in legumes and the overall biomass yield i.e. the higher the branching, the higher the biomass yield. With the exception of Mucuna, Purple vetch and Dolichos which registered high branching of >10 per plant, all the other legumes' branching fell within the average of 6 reported previously by Indhumathi *et al.*, (2020). The branching also has a positive bearing on cover and the higher it is, the better the soil cover which minimizes moisture loss through evaporation and soil loss through erosion. For the grasses, a high grass density or plant population is desirable due to increased competition it provides against invading weeds and weed grasses. It has a positive bearing on soil cover and performance. Tillering/shoot density gives the crop the necessary number of stalks required for a good production. Shoot densities vary among grass species and cultivars, the rate of seeding and degree of initial establishment are also important factors in determining the shoot density of the non-creeping grass species. High shoot density is the most effective means of reducing runoff volume. In this case, fully established rangeland grasses registered over 100 tillers but rest of the grasses had tillers falling with the range reported before i.e. 13 or less, 28 – 34 tillers as reported by Thukur *et al.*, (2010).

Regarding the disease and pests score, most of the grasses and legumes registered <1 in a scale of 1 – 4 meaning low pest and diseases incidents. However, there were exceptions including Dolichos and Sugargraze which registered 2 – 3 in the lowlands of Narok, Lucerne and Crotalaria which recorded 2 and 1.5 in the highlands and lowlands of Taita Taveta, respectively.

Conclusions and Recommendations

For the two performing grasses and legumes investing in pest and disease control is likely to increase productivity. The range grasses are more suitable a low input and low output production system

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Beef Cattle Preferred Forages and their Proximate Composition under Ranching Conditions in Lanet Beef Research Centre, Nakuru, Kenya

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Abstract

Beef cattle production in Kenya is predominantly dependent on natural forages that grow naturally during two main rain seasons i.e., long rains in March, April and May and short rains in October, November, and December. The type, quality and quantities of forages fed to beef animals is crucial in determining the growth rate, productivity, and overall health of the cattle. This study evaluated the preferred forages for beef cattle and their proximate composition under ranching conditions. Forages including Rhodes grass (*Chloris gayana*), Brachiaria grass (*Brachiaria brizantha),* Kikuyu grass *(Pennisetum clandestinum),* African couch grass *(Digitaria abyssinica*), goose grass *(Eleusine indica),* grey love grass *(Eragrostis cilianensis),* woolly finger grass *(Digitaria eriantha)* and legumes such green leaf desmodium *(Desmodium intortum),* silver leaf desmodium (*Desmodium uncinatum*), Kenya white clover (*Trifolium semi-pilosum*), Sesban *(Sesbania sesban)* were evaluated for their proximate composition, including dry matter, crude protein, crude fiber, energy and crude fat. The results showed that *Eragrostis cilianensis* (29%) and *Digitaria abyssinica* (28.3%) had the highest crude protein (CP) content followed by *Pennisetum clandestinum* (15.8%), while *Digitaria eriantha* had the highest crude fiber content (79.7%). *Trifolium semi-pilosum* (24.9%) and *Sesbania sesban* (24.4%) had the highest CP. *Sesbania sesban* (11.5 MJ. Kg^{-1} DM) and *Trifolium semi-pilosum* (11.1 MJ Kg^{-1} DM) legumes had the highest metabolizable energy (ME). Hairy hood grass (*Hyparrhenia hirta*) had the lowest ME (6.3 MJ. Kg-1 DM). *Sesbania sesban* had the highest crude fat content (3.4%). The study concludes that that *Eragrostis cilianensis*, *Digitaria abyssinica* and *Pennisetum clandestinum* are suitable forages for beef cattle production in highlands under ranching conditions in Kenya due to their high crude protein content. However, a balanced between grass and legume mixture is recommended to ensure optimal growth and health of the cattle.

Introduction

The beef industry plays a crucial role in Kenya's economy by providing food, income, and jobs for rural and urban communities (Khanal *et al.,* 2022). Cattle farming in Kenya is diverse, ranging from large commercial operations to smallholder systems. Prominent beef cattle breeds include Boran, Sahiwal, Ankole, and Zebu which are adapted to different ecological zones (Yadav *et al.,* 2023). Beef production utilizes various systems like extensive grazing, ranching, and feedlots based on factors like land availability and market demands (Msuya *et al.,* 2022; Kahi *et al.,* 2006; Rewe *et al.,* 2010). Feeding is mostly pasture-based across production systems. Availability of forages is affected by seasonality, impacting nutrient levels and cattle weight gain (Sunya, 2006; Brandao, 2018; Rini, 2016). Dry seasons decrease protein levels and palatability compared to rainy seasons (Brandao, 2018; Yani, 2004). Variations in feed nutrients and forage availability across seasons affect beef cattle's ability to gain weight (Fernandes *et al.,* 2022; Garber *et al.,* 2022), which impacts on productivity and returns. The study aimed to determine nutrient levels in forages and their seasonal availability to beef cattle in Kenya, as this impacts growth and production, which are critical economic factors for the beef industry.

Materials and Methods

Site description

The study was conducted in Beef Research Institute, Lanet, Nakuru County, Kenya. The station is located at latitude 0º N 18º S and longitude 36º W 09º E, 1920m above sea level. Annual rainfall is often below 800mm and unreliable both in quantity and distribution. The research Center is located at the interface of agro-ecological zones 3 and 4 (Wasike *et al.*, 2007). Temperatures range between 8 to 30ºC. Soils are deep sandy loam with good water holding capacity with pH range of 5.5 to 6.5.

Experimental animals, feeding regimes and management.

The study involved improved Boran, Improved Boran and Sahiwal crosses and Small East African Zebu breeds of cattle reared under free range ranching conditions. The ranch has a variety of highly nutritive natural forages. The animals ages were between twenty-four and thirty months old. The animals grazed from 0800 hours to 1700 hours daily. Animals were provided with water on daily basis at *ad libitum*. The study was conducted during rainy season when most forage species were available and in right nutrients levels.

Grazing observation and sampling methods for preferred forages for beef cattle

Six beef herds grazing under free range ranching system were observed for a period of six days i.e., each day 5 animals were observed. The animals were randomly picked and observed for a period of 15 minutes per animal where complete bites made by each animal on various forages and parts eaten were recorded. Where the animal made a bite, a sample was collected estimating cattle bite using circumference of researcher's hands. The end of bite was marked by the time the animal raised its head for purposes of chewing and ingestion. A total of thirty beef cattle were observed in six different herds. The grazing observation was done early in the morning between 9.00 am to 11.00 am when the beef cattle were actively grazing. The bite samples per animal were summed up and sorted by species. The availability of browsed forages species ingested by individual, and all the sampled animals were done, and top 20 preferred forage species by beef cattle were sampled for laboratory analysis of their proximate composition.

Sample Preparation

After collection of the various forage species, they were labelled and coded with a laboratory number for ease of identification. Samples were chopped into small pieces and dried in an oven. The dried samples were grounded, and each put into samples jars which were labelled for the proximate analysis procedure.

Laboratory analysis: Proximate, tannins and minerals assay of samples.

Proximate analysis of preferred browses by grazing cattle in free-range system under ranching conditions were analyzed to determine their dry matter (DM), crude protein (CP), ether extract (EE), metabolizable energy (ME), and ash according to the standard methods of AOAC (2006). Neutral detergent fiber (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were analyzed according to the procedure described by van Soest *et al.*, (1994). Minerals (macro and micro elements) were determined using atomic absorption spectrophotometry (AAS).

Results and Discussion

Key forage species for free-range grazing systems and factors affecting their availability.

The availability of forage species in ranches varies depending on the rainy and dry seasons. During the rainy season, many of the plants are highly available, while during the dry season, their availability decreases. Some plants, such as *Themeda triandra* and *Trifolium semi-pilosum*, are highly available during the rains but rarely available during the dry season. On the other hand, plants like *Sesbania*

sesban and *Digitaria milanjiana* are available on riverine and riparian areas during the dry season. Overall, the availability of these plants is influenced by the climate and specific ecological conditions.

Rhodes Grass (*Chloris gayana*) is a perennial tropical grass that thrives well in a variety of soil types. It has high productivity, good palatability, and is highly nutritious. Brachiaria grasses are commonly used in free range grazing systems due to their adaptability to different soil types and climates. They are known for their high productivity, drought tolerance, and good nutritional value. Kikuyu grass (*Pennisetum clandestinum*) is a vigorous, perennial, and drought-resistant grass that is well-suited for free range grazing. It establishes quickly and provides good ground cover.*Cenchrus ciliaris* is a highly productive and drought-tolerant perennial grass. It has good forage quality and can withstand heavy grazing pressure. Star Grass (*Cynodon nlemfuensis*) is a warm-season perennial grass that is well-adapted to free range grazing systems. It has good palatability, regrowth ability, and can tolerate a range of soil conditions. Panicum grass are widely distributed and include several species like Guinea grass (*Panicum maximum*). They are highly productive, palatable, and provide good nutritional value for cattle.

Several factors can affect the availability of forages and grasses. Environmental conditions, such as drying or wilting, can also impact availability and alter the composition of forages (Glasser *et al.*, 2013). Bush fire can cause disappearance of some quality species. Nutrient availability, particularly nitrogen, plays a crucial role in the production and quality of forage grasses (Costa *et al.*, 2013). Biotic factors, including regeneration, shrub density, and herb density, can influence the availability of grasses for grazing (Ashokkumar *et al.*, 2021). In general, a combination of biotic and abiotic factors affects the availability of forages and grasses in various ecosystems, which might have an impact on the free-range grazing system in ranching situations.

Chemical composition

The chemical composition of the browses and grasses is presented in Table 1. The table provides information on the DM, CP, NDF, ADF, ADL, fat, and ME content of various plant species. These values are important indicators of the nutritional composition and quality of the forages.

Table 1. Proximate composition of most preferred forages

Scientific names	Common names	DM	CP	NDF	ADF	ADL	Fat	ME
Themeda triandra	Red oat grass	47.1^{a}	5.7^{n}	69.1^{g}	39.4^{g}	5.3^{h}	2.1^{g}	8.4^{ih}
Trifolium semi-pilosum	Kenya white clover	16.8^{o}	24.9^{c}	27.5^{o}	22.1^{p}	3.9^{k}	2.7^{c}	11.1^{b}
Sesbania sesban	Sesban	26.0^{i}	24.4^{d}	27.4^{o}	18.8^{q}	5.8^{f}	3.4^{a}	11.5^{a}
Setaria sphacelata	*Nandi setaria*	23.1^{m}	7.7^{m}	72.9^{c}	44.1^{b}	6.3^{d}	2.1^{g}	9.8^{d}
Cynodon dactylon	star grass	31.3^{f}	9.8^{j}	66.7^{h}	36.7^{k}	4.7^{j}	1.9^{h}	8.1^{ih}
Indigofera arrecta	Bengal indigo	35.0^{d}	24.7^{c}	24.8^{p}	31.7^{o}	6.0^{e}	2.2^{fg}	10.1^{c}
Desmodium intortum	Greenleaf desmodium	24.2^{l}	15.5^{f}	51.4 ^{m}	37.1^{i}	9.1^{a}	0.7^{k}	8.4 ^{ih}
Desmodium uncinatum	Silver leaf desmodium	25.7^{j}	15.1^{g}	52.2^{l}	40.0^{f}	4.8^{j}	2.4^{d}	7.4^{k}
Glycine wightii	Perennial soybean	33.3^{e}	17.1^{e}	50.7^{n}	37.4^{i}	7.9^{c}	2.4^{d}	9.1^{e}
Aristida adscensionis	Mountain needle grass	33.4^{e}	10.4^{i}	71.2^{d}	41.9^{c}	5.8^{f}	1.9^{h}	8.6^{g}
Brachiaria brizantha	Bread grass	29.6^{g}	10.4^{i}	66.8^{h}	39.4^{g}	5.6^{g}	2.1^{g}	8.1 ^{ih}
Pennisetum clandestinum	Kikuyu grass	20.1^{n}	15.1^{g}	65.3^{i}	35.1^{l}	4.3	2.7^{c}	9.7^{d}
Hyparrhenia hirta	Hairy hood grass	43^{b}	4.2^{o}	79.7^{a}	54.3^{a}	8.2^{b}	1.5^{i}	6.3^{l}
Sporobolus pyramidalis	Pyramid dropseed grass	41.4^{c}	7.6^{m}	68.5^{g}	38.5^{h}	5.1^{i}	1.3^{j}	8.9^{f}
Chloris gayana	Rhodes grass	24.9^{j}	9.1^{k}	75.1^{b}	43.0^{c}	6.2^{e}	2.2^{ef}	8.5^{gh}
Digitalia scalarum	African couch grass	15.6^{p}	28.3^{b}	63.9^{k}	33.5^{n}	3.8^{k}	3.1^{b}	10.0^{c}
Eleusine indica	Goose grass	27.3^{h}	10.9^{h}	64.4^{j}	34.1^{m}	4.1^{l}	2.8^{c}	9.1^{e}
Eragrostis cilianensis	Grey love grass	15.3^{p}	29.0^{a}	64.5^{j}	34.2^{m}	4.1^{l}	2.4^{d}	9.7^{d}
Digitaria milanjiana	Woolly finger grass	31.3^{f}	8.1^{l}	69.7^{e}	40.3^{c}	5.4^{h}	2.3^{d}	8.6^{g}
SEM		0.1322	0.0518	0.0577	0.0382	0.0366	0.0367	0.0359
P		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

According to Van Die, (2020), forages supplying CP > 12%, Total digestible nutrients (TDN) > 60% and NDF < 50% are considered very good quality for grass-fed to cattle for beef production. Grey love grass (*Eragrostis cilianensis)* and African couch grass (*Digitalia scalarum*) had the highest crude protein content (28%) followed by *Pennisetum clandestinum* (15.8%), while Hairy hood grass (*Hyparrhenia hirta*) had the highest crude fiber content (79.7%) **(Table 1).** *Sesbania sesban* legume had the highest crude fat content (3.4%). *Hyparrhenia hirta* had the lowest ME (6.3 MJ. Kg^{-1} DM) content. In Kenya, grasslands are mainly found in the arid and semi-arid regions, where they support pastoral livestock production systems. Grasslands in Kenya are threatened by land degradation, overgrazing, invasive species, climate change and human population growth. Some of the common grass species in Kenya's rangelands are *Cenchrus ciliaris, Chloris roxburghiana, Enteropogon macrostachyus, Eragrostis superba, Pennisetum mezianum* and *Themeda triandra*. Some of the common legume species in Kenya are *Desmodium intortum, Desmodium uncinatum, Macroptilium atropurpureum, Stylosanthes guianensis* and *Trifolium semipilosum*. Legume plant species with higher CP content, such as *Trifolium semi-pilosum* and *Sesbania sesban* may be more suitable for inclusion in livestock diets to meet their protein requirements. On the other hand, plant species with higher fiber content, like *Themeda triandra*, may be less digestible and may require additional supplementation to meet the animal requirements. Forages with NDF less than 50% have lower fiber content and higher levels of easily digestible nutrients. They pass through the rumen more rapidly, allowing for greater forage intake and animal productivity.

The Mineral analysis of most preferred forages is presented in Table 2.

Table 2: Mineral analysis of most preferred forages

Scientific names	Common name	Ca g/kg	P g/kg	Mg g/kg	Co mg/kg	Fe mg/kg	Zn mg/kg
Themeda triandra	Red oat grass	2.9^{n}	0.9^{p}	1.7^{m}	5.7^{r}	201.5^{l}	21.1^{s}
Trifolium semi- pilosum	Kenya white clover	10.1^{d}	3.3^{e}	3.1^{f}	12.1^{i}	121.3^{r}	28.1^{p}
Sesbania sesban	Sesban	15.9^{a}	3.3^{e}	3.5^{c}	18.4^{a}	288.3^{g}	41.1^{h}
Setaria sphacelata	*Nandi setaria*	3.2^{n}	2.4^{j}	2.0^{k}	7.1^{0}	232.6^{j}	30.3^{m}
Cynodon dactylon	Common star grass	4.4^{j}	2.2^{l}	1.8^{l}	8.2^{m}	133.3^{p}	44.3^{g}
Indigofera arrecta	Bengal indigo	15.4^{b}	2.8^{g}	10.1^{a}	11.0^{j}	306.9^{e}	36.4^{k}
Desmodium intortum	Greenleaf desmodium	10.2^{d}	3.1^{f}	3.2^{d}	14.3^{e}	301.3^{f}	37.1^{i}
Desmodium uncinatum	Silver leaf desmodium	8.5^{e}	2.2^{l}	2.5^{i}	10.1^{k}	126.3^{q}	23.8^{r}
Glycine wightii	Perennial soybean	14.8^{c}	2.5^{j}	3.1^{d}	12.3^{h}	143.7^{m}	33.2^{l}
Aristida adscensionis	Mountain needle grass	3.4^{m}	0.4^{o}	1.1^{m}	16.1^{c}	225.5^{k}	26.4^{q}
Brachiaria brizantha	Bread grass	4.6^{i}	2.2^{l}	3.1^{d}	13.1^{g}	401.3^{a}	36.6^{j}
Pennisetum clandestinum	Kikuyu grass	3.1^{n}	3.7^{b}	2.9^{g}	9.2^{l}	309.3^{d}	45.1^{f}
Hyparrhenia hirta	Hairy hood grass	6.5^{f}	3.4^{d}	2.1^{j}	16.3^{b}	348.1^{c}	51.2^{d}
Sporobolus pyramidalis	Pyramid dropseed grass	8.5^{e}	1.9^{m}	1.3^{n}	7.0^{o}	138.2^{n}	29.3^{n}
Chloris gayana	Rhodes grass	3.8^{l}	2.9^{g}	1.9^{l}	6.4^{p}	237.3^{i}	28.3^{o}
Digitalia scalarum	African couch grass	4.0^{k}	3.6^{c}	3.9^{b}	15.2^{d}	243.4^{h}	67.2^{b}
Eleusine indica	Goose grass	5.3^{h}	2.6^{i}	3.2^{e}	7.4^{n}	391.1^{b}	60.3^{c}
Eragrostis cilianensis	Grey love grass	2.3^{o}	1.2^{n}	0.9^{o}	6.1^{q}	126.8^{q}	77.5^{a}
Digitaria milanjiana	Woolly finger grass	6.3^{g}	5.3^{a}	2.7^{h}	13.6^{f}	133.1^{o}	49.2^{e}
SEM		0.0333	0.0333	0.0323	0.0333	0.0333	0.0351
P		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

The preferred forages had a varying level of essential mineral composition such as calcium (Ca), phosphorus (P), magnesium (Mg), cobalt (Co), iron (Fe), and zinc (Zn). *Sesbania sesban* had the highest levels of Ca, Mg, Co, Fe, and Zn among the listed species (**Table 2)**. On the other hand, *Eragrostis cilianensis* had the lowest levels of Ca, P, Mg, Co, and Fe. These variations in nutrient content can have implications for livestock feed and forage selection. Minerals are essential nutrients required by livestock for various physiological functions, including growth, reproduction, and immunity (Palomares, 2022). Mineral analysis is the measurement of mineral levels in forages and feeds and can help to determine whether supplementation is required and at what level. Therefore, understanding the mineral content of forages is important for proper feeding and optimal animal production. *Sesbania sesban* and *Indigofera arrecta* were high in calcium and phosphorous compared to other preferred forages found in the ranch.

These variations in nutrient content can have implications for livestock nutrition and forage selection. For instance, plant species with higher nutrient content, such as *Sesbania sesban*, may be more suitable for inclusion in livestock diets to meet their nutritional requirements. On the other hand, plant species with lower nutrient content, like *Eragrostis cilianensis*, may need to be supplemented with other feed sources to ensure adequate nutrient intake and improve animal performance. With the right combination of forage management, testing, and strategic supplementation, the macro and micro mineral needs of grazing cattle can be optimally met. This is key to maintaining productivity and herd health.

Conclusion and Recommendations

The study evaluated preferred forages for beef cattle under ranching conditions in Kenya and found Kikuyu grass, African couch grass, and grey love grass to have high CP content, making them potentially suitable. However, a balanced forage mixture of pasture and fodder like the case of ranch in reference is recommended for optimal cattle growth and health. The findings can help farmers and policymakers select appropriate forages. Livestock owners should consider incorporating legumes like *Sesbania sesban* and Kenya white clover to boost nutrients. Further research on using specific nutrient-rich plants in cattle diets is recommended. Regular testing of forage nutrient content is advised to ensure cattle nutritional needs are met. Re-evaluation every 10 years is recommended as availability of forages can change over time due to factors like overgrazing and burning. Overall, the study provides useful insights for selecting suitable forages for beef cattle production under ranching conditions in highlands of Kenya.

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Evaluation of Yield and Nutritive Composition of Forage Sweet Potato Vines (Ipomoea batatas) in Kenya

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Abstract

Sweet potato vine (SPV) is a widely grown but underutilized feed resource for livestock. The vines have desirable characteristics suitable for fodder production due to high contents of protein and digestible energy. The objective of this study was to evaluate growth and nutrient composition of Wagabolige variety in Bomet for increased animal productivity. Pre-planting soil samples were taken using recommended methods. The vines were established using Randomized Complete Block Design (RCBD). Wagabolige was planted using Di-ammonium phosphate (DAP 18:46:0) fertilizer at a rate of 250kg/ha. Agronomic, proximate and digestibility data was collected and subjected to analysis of variance (SAS, 2010). Results showed that there was no significant effect of the site on the days to 50% ground cover. However, the site had significant effect on days to 100% ground cover. Plant height, internode length, leaf surface area, number of tillers, were significantly higher in Longisa than in Lanet. Vine biomass yield was significantly higher in Longisa (48.7t/Ha) as compared to Lanet (45.8t/Ha). Crude protein was significantly higher in Longisa than in Lanet. Acid detergent lignin was significantly higher in Lanet than in Longisa. *In vitro* dry matter digestibility, *in vitro* organic matter digestibility and dry organic matter digestibility were high in Longisa. This study concluded that the improved cultivar demonstrated potential in quality and quantity for increased animal productivity in Longisa than in Lanet. Wagabolige cultivar is recommended for upscaling in Bomet as protein supplement for increased productivity during dry seasons.

Keywords; *Forages, digestibility, performance, and nutritive value.*

Introduction

One traditional crop in tropical countries is sweet potatoes (*Ipomoea batatas*) which is a key crop in family farming systems, since it is easy to grow, widely adapted to various soil and climatic conditions, and tolerant to drought. In addition, it has a relatively low production cost when compared to other vegetable crops. Countries such as China and Vietnam use sweet potato vines alone or in combination with roots to feed pigs, in fresh or as silage as reported by Monteiro *et al.*, (2007).In Kenya about 65.8 thousand hectares of land is grown with sweet potato annually with a production of 11.8t/ha (FAO, 2021). However, the vine production is been considered as waste after tuber harvest. The selection and adoption of sweet potato cultivar with the potential as animal feed will assist a great deal in mitigating the pressure on conventional feed resources owing to competition by humans. Furthermore, the utilization of sweet potato vines in livestock

feeding could help to reduce some of the nutritional problems associated with the dry season feeding of livestock during which time the crude protein content of native grasses falls below the minimum threshold level for animal maintenance and production. In the past KALRO-Lanet carried out research by selecting and evaluating several vine producing types among them Wagabolige, Marooko and K158. These types have good Crude Protein (18%) content and are high in nutritive value (Ondabu *et al*., 2004). However, studies on growth and nutritional value of sweet potato vines for livestock feed in Kenya is limited. This study therefore, aimed at evaluating growth and nutritive composition of forage sweet potato vines for increased animal productivity in two contrasting regions, in Kenya.

Materials and Methods

Experimental site

The experiment was conducted in two sites at KALRO Lanet, Nakuru County and Longisa, Bomet County. KALRO - Lanet lies at an elevation of 1600 meters above sea level. The area has an annual mean rainfall of 800mm ranging from 534 to 1,049mm. Temperature ranges between 10- 30ºC (Jaetzol et al., 2006). Longisa in Bomet county lies at an elevation of 2167m above the sea level. The region is characterized by evenly distributed rain throughout the year ranging from 1100mm to 1500mm. The area has a mean monthly temperature of 18°C (Jaetzold *et al* 2006a).

Soil sampling

Soil samples were both collected in Lanet and Longisa before planting using soil auger at depth of 0-15cm and their chemical properties analyzed following standard methods as described by Okalebo et al. (2002).

Field Experimental Design:

Land preparation in both sites was done using tractor by ploughing to a fine tilt for establishment. The plot sizes were 5x3m and replicated 3 times. Cultivar Wagabolige, which has shown high vine production, tolerance to prolonged drought and harvestable for five years was used (Ondabu *et al*. 2004). The planting materials were sourced from Kenya Agricultural and Livestock Research Organization (KALRO) Lanet. Cuts of stables of about 30cm were prepared and planted using valley method at a depth of 3.0cm. The spacing of the cuttings was maintained at 60 cm between rows and 30cm between stations and a population of 84 stables was maintained in each plot. The distance between plots was maintained at 1 m. Di-ammonium phosphate (DAP 18:46:0) was applied at the rate of 250kg/Ha. The Weeds were manually controlled during the establishment. The vines were top dressed using Calcium ammonium nitrate CAN (27% N) at 250 kg/ha when the crop was 60 cm long. Agronomic variables taken included days to 50% and 100% ground cover, stem elongation, internodes length, tiller population, leaf length, leaf width, leaf surface area and herbage yield. The vines were cut after 120 days by throwing a 1 m^2 quadrant at each replication and the vines and tubers within the square were harvested, weighed and vine to tuber ratio was determined. A representative sample was taken and used for chemical analysis as described by Association of Official Analytical Chemists (AOAC, 1990).

Results

Soil characteristics

Soils of the study sites were slightly acidic (5.55-5.89) with adequate nitrogen levels, (0.25 - 0.31 %,) respectively. Phosphorous level was deficient in the Lanet soil and moderate in the Longisa soil. The micronutrients were generally adequate on both soils (Table 1).

Table 1: Soil characteristics

Soil characteristic	Lanet	Longisa
pH	5.89	5.55
Total N (%)	0.25	0.31
Organic carbon (%)	2.48	3.45
Phosphorous (ppm)	3	24
Cu (ppm)	2.0	0.61
Potassium meq%	1.3	0.72
Calcium (meq %)	0.7	10.8
Magnesium (meq %)	3.21	2.54
Manganese (meq %)	0.38	0.93

Effect of site on the growth and biomass yield

There was no significant effect of site on days to 50% ground cover, leaf length, leaf width and the LSR. There was significant site effect on days to 100% ground cover (Table 2) with sweet potato grown in Longisa taking less days (44 days) compared to those in Lanet (47 days). The plant height, LSA and number of tillers were significantly higher in Longisa than in Lanet (Table 3). There was significant difference in fresh weight of sweet potato vines with Longisa having a higher biomass yield (48.7ton/Ha) than Lanet (45ton/Ha). The vine: tuber ratio was higher in Longisa than in Lanet though the difference was not significant (Figure 1)

Table 2: Analysis of variance (ANOVA) for agronomic variables

Source of variation	df	50% GC	100% GC	PH	Leaf length	Leaf width	IL	LSA	Tillers	LSR	BM	V:T
Replicate	2	24.5	3.5	2.30	19.36	0.43	0.105	1.13	0.33	0.00	2.87	25.13
Site	1	13.5^{ns}	13.5^{*}	102.75^{*}	7.94^{ns}	2.41^{ns}	2.28^{**}	126.50^{*}	49.48^{**}	0.00^{ns}	12.62^{*}	253.04^{ns}
Error	2	1.5	0.5	4.97	8.29	0.19	0.012	1.55	0.13	0.00	0.56	39.54
Total	5											
CV (%)		3.8	1.6	3.9	18.4	5.1	2.0	2.7	2.2	3.9	1.6	5.7
R^2		0.95	0.95	0.91	0.74	0.89	0.99	0.98	0.99	0.53	0.94	0.79

***, **- significant at 0.05, 0.01 levels of significance respectively, ns- not significant**

CV-Coefficient of Variation, df- degrees of freedom at 5%. **GC**- Ground cover, **PH**- Plant height, **IL**- Internode length, **LSA**- Leaf Surface Area, **LSR**- Leaf to Stem Ratio, **BM**- Biomass, **V: T**- Vine to tuber ratio

Table 3: Effect of site on the sweet potato growth parameters

Site	Plant height	Leaf length	Leaf width	Internode length	Leaf surface area	Tillers	Leaf to stem ratio
Lanet	53.2b	14.5a	7.9a	6.0a	42.0b	12.9b	0.51a
Longisa	61.5a	16.8a	9.2a	4.7b	51.2a	18.6a	0.51a
LSD (≤0.05)	7.8	10.1	1.5	0.4	4.4	1.2	0.07

Means followed by the same letter in each column are not significantly different at α≤0.05

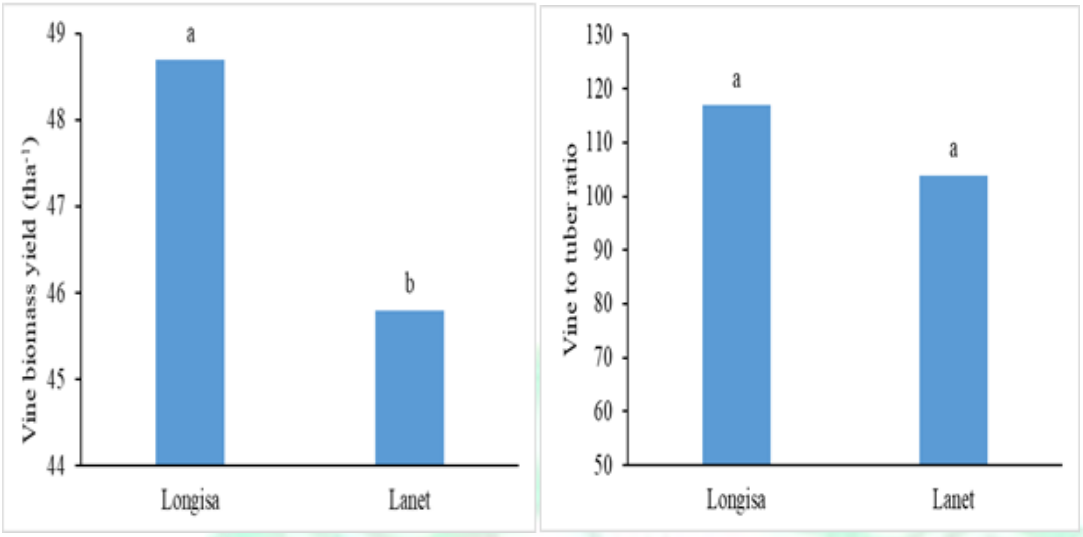

Figure 1: Effect of site on the biomass yield and vine to tuber ratio of sweet potato vines respectively. Means followed by the different letter are not significantly different at $\alpha \leq 0.05$

Proximate analysis

There was significant effect of site on the Ether Extract (EE), crude protein (CP), crude fibre (CF) and Nitrogen Free extract (NFE). The site did not have a significant effect on the Dry matter (%DM), ash and the Estimated metabolizable energy (EST: ME) (Table 4). The EE was significantly higher in sweet potato grown in Longisa (2.69) than those in Lanet (1.62) . CP, CF and the NFE were significantly higher in Longisa site vines than in Lanet

Table 4: Analysis of variance (ANOVA) mean square values for the proximate analysis of the sweet potato vines

Source of variation	df	%DM	%Ash	%EE	%CP	%CF	%NFE	EST:ME
Replicate	2	1.137	0.015	0.008	0.089	0.019	0.119	4927.37
Site	1	20.46^{ns}	0.004^{ns}	1.707^{**}	1.58^{***}	1.402^{**}	5.802^{***}	41352.26^{ns}
Error	2	1.18	0.001	0.002	0.000	0.002	0.002	6530.4
Total	5							
CV (%)		1.2	3.6	1.9	0.03	0.4	0.1	3.2
R^2		0.91	0.95	0.99	0.99	0.99	0.99	0.79

****, ***- significant at 0.01, 0.001 levels of significance respectively, ns- not significant**

DM-Dry Matter, CF-Crude fiber, **EE** -Ether Extract (crude lipids and crude fats), N**.F.E** -Nitrogen Free Extract (soluble carbohydrates), CP -Crude protein, EST: ME- Estimated Metabolizable Energy

Vansoet and digestibility

There was significant site effect on the Neutral Detergent fibre (NDF), Acid Detergent Lignin (ADL) and Feed organic matter FOM. The NDF was significantly higher in sweet potato grown in Longisa than those in Lanet (Figure 4). The ADL was significantly higher in the sweet potato grown on Lanet compared to those grown in Longisa (Figure 4). The FOM was significantly higher in sweet potato grown at Longisa than those grown at Lanet (Figure 5).

Table 5: Analysis of variance (ANOVA) for vansoet and digestibility

Source of variation	df	%NDF	%ADF	%ADL	%IVDMD	%FOM	%IOM	%IVOMD	%DOMD
Replicate	2	1.315	0.463	0.227	0.424	0.099	1.904	0.676	1.243
Site	1	13.50*	54.361^{ns}	9.601*	12.212^{ns}	11.704**	10.64^{ns}	12.18^{ns}	14.415^{ns}
Error	2	0.50	0.630	0.113	0.85	0.067	0.675	0.759	1.50
Total	5								
CV (%)		1.3	1.8	1.5	1.7	0.3	1.8	1.8	2.8
R^2		0.94	0.81	0.98	0.88	0.99	0.91	0.89	0.85

***, **- significant at 0.05, 0.01 levels of significance respectively, ns- not significant** NDF=Neutral detergent fibre, ADF=Acid detergent fibre; ADL=Acid detergent lignin; IVDMD=in-vitro dry matter digestibility; FOM=free organic matter; IVOMD in-vitro organic matter digestibility; IOM= In-vitro Insoluble Organic Matter

Discussion

There was high growth in Longisa than Lanet since the vegetative growth of sweet potato vines (plant height, leaf length, leaf width, leaf surface area and number of tillers) were higher in Longisa than Lanet (Table 2). This could be due to the different amount of Phosphorous (P) and Nitrogen (N) in the soils. The high P and N in Longisa stimulated the growth of sweet potato vines in the site. This agrees with the results of Gemechu (2019) who reported adequate supply of N and P promotes higher photosynthetic activity and vigorous vegetative growth and promotes the chance for emergence of new vines. The significant difference in vegetative growth could also be attributed to different amounts of rainfall received in the two sites (Lanet 534 to 1,049mm) and Longisa (1100mm to 1500mm) since rainfall plays a vital role facilitating soil water recharge thereby impacting positively on the soil water balance hence high growth. This agrees with the findings of Nyawade et al. (2019) who reported that higher canopy cover goes hand in hand with a rise in soil moisture and a decrease in soil temperature which has a positive effect on the soil microclimate and hence on the overall productivity of crops. This was be further explained by Gitari.(2018) who reported that high ground cover may have created a microclimate by sheltering moist air near the soil surface, thereby reducing soil evaporation and thus retaining soil moisture hence high vegetative growth.

The high Biomass yield in Longisa than in Lanet could be due to early establishment of crop (Figure 1), long plant height, large leaf surface area and high number of tillers, which contributed to high canopy cover hence high biomass yield. This agrees with the findings of Nyawade et al. (2019) who reported that higher canopy cover enhance the overall productivity of crops.

Proximate analysis revealed significant effect of site on the EE, CP, CF and the NFE (Table 4). The difference in %CP in the vines could be due to difference in amount of rainfall in the two sites. Longisa had higher rainfall which could have increased soil water availability and through the improvement of the nitrogen content of the leaves (Núñez *et al*., 2022) the %CP increased.

Lanet had higher ADL as compared to Longisa this could be due to low CP and EE values and hence high ADL values observed. These results are consistent with those of Mountousis et al (2008) who indicated that digestibility are mainly related to those of crude protein and fibre contents. However, NDF was higher in Longisa than Lanet and due to the temperatures leading to a more rapid maturation of plants, which increased the stem-to-leaf ratio and cell wall content, including lignin (Dumont *et al*., 2015). However, the fibers at both sites were not sufficiently high to affect digestibility.

Conclusion

Wagabulige had high: yields, protein levels tillering, digestibility in both sites. However, it had very low tuber to stem ration in both sites. It showed higher potential as livestock feed than human food due to few tubers underneath and high vine production.

Recommendations

Wagabolige cultivar is recommended for upscaling in Bomet as protein supplement for increased productivity during dry seasons. Continued breeding and selection of the variety to diversify the gene base. Develop conservation technologies for sweet potato vines as an animal feed

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Performance Evaluation of Improved Kenyan Brachiaria Variety in Kericho County

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Abstract

Inadequate availability of forage and their poor qualities are major impediments of livestock productivity especially during the dry seasons. Brachiaria grass produces high quantity and quality hay that could ameliorate the shortage. Performance evaluation of improved Brachiaria *brizantha* (KS1) variety was done in Kericho County and Boma *rhodes* was included as a control. The experiment was laid out in randomized complete block design with three replicates. Agronomic data was collected using standard methods. Nutritional and digestibility analysis was done using established techniques. KS1 had significantly higher number of tillers (41.4) compared to Rhodes (8.8). The KS1 variety had significantly higher nutritional values (CP=13.8%; IVDMD=42.6%) than Rhodes (CP=10.6%; IVDMD=32.8%). Variety KS1 performed better than Rhodes and therefore it is recommended to be grown in Kericho County. There is need for further evaluation of the KS1 variety in other counties.

Keywords*: KS1, performance, agronomic, digestibility variables*

Introduction

Inadequate availability of forage and their poor qualities are major impediments of livestock productivity especially during the dry seasons across Africa (Djikeng *et al.,* 2020). In livestock production systems, several forage innovations have been used to alleviate livestock feed shortage. Among the common forage grasses in Kenya are *Pennisetum clandestinum, Chloris gayana* and *Pennisetum purpureum*. Ninety percent of dairy farmers depend on *Pennisetum purpureum* which is susceptible to diseases (Lusweti *et al.*, 2004). Introduction of improved forages that are climate smart, high yielding, tolerant to drought and pests is key. Brachiaria grass has been reported to have these qualities (Ghimire *et al.,* 2015). Brachiaria grass has been reported to have over 100 species in Kenya (Boon man, 1993). This grass produces high quantity and quality hay that could curb the shortage of feeds especially during the dry season (Ochola *et al.,* 2022). Improved local Brachiaria *brizantha* var. KS1 developed at KALRO Lanet through gamma irradiation by Hoka *et al.,* (2019) can be used to increase livestock productivity in Kenya. However, there is limited information on the performance of this variety in some agroecological zones of Kenya. The objective of the study was to evaluate the performance of KS1 variety in Kericho County.

Materials and Methods

Study area

The study was carried out in Soin and Sigowet wards, Kericho County. Soin farm is located at latitude -0º22' and longitude 35º 14' while that of Sigowet is located at latitude -0º40' and longitude 35º05'. Kericho county receives rainfall ranging from 1400mm-2125mm and temperatures range between 10°C-29°C per annum. Soin is in the Lower Midlands agro ecological zone while Sigowet is in the Upper Midland agro ecological zone. An inventory on the pre-existing pastures and fodders was carried out before the study. Soil sample, 0-15cm from the plots was collected before planting using soil auger and analyzed for the macro and micronutrients. The analysis was done following standard methods as described by Okalebo *et al.*, (2002).

Experimental design and management

Planting materials were acquired from KALRO-Lanet. Plots of 3m by 4m were ploughed and harrowed for planting of KS1 and Rhodes grass. Treatments were done in a randomized complete block design with three replicates. Brachiaria seeds (KS1) were planted in holes at a spacing of 60cm by 60cm and at a depth of 3cm.Rhodes was broadcasted at a seed rate of 4kgs per acre and covered lightly. Di-Ammonium phosphate fertilizer was applied at planting at a rate of 50kgs per acre. Top dressing was done using CAN at 60 days post-emergency at the rate of 50kgs per acre.

Data collection and analysis

At booting stage, a one m^2 quadrant was randomly thrown in each plot and the plants within were cut, homogenized and representative samples were used for the determination of agronomic, nutrient and digestibility values.

Lab analysis

Neutral detergent fibre and acid detergent fibre were determined according to van Soest analysis. Crude protein content (g/kg DM) was calculated as 6.25 x N (Kjeldahl nitrogen) content in the feed. The nitrogen content was determined according to AOAC (2006) method. Dry matter contents were determined according to AOAC (1990) method while organic matter and ash were determined according to AOAC (2006) method.

Data analysis

Statistics analysis software (SAS) Version 9.3 was used for the analysis (SAS Institute, 2010). Analysis of variance was carried out using the PROC GLM procedure. Mean separation was done using Fisher's Least significant difference (LSD).

Results

Napier grass (9.94 acres), Boma Rhodes (2.5 acres) and Brachiaria grass (Mulato II) (1.2 acres) were among the common forages in Soin and Sigowet. Soils in both locations were medium acidic, low in Phosphorous (14-15ppm) and had adequate organic matter and micronutrients (Table 1).

Table 1: Soil characteristics

	Soin	Sigowet
Soil pH	5.24	5.16
Exch. Acidity meq%	0.4	0.5
Total Nitrogen %	0.34	0.31
Total Org. Carbon %	3.65	3.40
Phosphorus ppm	15	14
Potassium meq%	0.62	0.68
Calcium meq%	7.6	5.0
Magnesium meq%	3.58	3.15
Manganese meq%	0.54	1.40
Copper ppm	1.45	2.49
Iron ppm	197	112
Zinc ppm	7.75	26.9
Sodium meq%	0.10	0.24

Agronomical characteristics

There was significant variety effect on the stem length, leaf width, internode length and number of tillers (Table 2). KS1 recorded significantly higher (11 t ha^{-1}) dry matter yield than the Rhodes grass with 7.7 tha^{-1} (Figure 1).

Table 2: Analysis of variance (ANOVA) for growth parameters

Source of variation	df	Stem length (cm)	Leaf length(cm)	Leaf width (cm)	Tillers (No.)	Internode Length (cm)	Leaf Shoot ratio(gm)
Replicate	2	52.03	5.63	0.002	10.33	5.20	0.001
Variety	1	15253.2^{***}	1.25^{ns}	4.44^{***}	176.33^{***}	929.28^{***}	0.0001^{ns}
Location	1	18.6^{ns}	61.3^{*}	0.04^{ns}	16.33^{ns}	31.36^{*}	0.000^{ns}
variety* Location	1	185.1^{*}	8.17^{ns}	0.001^{ns}	1.33^{ns}	11.21^{ns}	0.000^{ns}
Error	6	25.4	11.16	0.02	7.7	3.59	0.0003
Total	11						
CV (%)		4.1	14.2	11.0	21.9	11.5	3.3
R^2		0.99	0.60	0.98	0.82	0.98	0.44

*, **, ***- significant at 0.05, 0.01, 0.001 levels of significance respectively, ns- not significant

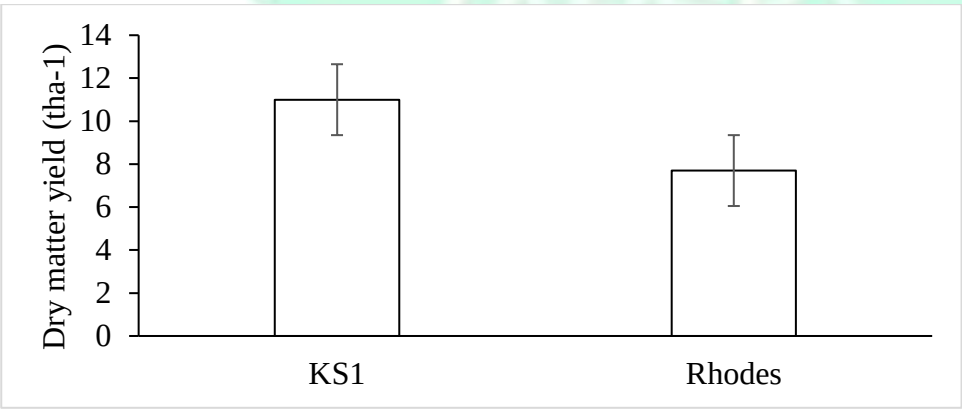

Figure 1: Dry matter yield of KSI and Rhodes

Proximate analysis

There was significant effect of variety on all of the nutrition parameters measured (Table 3).

Table 3: Analysis of variance (ANOVA) mean square values for the proximate analysis

Source of variation	df	DM	Ash	EE	CP	CF	NFE	EST:ME
Replicate	2	0.01	0.001	0.01	0.16	0.003	0.133	490.97
Variety	1	6.87^{**}	1.206^{**}	8.71^{**}	15.68^{**}	27.65^{***}	37.30^{**}	24049.57^{*}
Location	1	8.43^{ns}	2.401^{ns}	5.96^{ns}	11.23^{ns}	31.03^{ns}	41.96^{ns}	876.85^{ns}
variety*location	6	2.46^{ns}	3.44^{ns}	1.37^{ns}	3.61^{ns}	8.14^{ns}	22.03^{ns}	97.53^{ns}
Error	2	0.06	0.003	0.01	0.10	0.01	0.22	522.17
Total	11							
CV (%)		0.3	0.4	2.6	2.6	0.3	1.3	0.9
R^2		0.98	0.99	0.99	0.99	0.99	0.99	0.96

*, **, ***- significant at 0.05, 0.01, 0.001 levels of significance respectively, ns- not significant*; Rhodes* was included as control*; CP=Crude protein; EE=Ether Extract; DM=Dry Matter; CF=Crude Fiber; NFE=Nitrogen Free Extract; EST:ME=Estimated Metabolizable Energy*

Vansoest and digestibility

There was significant effect due to variety on all the Vansoet analysis except for the ash content (Table 4). The *in vitro* organic matter digestibility was significantly higher in the KS1 than in the Rhodes grass (Figure 2).

Table 4: Analysis of variance (ANOVA) for organic matter digestibility

Source of variation	Df	%NDF	%ADF	%ADL	%Ash	%IVDMD	%FOM	%IOM	%IVOMD	%DOMD
Replicate	2	0.012	0.02	0.038	0.004	0.02	0.035	0.82	0.209	0.146
Variety	1	49.94^{***}	347.02^{***}	97.85^{***}	0.001^{ns}	28.42^{**}	54.54^{**}	69.36^{***}	40.82^{**}	7.26^{*}
Location	1	14.213^{ns}	99.43^{ns}	12.31^{ns}	0.003^{ns}	15.65^{ns}	37.33^{ns}	21.89^{ns}	34.51^{ns}	2.54^{ns}
Variety* location	1	5.003^{ns}	37.87^{ns}	3.42^{ns}	0.006^{ns}	7.90^{ns}	12.36^{ns}	6.83^{ns}	10.44^{ns}	1.03^{ns}
Error	6	0.018	0.185	0.062	0.021	0.096	0.019	0.014	0.286	0.222
Total	11									
CV (%)		0.2	1.1	4.4	3.0	0.8	0.2	0.2	1.4	1.5
R^2		0.99	0.99	0.99	0.82	0.99	0.99	0.99	0.99	0.94

*, **, ***- significant at 0.05, 0.01, 0.001 levels of significance respectively, ns- not significant; NDF=Neutral detergent fibre, ADF=Acid detergent fibre; ADL=Acid detergent lignin; IVDMD=in-vitro dry matter digestibility; FOM=free organic matter; IVOMD in-vitro organic matter digestibility; IOM= In-vitro Insoluble Organic Matter

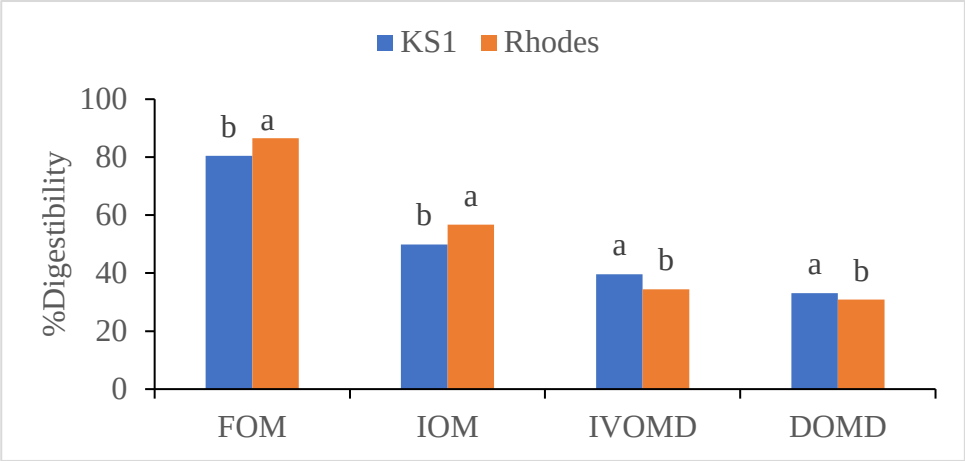

Figure 2: Means followed by different letters for each parameter are significantly different from each other.

Correlation analysis for the nutritive composition and digestibility

The IVDMD was significantly positively correlated with the % DM (r^2= 0.904, p<0.01), ash and CP (r^2 = 0.831, p <0.001); and negatively correlated with the CF, ADF, ADL, FOM and IOM. The IVOMD was significantly positively correlated with the ash content and EE, but negatively correlated with the CF, ADF, ADL, FOM and IOM. The DOMD was significantly positively correlated with the %DM, ash, CP and negatively correlated with the CF, NFE, ADF, ADL, FOM and IOM.

Discussion

KS1 had higher performance in number of tillers compared to Rhodes. The higher tillering ability of KS1 could be due to the well-established root system which enhances high nutrients uptake increasing the number of tillers. It could also be attributed to difference in growth habit where KS1 forms rhizomes, while Rhodes grass spreads by stolon. This result is in line with Ondiko *et al.*, (2016) who showed increased number of tillers in Brachiaria *brizantha* ecotypes as a result of its massive root system which maximises nutrient absorption. KS1 had significantly higher herbage yield than Rhodes. This could be attributed to wider leaf, shorter internode length and high number of tillers in KS1. This result is similar to that of Wassie *et al.*, (2018) who reported high dry matter yield in Brachiaria as a result of increased number of tillers. Varieties grown in Sigowet had longer stem and leaf length compared to those in Soin. The variation could be due to differences in the agro-ecological zones. This concurs with study by Adnew *et al.*, (2019) reported significant difference in plant height for B. *brizantha* ecotypes grown in different agro-ecological zones.

The CP content is one of the most important criteria to determine the nutritional quality of livestock feeds; this is because CP increases the DM intake by livestock and rumen microbial growth, as explained by McDonald *et al.*, (2010). Crude protein content in the KS1 was higher than in Rhodes grass. The low crude protein in Rhodes grass may be attributed to accumulation of cell wall carbohydrate in the stem. This result agrees with findings of Nguku *et al.*, (2016) who reported low crude protein in stems of Rhodes. The in vitro dry matter digestibility was significantly positively correlated with the % DM, ash and %CP and negatively correlated with the CF, ADF, ADL, FOM and IOM. The positive correlation could be due to high amounts of %CP which increases DM intake hence availing feed for digestion. This result agreed with Spurgin *et al.*, (2021) who reported a positive relationship between CP and IVDMD in forages. Negative correlation could be due to presence of lignin in NDF which cannot be digested and is very resistant to strong acids and microbial degradation (Indah *et al.*, 2020). The IVOMD was significantly positively correlated with the ash

content and EE, but negatively correlated with the CF, ADF, ADL, FOM and IOM. The negative correlation could be due to increased lignin and fiber (Kebede *et al.*, 2016).

Conclusion

Agronomic performance and nutrient values of forage harvested at booting (120 days) were significantly affected by site, variety and their interactions. Variety KS1 outperformed Rhodes in agronomic, proximate and digestibility results. The IVDMD value (42.6%) of the current study indicates KS1 is a promising feed resource. Based on evaluation parameters, KS1 was selected to fulfill forage quantity and quality shortage and to enhance livestock production and productivity in Kericho County.

Recommendation

KS1 is highly recommended for adoption and upscaling as feed for livestock in Kericho county. Research on the performance of KS1 in other counties for increased livestock productivity is encouraged.

Acknowledgment

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Adaptability of Brachiaria brizantha BS1 and KS1 varieties in the Semi-humid Areas of Bomet County, Kenya

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Abstract

Inadequate quantity and quality of feeds is the major constraint to livestock production in Kenya. Brachiaria has high biomass production potential, is drought tolerant and produces nutritious herbage thus increased livestock productivity. The adaptability of two *Brachiaria brizantha* varieties (BS1 and KS1) were assessed in two wards, Longisa and Kipreres in Bomet County, Kenya. The grass treatments were laid out in a randomized complete block design with three replications. The Rhodes grass was used as control. Agronomical parameters, dry matter yield, nutrient levels and digestibility data were measured at booting stage. The location had no effect on the growth parameters of the two varieties. KS1 was significantly higher values in the stem length (96.3cm), internode length (6.8cm) and biomass yield (11.2tonnes) than BS1 with (74.2cm,5.9cm and

9.7tonnes) respectively. The biomass values (7.65tonnes) per acre of Rhodes grass was significantly lower than those of the two *Brachiaria* varieties. There was no significant difference (P>0.05) on germination percentage, leaf length, leaf width, number of tillers and the leaf: shoot ratio. There was significant varietal effect on the BS1 having high values in ash (18.1%) and the estimated metabolizable energy (2479.1 Kilo J/g) than KS1 variety. Crude fibre was significantly higher in KS1. There was no significant varietal differences on the % dry matter, ether extract, crude protein and the nitrogen free extract. There was significant difference in the acid detergent fiber and acid detergent lignin in the two varieties. The BS1 variety had significantly higher digestibility (*invitro* dry matter digestibility, *invitro* organic matter digestibility and dry organic matter digestibility. KS1 and BS1 varieties are therefore recommended as suitable varieties for Bomet County climatic conditions due to its high performance in yield, digestibility and nutritional values. Further studies to consider the adaptability of the two varieties in other Counties.

Keywords: *Brachiaria, adaptability, nutrition, digestibility, dry matter*

Introduction

Feed is a major component of livestock production systems in Kenya accounting for 60- 80% of the total production cost in the intensive systems. Feed for livestock in semi-arid areas of Kenya is based on natural pasture, which is low in quantity and quality leading to low livestock productivity (Njarui *et al.,* 2016). Feed scarcity is a major constraint to livestock production during the dry seasons (Njarui *et al.,* 2011). The rising interest in livestock by rising demands of livestock products, has led to research in drought tolerant and quality forages for increased livestock productivity. Brachiaria is one of the important tropical forage of African origin. It has high biomass production potential and produces nutritious herbage thus increase livestock productivity (Holmann *et al.,* 2004). The grass has revolutionized the livestock industry as the most adaptable and high yielding grass in South and Central America (Miles *et al.,* 2004), however it's potential in the native land Africa remains largely unexploited. Therefore, there was need to develop improved Brachiaria varieties that can adapt to the Kenyan conditions. Kenya Agricultural and Livestock Research Organization (KALRO) has developed mutant Brachiaria varieties (KS1 and BS1) from the local Brachiaria ecotypes. The varieties have shown good agronomic and nutritional qualities (Ondabu *et al*., 2017; Hoka *et al.,* 2019). However, there is limited information about the adaptability of these varieties in different agro-ecological zones of Bomet County. Knowledge of their adaptability would be ideal in scaling-up technology adoption through extension dissemination systems.

Materials and methods

Study site

The study was conducted in Bomet County that is located in the semi-humid agro ecological zone of Kenya and with the mean annual maximum temperature of 28°C (Bryan *et al.,* 2013). Average rainfall ranges from 500 to 2000 mm annually. The general altitude varies between 1800m ASL in the south and 3000m ASL in the north. The study was conducted in two wards (Kipreres and Longisa) in Bomet County.

Soil sampling

Soil samples were collected prior to commencement of the trials from a depth of 0-15cm thoroughly mixed to make a composite and a sub-sample analyzed using the methods described by Okalebo *et al.,* (2002).

Field Experimental design

This study used two Brachiaria *brizantha* varieties: KS1 and BS1. Rhodes grass was used as control. The experiment was laid out as a randomized complete block design (RCBD) with three replications for each variety. Plot sizes were 3m x 4m with 1 m between the replicates and blocks. Di-ammonium Phosphate (DAP) was used at a rate of 250kg/ha. The seeds were planted at a depth of 3cm with a

spacing of 60cm by 30cm. Weeding was done manually and plots were top dressed using Calcium Ammonium Nitrate (CAN) fertilizer at 250kg/ha when the crop was at 60 cm high.

Data collection and nutritional analysis

Agronomic performance was recorded at booting stage as recommended by Kumar (2014). One-meter square quadrant was thrown on each plot and grass within the quadrant cut at 2 cm above ground to determine leaf to stem ratio, herbage yield (t/ha) and nutrient analysis (Hoka *et al.*, 2019). The nutritional composition analysis, dry matter yield, amount of ash and organic matter were determined following the procedures outlined by AOAC (1990; 2006a). Crude protein content (g/kg DM) was calculated using 6.25 x N (Kjeldahl nitrogen) as outlined by AOAC (2006b). Tilly and Terry technique was used to calculate *in vitro* dry matter digestibility, while van Soest *et al.*, (1991; 1994) method was used to determine neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL).

Data analysis

Statistics analysis software (SAS) Version 9.3 was used for the data analysis (SAS Institute, 2010). Analysis of variance was carried out using the PROC GLM procedure for the data collected. Means separation was done using Fisher's Least significant difference (LSD). Pearson's correlation analysis was done to determine the association between the nutrient composition and digestibility of the Brachiaria grass.

Results

Agronomic performance

There were significant differences ($p<0.05$) between the varieties on the stem length, internode length and biomass yield whereas there were no significant differences ($P>0.05$) on leaf length, leaf width, number of tillers and the leaf:shoot ratio (Table 1). The location had no effect on the growth parameters of the varieties (Table 1). The KS1 variety had significantly longer stem length (96.3cm) and internode length (6.8cm) compared to the BS1 variety (Table 3). The KS1 variety had significantly higher (11.2 t/ha) biomass than the BS1 variety (Figure 1).

Table 1: Means for KS1,BS1 and Rhodes varieties on the growth parameters

Variety	Stem length	Leaf length	Leaf width	Internode length	Tillers	Leaf: ratio	Shoot
KS1	96.3b	19.5a	1.43a	6.8b	35.2a	0.51a	
BS1	74.2c	18.4a	1.35a	5.9c	42.8a	0.51a	
Rhodes	113.9a	21.2a	0.52b	24.3a	8.5b	0.19b	
LSD (≤0.05)	15.6	2.9	0.29	0.7	8.5	0.04	

Means followed by the same letter in each column are not significantly different at $\alpha \leq 0.05$

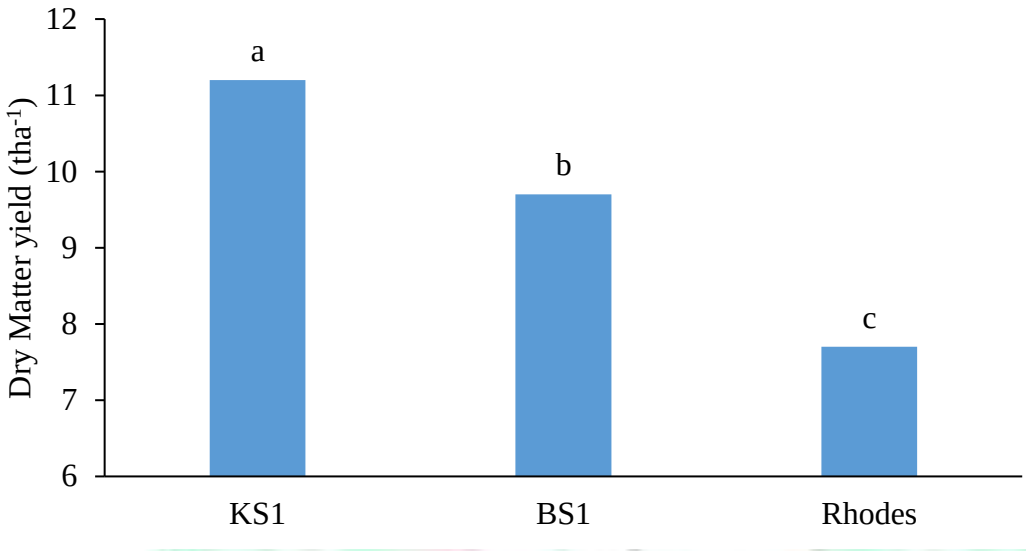

Figure 1: Dry matter (biomass) yield of the *Brachiaria* and *Rhodes* varieties. Means followed by the same letter for each germination are not significantly different at α≤0.05

Effect of varieties on proximate analysis

There was significant varietal effect on the ash, crude fibre and the Estimated metabolizable energy (EST: ME) with BS1 having the highest values (18.1% and 2479.1 respectively). Crude fibre (CF) was significantly higher in KS1 variety. There were no significant varietal differences on the %Dry matter (DM), Ether Extract (EE), Crude Protein (CP) and the Non fibre ethe r(NFE) (Table 2).

Table 2: Effect of variety on the proximate analysis

Variety	%Dry Matter	Ash	Ether extract	Crude protein	Crude fibre	Nitrogen free extract	Estimated metabolized energy
KS1	96.5a	16.8b	3.0b	15.5a	29.8b	34.8b	2422.0b
BS1	96.6a	18.1a	3.2b	17.6a	28.0c	33.0b	2479.1a
Rhodes	96.7a	13.5c	5.2a	8.9b	32.2a	38.7a	2480.6a
LSD (α≤0.05)	0.3	0.2	0.4	2.6	0.3	2.1	29.7

Means followed by different letters for each column are significantly different from each other (α≤0.05).

Effect of varieties on the van Soest Fibre and *in vitro* digestibility

The analysis of variance results showed that there was significant variety effect on the ADF, ADL, Ash, *in vitro* DMD, FOM, IOM and DOMD. However, there was no significant variety effect on the NDF and *in vitro* OMD. The ADF, ADL and ash content were significantly higher in the KS1 (Figure 2). The *in vitro* DMD was significantly higher in the BS1 variety. The IOM was significantly higher on the KS1. The IVOMD and DOMD were significantly higher on the BS1 (Figure 3).

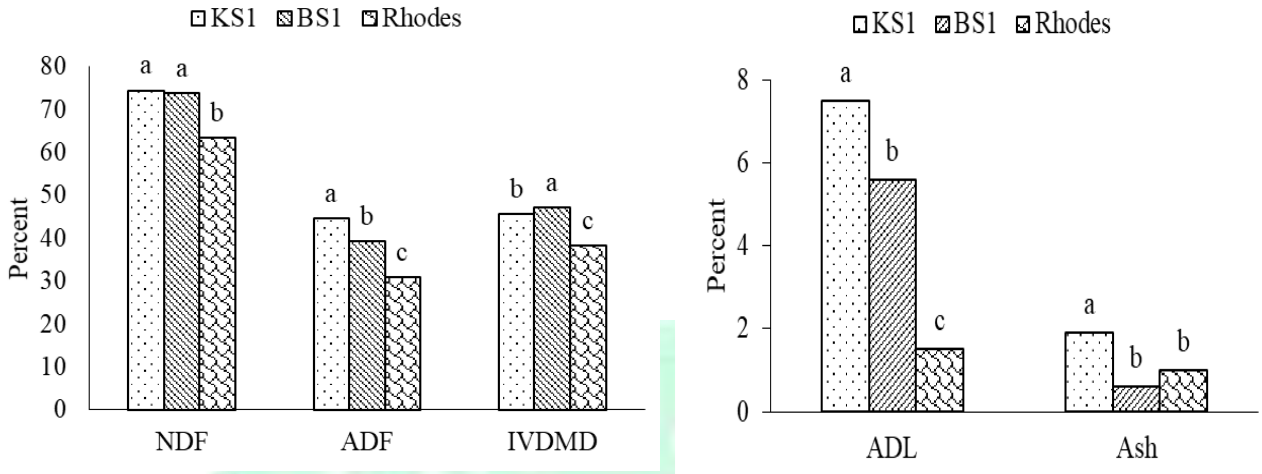

Figure 2: Effect of variety on the Vansoest and in vitro digestibility. Means followed by different letters for each parameter are significantly different from each other (α≤0.05).

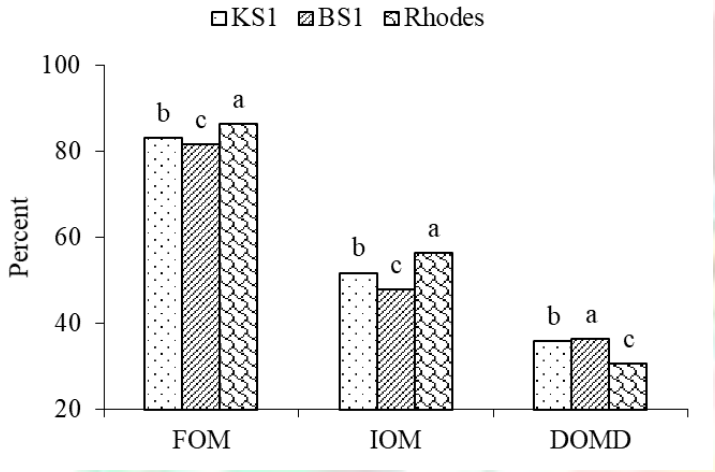

Figure 3: Effect of varieties on the organic matter parameters. Means followed by different letters for each parameter are significantly different from each other (α≤0.05).

Discussion

The longest plant height was recorded in KS1 (96.3cm) as compared to BS1 (74.2cm). The differing among the varieties with the same management system could be due to the variety potential of the species. The two *Brachiaria* varieties recorded higher plant heights than other *Brachiaria* grass cultivars in Kenyan dry lands as reported by Nguku *et al.,* (2015). Tillering was high in both varieties in the two sites, this could be due to growth potential of the varieties. The high tillering indicated good adaptability to the soils. This concurs with Mganga, (2009), who reported that tillering ability complements yield. The KS1 variety had significantly higher dry matter than BS1 with (11.2t/ha and 9.69t/ha) respectively. However, the BS1 variety yield was still higher than other Brachiaria varieties.

The CP contents was high in both *Brachiaria* varieties (KS1-15.5%) and (BS1-17.2%). This CP values were significantly higher than those of *Rhodes* grass (8.9%). This could be attributed to massive root system of *Brachiaria* varieties which enhanced nutrient uptake that contributed to the high CP formation. These values were higher than those of 7-10% reported by Nguku *et al.,* (2015). These values could provide double the required CP by the critical levels required for the satisfactory development of ruminal cellulolytic bacteria (Van Soest, 1994). The digestibility of a feed determines

the availability of nutrients for growth and reproduction as reported by Awoke, (2019). The results showed a negative correlation between the fibre content and digestibility; this could be due to indigestibility of fibres. This agreed with the studies of Kebede, (2016) who reported that the higher the ADF the lower the feed digestibility.

Conclusions and recommendations

The study showed high CP which ranged from 15.5 to 17.6 % in KS1 and BS1 respectively. The Brachiaria varieties outperformed Rhodes in proximate and digestibility results. The varieties had high tillering capability in both sites which contributed to high yields. Based on these parameters (CP and tillering), the two varieties were well adapted in the two sites. These varieties could be recommended for cultivation and production in Bomet County and similar agro-ecological zones.

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Determining Ethyl Methane Sulfonate-Mediated (EMS) Mutagenesis Protocol for Inducing High Biomass Yield in Fodder Barley (Hordeum vulgare L.)

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Abstract

Barley (*Hordeum vulgare L.*) has narrow genetic base for selection of promising ideotypes for the following traits: high biomass yield for livestock feed, enhanced agronomic and nutritional traits, and resistance to biotic and abiotic stresses. Ethyl methane sulfonate (EMS) mutagenesis offers opportunities for inducing genetic variation for key traits for development of feed barley ideotypes. The objective of this study was to determine optimal EMS dosage and exposure time to induce genetic variation for selection of high biomass yield six-row feed barley mutants. Five EMS dosages (i.e. 0.1%, 0.3%, 0.5%, 0.7% and 0.9% v/v) and five exposure times (i.e. 0.5 hr, 1 hr, 1.5 hr, 2 hrs and 2.5 hrs) were used on a six-row fodder barley using a 5 x 5 factorial treatment structure in a complete randomized design with three replications. Non-treated seed were used as a comparative control. Data was recorded for percent germination, seedling survival, shoot height, root height, shoot and root biomass. Significant ($p < 0.05$) EMS dosage x exposure time was observed for assessed traits indicating their influence on phenotypic variation in feed barley. Overall, a declining trend was observed for assessed traits with increased EMS dosage and exposure time. The LD50 value of 0.64% (v/v) EMS dosage was identified as an optimal dose for large-scale mutagenesis protocol to select fodder barley mutants with high biomass yield.

Keywords: *Chemical mutagenesis, EMS, feed barley, lethal dose, optimal dose*

Introduction

Barley (*Hordeum vulgare* L.) is an important crop serving as human food and livestock feed (Giraldo *et al.,* 2019). Barley grain provides essential vitamins, minerals, antioxidants and phytochemicals that provide excellent nutrition and health benefits (Sullivan *et al.,* 2013). Six-rowed barley has a narrow genetic base due to its inherent self-pollinating nature (Matus and Hayes, 2002). This has resulted in limited genetic variation for selection of promising ideotypes for high biomass yield for livestock feed, enhanced agronomic and nutritional traits, and resistance to biotic and abiotic stresses (Gao *et al.,* 2018). Therefore, there is need to widen the genetic base of barley to improve key agronomic traits including biomass and grain yield.

Mutation breeding using chemical mutagenesis is a widely used procedure in improvement programs to create genetic variation and select "new" mutants possessing suitable agronomic, food and feed related nutritional traits (Krishna *et al.,* 2016; Monica and Seetharaman, 2016). Ethyl methanesulfonate (EMS) is the most effective chemical mutagen commonly used for inducing genetic variation for quantitative and qualitative traits in crop plants (Ke *et al.,* 2019). The ease of application to seeds and its detoxification through hydrolysis for disposal makes EMS a recommendable mutagen for improving genetic diversity in crops (Pathirana, 2011; Serrat *et al.,* 2014). The most important step for inducing mutations is selection of an appropriate dosage of the mutagen; defined as the concentration of mutagen together with duration of treatment at a specific temperature. Determining the 50% lethal dosage (LD_{50}) is an important step for initiating EMS mutagenesis (Jain, 2010). LD_{50} refers to the mutation dose that result in 50% reduction in seed germination percentage after seed exposure for a prescribed time period under specific conditions (Mba *et al.,* 2010). The use of EMS to develop barely mutants with increased biomass yield in six-row fodder barley has not been reported in SSA. Therefore, it is important to induce mutation in fodder barley and select mutants with increased biomass yield for use in livestock production systems to improve livestock productivity. Therefore, the objective of this study was to determine optimal EMS dosage and exposure time to induce genetic variation in six-row fodder barley to select novel mutants.

Materials and Methods

Experimental site and plant materials

The study was conducted under glasshouse conditions at the Controlled Environmental Facility (CEF) of the University of KwaZulu-Natal, Pietermaritzburg, South Africa. A commonly used six-row feed barley landrace variety that is early maturing but less biomass was obtained from Kenya Agricultural and Livestock Research Organization (KALRO) Lanet and used for the study.

Experimental design and treatments

The experiment was conducted as a factorial (5 x 5) treatment structure involving five EMS dosages (i.e., 0.1%, 0.3%, 0.5%, 0.7% and 0.9%) and five levels of exposure periods (i.e. 0.5 hr , 1 hr, 1.5 hr, 2 hrs and 2.5 hrs) using a factorial treatment structure in a completely randomized design (CRD) with three replications. EMS treated seeds were established in seedling trays under a constant temperature of 24°C. Untreated seed were used as a comparative control. Seed sterilization, pre-soaking, EMS preparation and mutagenesis process was done as described by Mba *et al.,* (2010).

Trial establishment

EMS-treated and untreated seeds (comparative control) were planted at 1 cm depth in seedling trays under glasshouse condition using pine bark growth medium and one seed was planted per hole. The seedlings were watered four times daily using a mist irrigation system. The relative humidity in the glasshouse was set at ~63% and controlled using a fogger system.

Data collection and analyses

Data on percent germination (%G), seedling survival (%SS) were taken. Destructive sampling was done 21 days after planting and data on shoot height, root height, shoot biomass and root biomass was collected. Seedling vigour index (SVI) was estimated using a formula described by Abdul-Baki and Anderson (1973) as follows:

$$\text{SVI} = \text{Germination}(\%) \times \text{Total seedling length (cm)}$$

Data collected was subjected to analysis of variance (ANOVA) using PROC GLM procedure of the SAS package version 9.3. Treatment means were separated using Tukey's test procedure at 5% level of significance. The lethal dose (LD_{50}) was estimated using a linear regression model as follows: $y = a + bx$ where *y* is the dependent variable (i.e., germination percentage), *x* is the independent variable (EMS dosage), and *a* and *b* are the constant and slope, respectively.

Results

Effect of EMS dosage, exposure time and their interaction effects on assessed traits

Analysis of variance showed that the EMS dosage x exposure time interaction effect was highly significant ($p < 0.001$) for all recorded traits. EMS dosage showed significant ($p \leq 0.01$) effect on all assessed traits. The duration of exposure time to EMS showed significant ($p \leq 0.01$) effect on SL, RL, SB and RB (Table 1).

Table 1: Analysis of variance showing mean squares and significance tests for EMS dosage, exposure time and their interaction effects for assessed traits in six-row fodder barley.

Source of variation	df	SL	RL	SB	RB	%G	%SS	SVI
Replicates	2	5.27	13.04	0.04	0.05	15.10	143.94	44162.69
Dosage (D)	4	277.01**	132.80**	0.82**	0.09**	2006.53**	1161.79**	9800264.92**
Exposure time (ET)	4	88.94**	6.99*	0.22**	0.08**	46.48^{ns}	76.98^{ns}	350591.43^{ns}
D x ET	16	33.60**	15.68**	0.07**	0.03*	168.15*	430.51*	572030.85**
Error	48	1.43	1.66	0.02	0.01	53.37	167.58	517688.65

df = degrees of freedom, SL = Shoot length, RL = Root length, SB = Shoot biomass, RB = Root biomass, %G = Germination percent, %SS = Seedling survival percent, SVI = Seedling vigor index , * = significant at 5% level of significance, ** = significant at 1% level of significance, ns = non-significance.

Interactive effect of EMS dose and exposure time on assessed traits

The %G decreased with increased EMS dosage and exposure time. EMS dosage of 0.9% v/v for 2.5hrs recorded significantly low %G of 23.4% whereas 0.1% v/v EMS for 1hr improved %G by 71.3%. Untreated seeds (control) recorded the highest %G of 88.6%. The %SS also decreased with increased EMS concentration and exposure times. EMS dosage of 0.1% v/v for 2 hrs recorded the highest %SS of 76.2%, whereas EMS dosage of 0.9%v/v for 2.5hrs resulted in the lowest %SS of 14.3%. The control treatment recorded %SS of 90.5%. Seedling vigor index (SVI) also decreased with increased EMS concentration and exposure times. Seed exposure for 1 hr at EMS dosage of 0.1% v/v led to significantly higher SVI of 3814.4, whereas significantly lower SVI (906.5) was recorded for seeds exposed for 2 hrs at 0.9%v/v EMS dosage (Table 2).

The EMS concentration of 0.1% v/v for exposure time of 1.5hrs resulted in SL of 42.8cm, whereas the lowest SL of 25cm was recorded at 0.9 % v/v at exposure time of 1hr. RL decreased as the concentration of EMS and exposure times increased. The highest RL of 22.5 cm was recorded at the lowest EMS dosage of 0.1% v/v for an exposure time of 2 hrs. Contrastingly, the lowest RL of 10 cm was recorded at the highest EMS dosage of 0.9% v/v and longest exposure time of 2.5hrs. Shoot and root biomass decreased as the concentration of EMS and exposure times increased. The highest SB

of 1.27 g was recorded for EMS dosage of 0.3% v/v for exposure time of 1 hr, whereas EMS dosage of 0.9% v/v for the longest exposure time of 2.5 hrs led to the lowest SB of 0.36 g. Exposing the seeds for the shortest time of 0.5 hrs at the lowest EMS dosage of 0.1% v/v led to seedlings with the highest RB (0.68 g). The lowest RB (0.17 g) was recorded for seeds treated with 0.9% v/v EMS dosage for a period of 2hrs (Table 3).

Table 2: Mean for percentage germination (%G), percent survival (%SS) and seedling vigour index (SVI) of fodder barley assessed under variable EMS dosage and exposure time.

EMS dosage (%)	Exposure time (hr)	%G	%SS	SVI
0.1	0.5	53.4bcdefg	66.4b	2751.9bcdefg
	1	71.3b	67.9b	3814.4b
	1.5	67.8bc	71.4 b	3667.7bc
	2	61.9bcd	76.2b	3468.5bcd
	2.5	48.2bcdefg	57.1b	2903.8bcdef
0.3	0.5	52.4bcdefg	54.0bc	3134.5bcde
	1	48.2bcdefg	52.4bc	2451.3cdefgh
	1.5	62.4bcd	52.4bc	3094.8bcde
	2	52.4bcdefg	59.5b	2869.2bcdef
	2.5	56.6bcdef	74.8b	3078.4bcde
0.5	0.5	42.9defgh	67.3b	2420.6defgh
	1	56.0bcdef	55.7bc	3176.8bcde
	1.5	46.1cdefgh	47.1bc	2753.bdcefg
	2	40.8defgh	51.9bc	1802.9fghij
	2.5	55.0bcdefg	51.9bc	3008.3bcdef
0.7	0.5	57.6bcde	51.9bc	3301.6bcde
	1	46.6cdefgh	59.5b	2585.8cdefgh
	1.5	51.3bcdefg	59.5b	2500.6cdefgh
	2	55.0bcdef	57.1b	2278.2defghi
	2.5	42.8defgh	49.1bc	2203.0efghi
0.9	0.5	36.4efgh	57.1b	1578.8ghij
	1	33.4fgh	56.7b	1078.1ij
	1.5	31.3gh	52.4bc	925.4j
	2	23.8h	37.7bc	906.5j
	2.5	23.4h	14.3c	1418.7hij
Control		88.6a	90.5a	4284.7a

Means followed by the same letters in a column for each EMS dosage and exposure times are not significantly different

Table 3: Mean ± standard error for shoot and root traits of fodder barley assessed under various EMS dosage and exposure time.

EMS dosage (%)	Exposure time (hr)	SL (cm)	RL (cm)	SB (g)	RB (g)
0.1	0.5	34.7ef	16.9defg	1.13abcd	0.68a
	1	35.1ef	18.6bcde	1.11abcd	0.46abc
	1.5	33.4fg	20.83abc	0.93abcde	0.39abc
	2	33.5fg	22.5a	0.74defghi	0.25bc
	2.5	38.1cde	22.4a	0.76cdefghi	0.33abc
0.3	0.5	38.0cde	21.7ab	0.93abcde	0.44abc
	1	33.0fgh	17.7cdef	1.27a	0.59ab
	1.5	35.4def	14.1fgh	1.18abc	0.46abc
	2	37.3cde	17.5cdef	0.90abcdef	0.28bc
	2.5	39.6abc	14.8fgh	0.83bcdefgh	0.25bc
0.5	0.5	42.7ab	13.8ghi	1.22ab	0.30bc
	1	40.9abc	15.8efgh	1.03abcd	0.32bc
	1.5	42.8a	17.7cdef	0.68efghi	0.36abc
	2	30.1ghi	14.3fgh	0.88abcdefg	0.30bc
	2.5	37.8cde	16.8defg	1.21ab	0.27bc
0.7	0.5	42.7ab	14.7fgh	1.00abcd	0.25bc
	1	39.0bcd	16.4efg	0.96abcde	0.38bc
	1.5	34.9ef	13.7ghi	0.74defghi	0.33abc
	2	27.6ijk	13.8ghi	0.46ghi	0.27bc
	2.5	34.6ef	16.9defg	0.90abcdef	0.22c
0.9	0.5	29.8hij	14.5fgh	0.57fghi	0.21c
	1	25.0k	10.0j	0.50fghi	0.32bc
	1.5	28.4ijk	10.50ij	0.46ghi	0.28bc
	2	26.1jk	12.3hij	0.44hi	0.17c
	2.5	28.8ij	14.1fgh	0.36i	0.27bc
Control		40.3abc	20.8abc	1.10abcd	0.42bc

SL = Shoot length, RL = Root length, SB = Shoot biomass, RB = Root biomass. Means followed by the same letters in a column for each EMS dosage and exposure times are not significantly different

Determination of LD_{50}

A fitted model for %G and EMS dosage was used to calculate LD_{50} using the linear regression equation of y= -56.02x +85.81 (Figure 1). Generally, increased EMS dosage resulted in reduced %G. According to the fitted model, LD_{50} value of 0.64% (v/v) EMS dosage was the ideal for inducing mutation in fodder barley.

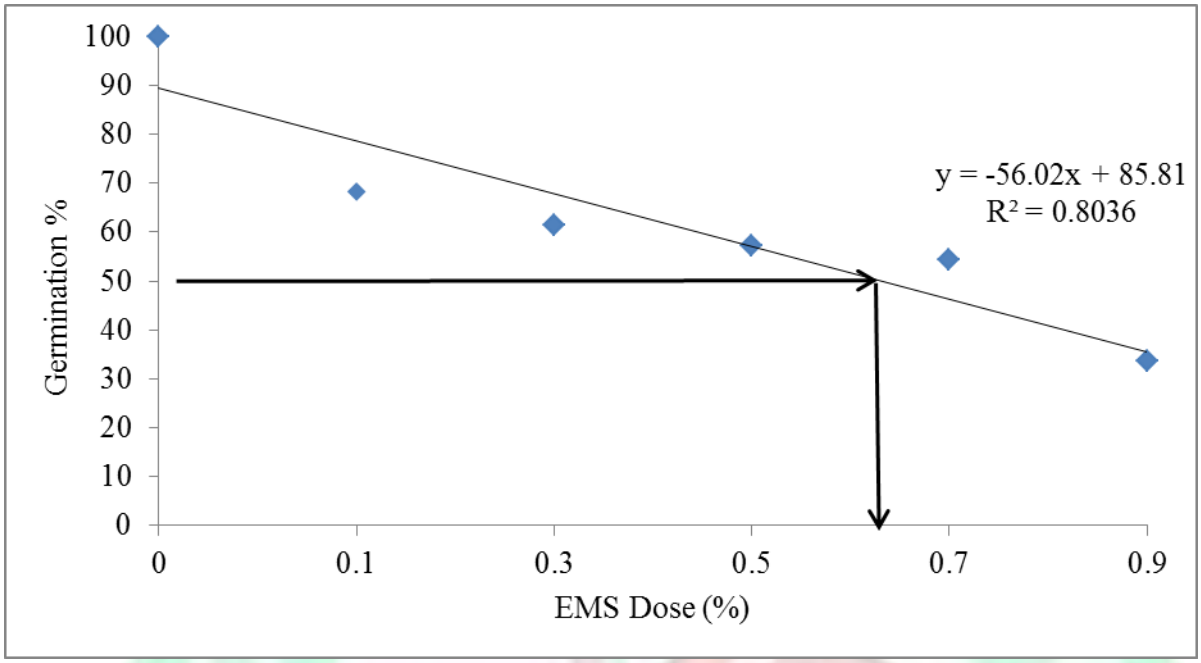

Figure 1: Germination percentage plotted against EMS dosage and used to calculate the lethal dose (LD_{50}) for inducing random mutations in a six-row fodder barley.

Discussion

The present study determined an effective EMS protocol for inducing genetic variation for high biomass yield of six-row fodder barley. The study revealed that increased EMS dosage resulted in decreased germination percentage, seedling survival, seedling height, root and shoot biomass (Table 2). A reduced germination percentage could be attributed to disturbances of seed meristematic tissue at cellular level resulting in chromosome damage, disrupting growth promoters due to increased accumulation of growth inhibitors (Jayakumar and Selvaraj, 2003). Hadebe *et al.,* (2017) reported that the highest reduction in germination (10%) was observed in vernonia seeds treated at high EMS dose of 1.1% and long exposure duration of 2hr, which is in agreement with the present study. Generally, EMS dosage of 0.9% v/v and exposure time of 2.5hrs appears effective for inducing genetic variation of the resultant mutant plants. This value is lower than the value reported in the previous studies and could be due to differences in crop species. The highest dose obtained in the present study could be the best dose to induce high mutation frequency in feed barley.

The present study showed that increased exposure duration and EMS dose led to a decline in seedling survival (Table 2). For example, 0.1% v/v EMS dosage for 2hrs gave the highest survival rate of 76.2%; whereas 0.9%v/v EMS dosage at 2.5hrs resulted in the lowest survival rate of 14.3%. This could be because seeds exposed to shorter periods absorb lower quantities of the mutagen, leading to lesser detrimental effect as compared to those exposed for longer durations (Kulkarni, 2011). For example, a study by Shirani *et al.,* (2016) showed that at high concentrations of EMS (3%v/v) and longer exposure duration of 3 hrs resulted in no survival of banana shoot tips. A significant reduction in survival percentage (42.84%) was observed at the highest EMS doses of 0.5% and exposure duration of 5 hrs in *Coriandrum sativum* (Kumar and Pandey, 2019). Decrease in survival rate may be due to physiological disturbances, cytogenetic and chromosomal damage which lead to mitotic arrest and reduced cell division (Khursheed *et al.,* 2008; Girija *et al.,* 2013). This indicates optimum EMS dosage and exposure time determine survival rate of barely seedlings.

In the present study, increased EMS dosage and exposure time caused a decline in shoot length, root length, shoot and root biomass (Table 3). This might be attributed to inactivation of auxin levels,

which are plant-growth promoters (Ashok Kumar *et al.*, 2009). Ali *et al.*, (2019) reported a significant decrease in the root length of upland rice using EMS concentration of 2% v/v, much higher than tested concentrations in the present study. Muñoz-Miranda *et al.*, (2019) reported that moderate concentrations of EMS (0.5% v/v) and longer exposure duration of 3hrs resulted in reduced plant growth. This implies that higher EMS dose and longer exposure duration to EMS caused decreased levels in the assessed growth parameters of barley.

The LD_{50} of the mutagen is useful for determining an optimal dose for mutation induction. From this study, EMS dosage of 0.64% v/v was recommended as the most effective and efficient for inducing genetic variability and selection of promising six-row barley mutants. The LD_{50} in the present study is much lower than a value of 1.2% reported in banana (Shirani *et al.*, 2016). Olaolorun *et al.*, (2019) reported lethal doses of 1.07% and 1.81% v/v EMS for wheat genotypes LM29 and LM75, respectively. These values are much higher than reported in the present study attributed to differences in crop species, genotypes used and ambient conditions during mutagenesis (Liamngee *et al.*, 2017). The mutagenesis protocol will be useful to develop recessive and point mutations to aid selection of best individuals involving the M2-M5 mutant families with high fodder biomass yield.

Conclusions and recommendations

The treatment combinations that yielded optimum treatment conditions in this study will be utilized to induce large-scale mutation in barley to select novel mutant varieties. The present study determined the optimum treatment condition for inducing genetic variation in feed barley. Results revealed that EMS dosage of 0.64%v/v of EMS can be used to increase genetic variability for key traits in barley.

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Forage Yields and Quality of Buffel Grass and Guinea Grass Ecotypes Under Varied Harvest Intervals in a Semi-arid Environment

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Abstract

Grasses form the main basal diet for livestock in dryland ecosystems worldwide and are currently being cultivated for feed in semi-arid Kenya. Management of these grasses is necessary for improved productivity. The objective of this work was to evaluate the forage yields, crude protein and digestibility of 4 selected grass ecotypes of two range grasses (*Cenchrus ciliaris* and *Panicum maximum*) commonly used in fodder production in semi-arid Kenya. Four grass ecotypes were planted in a randomized complete block design in a split-plot arrangement. Through a grazing simulation and utilization experiment, they were clipped at 3 harvest intervals (14, 28 and 84 days), simulating different utilization strategies employed in semi-arid Kenya. Forage yields, crude protein and *in vitro* dry matter digestibility were evaluated over two growing seasons and data collected was subjected to analysis of variance (ANOVA). The highest yields were obtained at 28-day harvest intervals and were 70% higher than the 14-day interval, though similar to the 84-day interval harvests. Cumulative yields were higher in the first season and declined by 30% in the second season with precipitation a key driver. With the advancement in age, forage quality declined where crude protein (CP) considerably reduced from a mean of 12% for the 14-day harvesting interval to 5% and at the end of the season, *P. maximum* ISY ecotype having the highest CP at the 14-day harvesting interval. Lower *in vitro* dry matter digestibility (IVDMD) was also noted at this stage. Harvesting the grasses at 28-day intervals offered a compromise between biomass yields and quality. It is however recommended not to cut the grasses as frequently as 14-day intervals as this will result in reduced yields as intensification of livestock production takes place.

Introduction

Rangeland grasses constitute the most important feed sources for livestock across the globe (Michalk *et al*, 2018) and comprise 48% of the total biomass used by livestock (Herrero *et al*, 2013). Lack of sufficient feeds of good quality has been a major drawback in dryland production systems resulting in reduced livestock productivity (Koech 2014; Mganga *et al.*, 2019; Balehegn *et al.*, 2022). Some of the important grasses include *Cenchrus ciliaris* and *Panicum maximum*, Masaai love grass (*Eragrostis superba*), Bush rye (*Enteropogon macrostachyus*), Horsetail grass (*Chloris roxburghiana)* among others (Koech, 2014; Mganga *et al*, 2021) which are of prime importance in rangeland production systems, not only in Kenya but also other parts of the world. They are drought-tolerant species with high biomass production and can thrive in varied environments. With changing land use patterns, overgrazing, and climate change, most of these grasses are on the decline (Boone *et al.*, 2018; Greiner *et al.*, 2021), compromising the sustainability of livestock production in semi-arid environments.

In semi-arid Kenya, in addition to natural pastures, there is unexploited potential for forage cultivation using indigenous grasses to sustain livestock production. The recent past has seen many farmers and other entities venture into fodder production in semi-arid Kenya for feed provision with the additional co-benefits of grass seed production (Omollo, 2017).

The determination of yields and nutritive attributes feeds is critical for growth, well-being and productivity of livestock. Some of the key factors affecting the productivity and nutritional profiles

of grasses include: - the choice of species and stage of utilization (defoliation interval and intensity). Research shows that as the harvesting interval increases, the feed quality declines (Gilo *et al.*, 2022). Utilizing forages at the correct growth stage and interval ensures that one obtains adequate feed with the required nutrition for livestock. For successful fodder production, management interventions adopted must aim at optimizing production. Knowledge of the responses of grasses to defoliation and harvesting management is necessary to design appropriate feeding strategies.

In rangeland grasses, few studies in Kenya have considered within species variability while investigating yield and nutritive attributes. Kirwa (2019) investigated the performance of grass ecotypes for potential reseeding in Kenya and found a wide variability and diversity among them. This wide morphological and genetic diversity is yet to be fully exploited. We conducted a study to determine forage yields and nutritive attributes of 4 selected grass ecotypes of two range grasses (*C. ciliaris* and *P. maximum*) commonly used for fodder in a semi in semi-arid Kenya under varied harvest intervals.

Materials and Methods

Description of the study site

The study was carried out from October 2019 to September 2020 at the Kenya Agricultural and Livestock Research Organization (KALRO) - Kiboko Research Station in South-East Kenya (02° 151 S, longitude 37° 43 E). The average annual rainfall of the area is 534.3 ± 66.2 mm and is distributed in a bimodal pattern with the long rains received between March and May and the more reliable short rains received between October and December. Temperatures range between 22° C and 32° C with a mean of 27.8° C (Ndathi, 2012). The vegetation at the station is mainly bushed grassland with various native tree and shrub species growing naturally. The soils in the experimental areas are classified as Acri-rhodic ferralsols (WRB, 2014).

Experimental design, planting and cultural management of grasses

The experimental design was a split-plot experimental design, in randomized blocks with three replicates. The 4 grass ecotypes (*Cenchrus ciliaris* KLF, *Cenchrus ciliaris* MGD, *Panicum maximum* ISY and *Panicum maximum* TVT) were the main plots with the harvesting frequencies (14, 28 and 84 days) were the sub-plots. The size of the plots was 10.5 m^2, with a 1-metre alley separating the plots and a 2-metre space between the blocks. The grass ecotypes used in the study were obtained from the KALRO Kiboko farm which serves as a field genebank for some grass accessions previously collected from different parts of semi-arid Kenya. The selection of the four ecotypes was based on previous work by Kirwa (2019) and the authors. Vegetative root splits with 3-5 daughter tillers were uprooted and transplanted to a well-prepared land and grown in small shallow holes in rows spaced 50 cm apart with a plant to plant distance of 50 cm. A standardization cut was done after 30 days where the grasses were all clipped at 10 cm height and then top-dressed with Calcium Ammonium Nitrate (CAN) fertilizer at the rate of 50 Kg N ha^{-1}. This was done as per recommendations by (Boonman, 1993) for cultivated grasses. Plants were maintained under rain-fed conditions over the experimental period.

Harvesting treatments and data collection

The grass ecotypes were subjected to three harvesting intervals i.e. once every 14 days; once every 28 days and one-off harvesting at 84 days. These intervals simulated a high, moderate, and low-frequency utilization/grazing respectively. These utilization intensities are currently practised in semi-arid Kenya, with the latter mainly adopted for hay production (Omollo, 2017).

Over two regrowth cycles, biomass production was determined for each treatment by harvesting all material within a 1 m^2 quadrat at the centre of the plot, at a stubble height of 10 cm from ground level. This was weighed in the field for each treatment and a subsample taken, weighed and taken to the

laboratory for oven drying at 65 °C for 48 hrs. The final subsample weight was used to compute dry matter yields per hectare. Cumulative yields per treatment were calculated by adding up individual yields at each harvest. The oven-dried samples were ground in an electric mill and analysed for crude protein (CP) and *in vitro* dry matter digestibility (IVDMD) following the procedures of AOAC, (2010). Three samples were used for each analysis. This was done at the Animal Nutrition Laboratory at the University of Nairobi, Kenya.

Statistical analysis

Analysis of variance was carried out using the general linear model (GLM) to determine the effects of harvesting intervals on cumulative herbage yield, crude protein and digestibility of the grass ecotypes. Means were compared using Tukey tests whenever significance was detected and differences were considered statistically significant at $p < 0.05$.

Results

Forage production

Harvesting interval had significant effects on cumulative herbage biomass yields as outlined in Table 1. Each ecotype responded differently to clipping with higher yields obtained as the harvest interval increased especially in the wet season. However, during the dry season, yields were only higher during the 28-day clipping interval and reduced at the 84-day harvest interval. Harvesting the grasses at 14-day intervals produced the lowest cumulative yields during this period. Overall, C. *ciliaris MGD* harvested at 28-day intervals produced the highest cumulative biomass (7,1863.08 Kg DM ha^{-1}) while the lowest was recorded in *C. ciliaris* KLF (5,726.64 Kg DM ha^{-1}). Mean yields for *P. maximum* ISY and *P. maximum* TVT were 6,017.28 and 6,843.84 Kg DM ha^{-1} respectively. Mean yields produced under 28-day intervals were significantly higher at 7805.49 Kg DM ha^{-1} than the 14-day (4,571.39) and 84-day (7,372.25) Kg DM ha^{-1} harvest intervals. A 30 % yield decline was also reported during the dry season.

Forage quality

The dry matter, crude protein and digestibility varied significantly ($p < 0.05$) among the grass ecotypes and harvesting frequencies as shown in Table 2. The harvesting interval had a highly significant ($p < 0.01$) effect on CP. Ecotypes harvested at 14-day intervals had the highest CP with a mean of 11.69 % followed by the 28-day interval at 8.89 % while the 84-day interval had the lowest mean value of 5.22 %. Finally, the IVDMD for the grass ecotypes ranged between 47 % - 68 % with the grasses harvested at 84-day intervals having significantly lower values compared to those harvested at shorter intervals.

Table 1: Effects harvesting interval on cumulative dry matter herbage yields in Kg DM ha^{-1} of 4 grass ecotypes in semi-arid Kenya over 2 growing seasons.

Harvest frequency	*C. ciliaris* MGD		*C. ciliaris* KLF		*P. maximum* TVT		*P. maximum* ISY	
	Wet Season	Dry season	Wet Season	Dry season	Wet Season	Dry season	Wet Season	Dry season
14 days	5,294.00 ^{cHIJ}	4,627.18 ^{cHIJ}	3,726.28 ^{cJ}	4,311.19 ^{cHIJ}	5,352.08 ^{deHIJ}	3,934.42 ^{eIJ}	5,676.39 ^{cGHI}	4,295.98 ^{cHIJ}
28 days	12,017.69 ^{aA}	8,271.43 ^{bCD}	7,729.81 ^{aDEF}	6,174.77 ^{bEFGH}	9,811.90 ^{bBC}	7,776.62 ^{cDE}	7,282.06 ^{bDEFG}	5,427.54 ^{cGHIJ}
84 days	10,624.17 ^{aAB}	5,575.77 ^{cGHIJ}	8,544.38 ^{aCD}	5,556.16 ^{bGHIJ}	11,419.05 ^{aAB}	5,817.66 ^{dFGHI}	10,651.17 ^{aAB}	4,900.59 ^{cHIJ}
p value	< 0.001		< 0.001		< 0.001		< 0.001	
LSD	658.4		652.8		970.8		1048.5	
CV (%)	18.1		11.4		13.9		17.3	

Different lower case letter after the number denotes significant difference at $p < 0.05$ between harvest intervals and season. Different upper case letter denotes significant differences between ecotypes at $p < 0.05$

Table 2: Effects of harvesting interval on crude protein and *In vitro* dry matter digestibility of 4 grass ecotypes in tropical semi-arid Kenya.

Harvest interval	***C. ciliaris* MGD**	***C. ciliaris* KLF**	***P. maximum* TVT**	***P. maximum* ISY**
Crude protein				
14 days	11.19 ^{aAB}	11.54 ^{aAB}	11.12 ^{aAB}	12.82 ^{aA}
28 days	10.13 ^{aABC}	8.08 ^{bCD}	7.25 ^{bCDE}	9.64 ^{bBC}
84 days	5.11 ^{bEF}	5.39 ^{cDEF}	5.90 ^{cDEF}	4.49 ^{cF}
p value	< 0.001	< 0.001	< 0.001	< 0.001
LSD	2.76	1.78	0.97	1.16
CV (%)	25.5	17.3	9.6	10.4
***In vitro* dry matter digestibility (%)**				
14 days	66.68 ^{aAB}	66.31 ^{aAB}	68.08 ^{aA}	67.42 ^{aAB}
28 days	63.16 ^{aABC}	60.93 ^{bBC}	63.10 ^{abcABC}	64.84 ^{abABC}
84 days	50.58 ^{bD}	47.23 ^{cD}	49.94 ^{dD}	58.08 ^{bC}
p value	< 0.001	< 0.001	< 0.001	0.024
LSD	4.53	1.73	3.31	6.43
CV (%)	6.1	2.4	4.5	8.2

Different lower letters after the number denote significant differences between harvest intervals at $p < 0.05$ while upper case letters denote differences between ecotypes at $p < 0.05$.

Discussion

Herbage production

Biomass yields are an important indicator of productivity of pasture indicating the amount of feed available. All the grasses used in this study were morphologically different and a distinction can be noted in the yields of the ecotypes subjected to different harvesting frequencies over the two seasons. For instance, *C. ciliaris* KLF is a short variety growing less than 30 cm in height, unlike *C. ciliaris* MGD which is taller. *C. ciliaris* MGD also has a higher tiller density compared to *C. ciliaris* KLF and this contributes to the difference in biomass yields (Kirwa, 2019). *P. maximum* TVT had thicker stems and larger leaves than *P. maximum* ISY. These structural attributes contribute to variation in growth and the eventual differences in biomass production.

Cumulatively higher yields were accrued at 28-day and 84-day harvesting intervals compared to the 14-day harvest interval attributable to the sufficient rest period before the subsequent harvest. From this study, the 28-day intervals can help enhance feed availability for livestock without compromising animal productivity in dryland environments. This outcome is consistent with investigations in an enclosure system in Ethiopia with similar harvest frequencies to this study, where Gilo *et al*. (2022), reported low yields at higher frequencies of harvest. The overall mean of 6,444.86 Kg DM ha^{-1} obtained for *C. ciliaris* ecotypes in this study is higher but comparable to the mean value (5,358 Kg DM ha^{-1}) obtained by Kirwa, (2019), in semi-arid Kenya for several ecotypes inclusive of the two. Overall, the mean values obtained for the two *P. maximum* ecotypes are however almost 50 % higher than those reported by (Njarui *et al*, 2015) in the study region for local *Panicum maximum* ecotypes. The probable influence of seasonal rainfall, which was higher during the study period, site and management practices could explain the differences in results obtained.

Overall, biomass yields in the second season dropped by almost 32 %. The notable decline for individual ecotypes in biomass production in the second season was a result of drier conditions experienced from May through September 2020. Such responses are common for grass plants in semi-arid environments as reduced soil moisture and precipitation may not have been sufficient for plant growth and development. These findings are in agreement with those reported by Njarui *et al*. (2015) in a multi-location study in eastern Kenya among *P. maximum* grass ecotypes. Even though there was a decline in cumulative biomass in the dry season among the grass ecotypes, an exception was found in *C. ciliaris* KLF under frequent harvesting. This is probably due to the tolerance of the variety to grazing and dry conditions. It is a rhizomatous ecotype and most of the nodal tillers are found below the defoliation level adopted for this study, hence the frequent clipping yield effects on the ecotype were minimal (Hodgkinson *et al*, 1989).

Forage quality: Crude protein and in vitro digestibility

The data presented in this study on quality attributes are consistent with general observations by Kirwa (2019), Koech (2014) Mganga *et al*. (2021) and Njarui *et al*. (2015) for grass ecotypes and key African indigenous rangeland grasses in general found in Kenya. The results also fall within the range of values as reviewed by Lee (2018) for forages.

Crude protein (CP)

The values obtained for this study at the 28-day harvest stage for *C. ciliaris* ecotypes, though higher, closely related to those reported by Kirwa (2019) of 6.6 and 9.6 for *C. ciliaris* KLF and *C. ciliaris* MGD ecotypes respectively. It is anticipated that with increasing intervals, the CP of the grasses reduce, which is also confirmed in this study with plant materials harvested at 84-day intervals. Pasture quality deterioration had already begun at this stage. This has also been demonstrated in the study by Koech (2014) in semi-arid Kenya and Keba *et al*. (2013) in southern Ethiopia for common rangeland grasses.

As the harvest interval increases, the number and amount of senescent leaves increases. Typically, these are low in protein as nitrogen is remobilized to other parts of the plant (Yang and Udvardi, 2018). This contributed to lower CP in the grasses at 84-day cutting intervals. A higher proportion of young leaves and the decreased stem component within the 14-day harvest intervals contributed to higher CP values.

Crude protein is an essential nutrient for livestock and feeding animals on these grasses especially at maturity (> 8 weeks) may not meet the nutritional requirements of the target animals (Erickson and Kalscheur, 2020).

In vitro Dry Matter Digestibility (IVDMD)

The differences in IVDMD between the grass ecotypes were also apparent and showed a pronounced decrease with increasing harvest intervals. This is because as plants advance and mature, they require stronger support tissues. These experience stronger signals that produce lignification enzymes hence lignin accumulation and deposition in cell walls. This tends to make the grasses less digestible (Getachew *et al*, 2018). These results suggest that the hay produced in semi-arid areas is generally of poor quality and this has implications for animal productivity. In the recent past, the frequency of drought events has increased in ASALs.

Conclusions and recommendations

Harvesting the grasses at 28-day intervals offered a compromise between biomass yields and quality. It is however recommended not to cut the grasses as frequently as 14-day intervals as this will result in reduced yields as intensification of livestock production takes place

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LIVESTOCK BREEDING AND GENETIC RESOURCES FOR SUSTAINABLE FOOD SYSTEMS

Potential of Stem Cell Technologies for Sustainable Conservation and Large-Scale Dissemination of Indigenous Kenyan Chicken to Improve Livelihoods

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Abstract

Cryopreservation of animal germplasm enables sustainable and economical maintenance of genetic resources in the livestock industry. Indigenous poultry farming is widely practiced in rural households and play a significant role in their financial stability and livelihoods. The increased demand of their products could offer an opportunity for the expansion of indigenous chicken farming in Kenya. KALRO-Poultry in Naivasha has been conserving and improving the local chicken using the conventional breeding. Taking into consideration the challenges presented by that method, there was a need for cryopreservation. In collaboration with CTLGH, a biobanking protocol of the Kenyan chicken ecotypes have been successfully established and piloted at the international livestock research institute, using primordial germ cell. The application of the PGC technology has allowed production of chimeric chicken, which zootechnical performances are still under evaluation. This demonstrates the potential of using the PGC technology for conservation and revival of the Kenyan indigenous chicken.

Introduction

Livestock plays significant economic and socio-cultural significance in majority of Kenyan communities where it is used as wealth criteria, serves as living insurance in drought situation for agro-pastoral communities, and plays numerous socio-cultural roles. An estimated 75% of Kenyan rural families keep chicken. Kenya produces 71% of its eggs and meat from indigenous chickens, which has a substantial influence on rural trade, welfare, and food security for smallholder farmers (SDL, 2020b). A 31 million bird estimate for the number of poultry in Kenya, 75% (23.8 million) of them are chicken from the local area, 22% (6.9 million) are broilers and layers, and 1% are breeding stock (Onono *et al.*, 2017; zootecnicainternational, 2016). Chickens are a valuable resource for smallholder farmers who grow regionally adapted, genetically unique varieties of chickens for eggs and meat. The 2015 biodiversity status report by FAO revealed that over 3.5% of chicken breeds were extinct, 33% were at high risk, and about 67% were in the unknown status category (Scherf and Pilling 2015). The conservation of indigenous poultry diversity in Africa is essential to meet future needs and support the global poultry industry. Maintaining poultry diversity is also an insurance package against future adverse conditions in the context the global environmental changes. The creation of effective reproductive technologies to preserve and regenerate chicken breeds protects current biodiversity and secures poultry genetic resources for future food supply, climate resilience, and biosecurity. A low-tech, affordable method of conserving diversity is required because the majority of the breeds of chicken are raised in poor and lower to middle income nations in resource-constrained, small-scale production systems.

Preservation of genetic diversity of extant populations that can be reintroduced at later times to avoid population bottlenecks is central to controlled flock management. This is especially important for the biosecurity of poultry production systems, which are at risk of emerging disease pandemics such as avian influenza. There is also a recognized need to preserve and safeguard the genetic diversity of traditional breeds of chicken (Wilkinson *et al.*, 2012). Many

of these breeds are maintained in regionally restricted populations and are vulnerable to both disease outbreaks and losses in genetic diversity due to fluctuations in population sizes. Similarly, poultry genetic resources used in research are being lost, as experimental lines of chickens developed to investigate a multitude of traits are being eliminated by research and governmental institutes.

The use of early germ cell precursors, the Primordial Germ Cells (PGCs) in avian species offers an innovative platform to reconstitute chicken breeds from frozen materials. It has been demonstrated that these cells can be isolated from the early embryonic blood, blastoderm and gonads. The cells can later be reintroduced into the circulatory system of host embryos where they colonize the host gonad and produce viable gametes (Nakamura *et al.*, 2013). The development of *in vitro* culture conditions for expanding the population of PGCs before cryopreservation potentiates the ability to safely store cells and largely disseminate the elite and locally adapted breed preferred in all agro-ecological zones of Kenya. The process of cryoconservation of Kenyan local chicken ecotypes initiated by KALRO Naivasha in collaboration between CTLGH, TPGS, African Union – InterAfrican Bureau for Animal Resources (AU-IBAR) on few ecotypes is now at its extension phase, with the potential to give back to local communities the desired quantity of the same genetic material that they have been custodians for many generations. To create a pipeline for the cryobanking of chicken male and female genotypes, in this study we chose to culture PGCs from White Leghorn chicken line and indigenous chicken. Here we describe a workflow (Figure 1) to gain, cultivate, and cryopreserve PGCs.

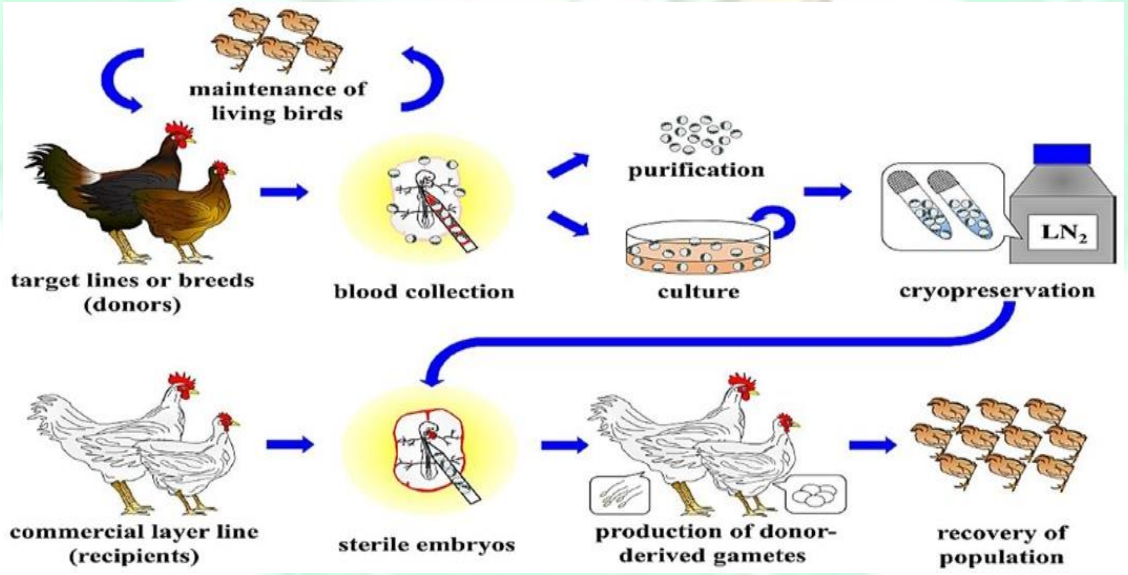

Figure 1: Schematic illustration of chicken PGC revival

Methodology

Collection of embryonic tissues containing PGCs from target lines or breeds

There are 3 methods for isolation of Primordial germ cells:

1. Germinal Crescent (Blastodisk/ Blastoderm) isolation
2. Embryonic Blood isolation
3. Embyonic Gonad isolation

All the three methods are described below.

Isolation of Primordial Germ Cells from chicken Blastoderm

The objective here is to remove the blastoderm from Day 1 embryos following 4–6 hours of incubation for derivation of PGC cultures with or without cryopreservation of tissue. The first part of the process consists of the removal of the blastoderm. Fertilized eggs are incubated from 4-6 hours at 38°C in an incubator with at least 60% humidity. The PGC will have accumulated at the embryonic disc. One egg was taken from the incubator, sprayed lightly with ethanol and a window was created. The blastoderm was visible on top of the yolk or alternatively break the shell can be broken into two halves, the egg was passed back and forth to break up the albumen. The albumen was dropped on a plastic weighing boat. Stroking was done on the surface of the yolk with a spoon or blunt forceps to bring the blastoderm to the top. Perimeter of the blastoderm was punctured with a sterile needle to make a circle. Drops of Phosphate-buffered saline (PBS) was added onto the surface to help isolate the blastoderm from the surrounding membranes. The blastoderm was carefully sucked into the tip of a 1 ml pipette. Blastoderm was washed briefly in PBS then transferred to 20 µl PBS in a sterile 1.5 ml centrifuge tube. The tissue was allowed to equilibrate then broken up in 300 µl FAOT (FGF2, Activin A, ovotransferrin) and culture was initiated in a 48-well plate. This was to expand primordial germ cell population. Alternatively, the blastoderm can be frozen directly in Stem cell banker at -80°C and then stored in liquid nitrogen (-196 °C).

Isolation of Primordial Germ Cells from Gonads

Gonads are well developed in the embryo from day 7-10 in this case gonads were isolated at day 9 (Figure 2) of incubation. At this stage the primordial germ cells are based in the gonads. Egg shell was opened at the blunt end using forceps and shell membrane broken (Figure 2A) until embryo body was visible. Figure 2B shows the position of the embryo in the egg. The embryo was picked out and put in a petri dish. The embryos are culled by disconnecting the neck using forceps or scissors. Under a light dissection microscope, the embryo body was positioned so that its stomach is facing upwards. The embryo was cut open using scissors to expose the internal organs. The organs were pushed towards cranial direction to expose the gonads and mesonephros (Figure 2C, Figure 3).

Both gonads and the mesonephros were gently dissected using 23 G (3.2 cm in length) hypodermal needle. The gonads were picked using a needle and transferred to DMEM medium which was pre-dropped at margin area on the same petri dish to wash off extra blood. The gonadal tissues were transferred into a 1.5 ml Eppendorf tube (screw top) containing 500 µl cold DMEM medium and kept on ice until all gonadal pairs were collected. Primordial Germ cell was isolated by digestion of the gonads with eventual culturing on to a 48 well culture plate. Alternatively, the gonads could be frozen by leaving gonadal tissue in stem cell banker at room temperature for 15 min to equilibrate. The tubes were placed into a Mr. Frosty™ freezing container pre-equilibrated at-20°C and placed in a -80°C freezer overnight. The following day, tubes are transferred into -196°C liquid nitrogen and the storage positions recorded. The PGC can later be isolated by culturing on recovery and thawing of the gonads.

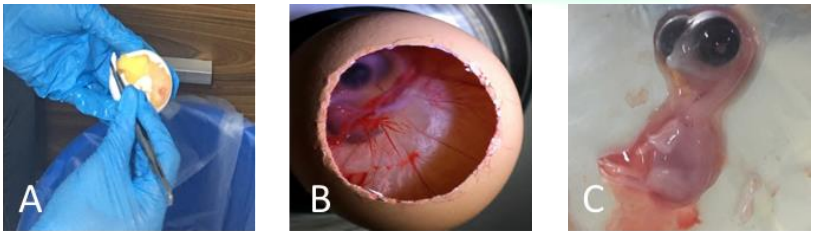

Figure 2: A Breaking the egg shell before dissection to obtain the PGCs. **B** position of the chick embryo at day 9 of incubation. **C** Chick- embryo at day 9 placed on a petri-dish ready for dissection to isolate the gonads.

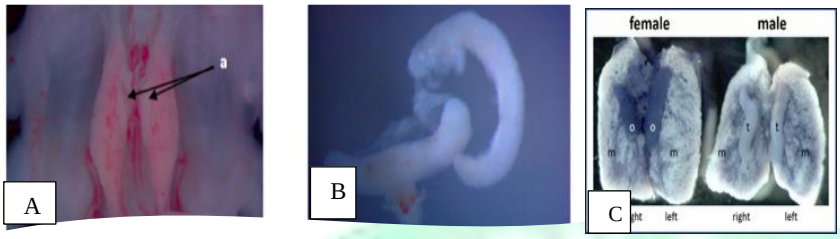

Figure 3: A: Arrows pointing the PGCs viewed under a light dissecting microscope next to the mesonephros. **B** Gonads that have been isolated as viewed under the light microscope. **C** *In-situ* hybridization showing female and male chick gonads after dissection. (t=testis; O=Ovary; m=mesonephros)

Isolation of the primordial germ cells from the blood

Primordial germ cells are isolated from the blood of indigenous chicken (dorsal aorta) as they transit to the gonadal ridge. Eggs were placed in the incubator early on Day 1 (e.g. Tuesday morning, 9am). They were removed and left at room temperature two days later (Thursday) at 5pm when they are 56 hours old. To prepare the needle, the end of a capillary is broken using ethanol sterilized forceps under a microscope then inserted at the large open end into an aspiration tube. aspirator apparatus is draped over the microscope making sure that both ends do not come into contact with laboratory surfaces. This position Is maintained throughout the procedure. This is done in a 2-3 day embryo. When it has reached a stage 16 of embryo development. About 1-2 microliters of blood are collected and cultured on serum free medium to isolate and propagate the PGC.

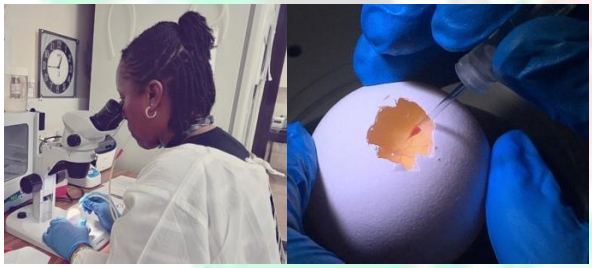

Figure 4: The procedure for blood collection at day 2.5 embryo at the dorsal Aorta (stage 14-15) by insertion of needle.

Injection of Primordial Germ Cells into host chicken embryos

Host eggs were set in a rocking incubator (60% humidity), for 2.5 days before injection to allow embryos to develop. On injection day, Fast green solution was added to an average of 500 primordial germ cells from indigenous chicken cell suspension using a ratio of 1 µl Fast green per 50 µl cell suspension. One micro litre of the cell suspension was aspirated using a mouth pipette and injected into the host through the central aorta. The window on the egg was shell using paper or silky tapes and the embryos returned into an incubator for further development.

Results

Our findings show that PGCs can be obtained from the embryonic blood, blastoderm and the gonads. By using PGC-mediated biobanking, the existing workflow can be simply adapted to protect other uncommon breeds and rare genes.

Derivation of cultured PGCs from different embryonic stages

Embryonated eggs were used to isolate PGCs during the migratory phase and shortly after colonization of the forming gonads to compare the different cell line establishment of the different embryonic origins. In the first days of the culture the derived samples were dominated by haemopietic progenitor cells, hence no PGCs were seen during the first few days while the gonads and the blastoderm took around 2 and 1.5 weeks respectively. For the cells obtained from embryonic blood the PGCs started to ploriferate at day 7 while the haemopietic progenitor cells started to disappear due to inappropriate culture conditions. For PGC ploriferation the appearance of round cells was detected in the culture medium (Figure 5B). Interestingly, among the gonadal PGCs the female ones tended to form cell clusters (Figure 5C). These aggregated appeared throughout the cell culture process and remained after successful establishment.

Figure 5: A PGCs derived from the blastoderm and. **B** PGCs derived from the blood established in culture medium. **C** PGCs derived from the gonadal stage established in culture.

Injection of cells into host embryos: Production of germline chimeras through PGC transplantation

Germline chimeric chickens were produced by transfer of primordial germ cells from indigenous chicken to White Leghorn. The chimeric-derived offspring were identified based on their feather color (Figure 6B).

Figure 6: **A** pure white-leghorn chicken. **B** Chimera (coloured feathers) derived offspring injected with PGCs from the donor (indigenous chicken).

Discussion

Our findings show that PGCs can be derived from the embryonic blood, blastoderm and the gonads of chickens from target lines or breeds and conserved *ex-situ*. Promordial germ cell mediated biobanking is an expansion to the sperm preservation (Atgilbres *et al.*, 2021). By using PGC-mediated biobanking, the existing method can be easily implemented to preserve additional rare breeds. This study also shows how chicken PGCs can be cultured, cryopreserved, re – transferred.

The project comes at a time when pastoralists in in Kenya are struggling to adapt to rising temperatures, erratic rainfall patterns and other effects of global climate change. For two thirds of people in Kenya, who rely on the food they grow and animals they keep, ongoing droughts have left many struggling to produce enough to feed their families (Poultry world). The major advantage of the PGCs from various chicken breeds with emphasis on indigenous chicken is that the cells obtained from a single donor embryo can be amplified significantly in vitro and transplanted into sterile recipients of a commercial layer line and this would lead to recovery of a population size from a small flock of the recipients. The most important aspect of this cryoconservation is collection of the germplasm and ensure recovery of a population while maintaining the sustainable genetic diversity. Collection of PGCs from the gonads has the advantage of recovering a large number of PGCs and ensuring prolonged period of collection (Nakamura 2016). Cryopreservation of PGCs together with frozen stocks of semen will ensure preservation of chicken genetic resources economically and semi-permanently.

Conclusion

The KALRO indigenous chicken breed from Naivasha has become very popular among farmers, the supply of day-old chicks has been on high demand forcing farmers to wait for a long time for day old chicks. Therefore, Primordial germ cell (PGC) biobanking technique have great promise to aid endangered animal species and native habitat preservation. These techniques offer the benefits of being able to store a lot of diversity in a small area, by keeping the genetics in an environment free of pathogens and safeguarded from dangers, and be able to revive a lot of chicken preferred breed lines when needed to meet the demands of the farmer. This new innovation of PGC preservation, in conjunction with sterile surrogate use, will revolutionize the preservation and future use of diverse poultry genetics. It will also enable ongoing efforts to conserve chicken genetic diversity for both commercial and smallholder farmers, and to preserve existing genetic resources at poultry research facilities.

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Assessment of the Factors Affecting Beef Cow Fertility Using Calving Interval as Measure in Beef Research Centre – Lanet

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Abstract

This study aimed to evaluate levels of beef cow fertility using calving interval (CI; measured in days) as a measure, and investigate the effects of breed, parity, and sex of the progeny on calving interval. The data collected between Jan 2022 to Dec 2022 which contained improved Boran breed, sahiwal crosses, red poll crosses and dairy crosses The mean calving intervals for the dams that calved female calves were; Boran breed 612.75, Dairy breed 775.7, Red poll crosses 619.2 and sahiwal crosses 563.68. Also the mean calving interval for the dam that calved male calves were as follows; Boran 559.5, Dairy 622.5, Red poll crosses 600 and Sahiwal crosses 533.08. The dairy breed had the longest calving interval, followed by Boran breed while the sahiwal crosses had the shortest irrespective of the sex of the calf. The objective of this study was to establish the level of beef cow fertility using CI as a measure in KALRO Lanet and provide opportunities for improvement. The effect of these factors had no significance in calving interval. The study was to provide knowledge to be used in direct breeding programs and inform knowledge transfer protocol to improve sustainability of beef production.

Keywords: *Beef cow, fertility, reproduction, calving interval*

Introduction

High rates of reproduction in a beef herd result to the profitability of beef production. The number of calves produced per cow per year has a major influence on the economics of beef production, with a high calf crop percentage being essential for profitability (Burris *et al.*, 1998). A suitable measure of reproductive performance is essential before reproductive performance can be improved (Mac Gregor *et al.*, 1999). Calving interval is one of the measures which can be defined as the number of days that elapse between two sequential parturitions from the same dam (Brown *et al.*, 1958). Calving interval for beef cattle vary, with mean values of 370 days (Morris *et al.*, 2016) and a herd average of 376 days as shown by Tapaloaga *et al.*, (2016). Some studies have identified calving interval beyond 399 days (Gutierrez *et al.*, 2002). Variation in calving interval can be as a result of low heritability (Brzáková *et al.*, 2016) and also environmental factors such as climate (Gwazdauskas, 1985) and nutrition (Maas, 1987). Evaluation and reducing calving interval and optimizing beef cow fertility is a key objective in modern beef production. The information obtained from this study will be used to improve breeding programs and encourage better management practices to improve reproduction efficiency and in turn, profitability.

Material and methods

Study area and animals

This study was conducted at the Kenya Agricultural and Livestock Research Organization at the Beef Research Centre located in Lanet, Nakuru, Kenya which is in Agro-Ecological zone 3 and 4 with bimodal rainfall pattern with an annual mean of 800mm and a relative humidity of 83% (Gitagia *et al.*, 2019). The mean minimum and maximum temperatures are 10°C and 26°C respectively. The animals considered in this study consisted of improved Boran, crossbreds between Sahiwal, Redpoll and improved Boran and Dairy breeds (Ayrshire and Friesians). The cattle are maintained on extensive grazing system on natural forages with mineral salt supplementation. Calves are weaned after they attain the age of 7 months after which they are branded. Selection is also done where the male ones not intended for breeding purposes are castrated.

Data source and analysis

Data were extracted from the Beef Research Institute routine livestock data records where dams that calved from January 2020 to December 2022 were considered. Information on breed, sex of the calf and parity of the dam was obtained from livestock records. Data was compiled in MS-Excel and analyzed using linear model in R software. Association of breed, sex and season of birth factors on calving interval and hence fertility was tested at $P<0.05$. All the dams that calved within the study period were recorded and considered for individual analysis. To calculate calving interval, the dates of two consecutive births (parturition 1 and parturition 2) were considered.

Results

The mean calving intervals for Boran, dairy crosses, Redpoll crosses and Sahiwal crosses are presented in Table 1. The mean calving intervals for the dams that calved female calves were; Boran breed 612.8, dairy crosses breed dams 775.7, Redpoll crosses 619.2 and Sahiwal crosses 563.68 days, respectively. The mean calving interval for the dam that calved male calves were; Boran 559.5, dairy crosses 622.5, Redpoll crosses 600 and Sahiwal crosses 533.08 days, respectively. The dairy crosses had the longest calving interval, followed by Boran breed while the Sahiwal crosses had the shortest irrespective of the sex of the calf. However, the dam that calved female calves across the breeds had a longer calving interval compared to the dam that calved male calves.

Table 1. Mean calving interval for different breeds and sex (M- Males, F-Females), N- Number of animals, S.D – Standard deviation

Sex	Dam breed	Calving interval	Standard deviation	N
F	Boran	612.75	190.93	40
F	Dairy	775.71	473.21	7
F	Redpoll cross	619.29	122.06	14
F	Sahiwal cross	563.68	110.72	19
M	Boran	559.53	236.30	43
M	Dairy	622.50	107.82	4
M	Redpoll cross	600.00	213.19	17
M	Sahiwal cross	533.08	232.12	26

The calving intervals for dams in different parities are shown in Table 2. The 4th parity dairy breeds had the longest calving interval of 1260, followed by 1st parity Boran while the 3rd parity dairy had the lowest calving intervals.

Table 2. Mean calving interval for different breeds and sex (M- Males, F-Females), N- Number of animals, S.D – Standard deviation

Sex	Dam breed	Parity	Calving interval	S.D	N
F	Boran	1	780.00	-	1
F	Boran	2	578.57	147.01	21
F	Boran	3	606.67	178.61	9
F	Boran	4	698.57	323.90	7
F	Boran	5	600.00	-	1
F	Boran	7	630.00	-	1
F	Dairy	2	930.00	-	1
F	Dairy	3	495.00	157.80	4
F	Dairy	4	1260.00	678.82	2
F	Redpoll cross	2	720.00	134.16	5
F	Redpoll cross	3	546.00	57.71	5
F	Redpoll cross	4	560.00	96.44	3
F	Redpoll cross	5	660.00	-	1
F	Sahiwal cross	2	562.50	137.20	4
F	Sahiwal cross	3	566.25	117.22	8
F	Sahiwal cross	4	561.43	106.37	7
M	Boran	1	390.00	-	1
M	Boran	2	552.63	219.84	19
M	Boran	3	646.00	288.61	15
M	Boran	4	435.00	78.56	8
M	Dairy	2	780.00	-	1
M	Dairy	3	570.00	30.00	3
M	Redpoll cross	2	576.00	57.71	5
M	Redpoll cross	3	696.00	373.14	5
M	Redpoll cross	4	548.57	122.12	7
M	Sahiwal cross	1	525.00	121.24	4
M	Sahiwal cross	2	596.25	372.10	8
M	Sahiwal cross	3	575.00	169.09	6
M	Sahiwal cross	4	442.50	108.46	8

The effect of breed of the dam, sex of the calf and parity of the dam parameters on calving interval is shown in Table 3. Breed of dam, sex of the calf and parity of the dam did not significant effect the calving interval of the dam at $P<0.05$.

Table 3. Factors associated with calving intervals (P<0.05)

Parameter	Calving interval	P value
Sex		0.1091
Male	578.78	
Female	642.86	
Dam breed		0.1554
Boran	586.14	
Dairy	699.10	
Sahiwal cross	548.38	
Redpoll cross	609.65	
Parity		0.9983
1	565.00	
2	661.99	
3	587.62	
4	563.26	
5	630.00	
7	630.00	

Discussion

The dairy breed had the longest calving interval followed by Boran breed while the sahiwal crosses had the shortest irrespective of the sex of the calf. This agrees with a previous study by Trial *et al.,* (1981) who stated that the Sahiwal cows had a shorter calving interval than the Boran cows. The dams at the Beef Research Centre usually run with the bulls throughout the year, while artificial insemination is normally used for the dairy dams. The running of the improved Boran bulls with the females throughout the year for natural mating can be given as the reason why the dairy breeds have a longer calving interval as compared to improved Boran breed due to reliance on heat detection before insemination for the dairy dams. For high reproductive performance, dairy cattle need adequately feeding prior to and after calving so that they are in good condition to conceive in a short period of time post calving (Muhuyi, 1997).

The dams that calved female calves across all the breed had a longer calving interval compared to the dam that calved male calves. Dairy female calves had the longest while the sahiwal male crosses had the shortest. In the current study, the effect of sex of calf on subsequent calving interval were non-significant. This agrees with Stone, R. M. (1968) who reported that sex of calf did not appear to influence the post-partum estrual interval.

The 4th parity Dairy breeds had the longest calving interval of 1260 days, followed by 1st parity Boran while the 3rd parity dairy had the lowest. This disagree with the previous study by Stone, R. M. (1968) and Eum *et al.,* (2016) who stated that calving interval tended to be short with an increase in parity. Primiparous take more time to replenish their body fat during lactation period compared to multiparous and hence primiparous have longer calving interval compared to multiparous (Kim *et al.,* 2009). According to Gwazdauskas *et al., (*1981), an advanced age has the tendency to increase interval of calving to conception resulting in long calving intervals. The non-significance of the parity of the dam on calving interval in the current study is attributed to the smaller sample size for dams in first parity as compared to the other parities.

Conclusion

This study has illustrated that the calving interval is long compared to normal calving which can result to one calf per year. There are management variables within the farmers' control (such as the choice of dam and sire breeds, and the length of the breeding period) which affect

calving interval. This information can be used to facilitate future management decisions to increase beef cow fertility within the farm and other beef farms.

Recommendations

There is a need for exploration of more factors which could have influenced the observed long calving intervals.

Acknowledgments

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Characteristics of Indigenous Chicken Incubation Traits Under Intensive System in Kenya

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Abstract

Fertility, embryo mortalities and hatchability are traits that influence reproductive performance and profitability in chicken enterprises. These traits have not been comprehensively described for indigenous chicken (IC) in Kenya. The objective of this study was to determine performance of these traits and explore some non-genetic factors with significant influences. A total of 2,534 eggs laid by chickens sourced from western, arid and semi-arid lands and coast regions were collected daily, labelled and stored for at most 19 days before incubation in nine hatch groups. Candling was done on day 7 and 18, and chicks harvested on day 22. Fertility, embryo mortalities (early, mid and late) and hatchability were calculated and data subjected to ANOVA. Mean fertility, early embryo mortality, mid embryo mortality, late embryo mortality and hatchability were 81.9%, 9.4%, 5.9%, 29.2% and 58.2%, respectively. All traits exhibited wide ranges. Hatch group had an influence on fertility and mid embryo mortality, ecotype affected fertility while egg size and storage period impacted on fertility, late embryo mortality and hatchability. It was concluded that there is potential for improvement of incubation traits through genetic or non-genetic interventions. Eggs heavier than 59g and pre-oviposition storage for more than 7 days should be avoided during incubation.

Keywords: *egg size, embryo mortalities, fertility, hatchability, ecotype, storage period*

Introduction

Apart from contributing to rural livelihoods, indigenous chickens (IC) play major roles in provision of food and nutrition, economic growth and empowerment, socio-cultural services and pest control, among others (Wong *et al.*, 2017). The IC are highly adapted to their

environments thus allowing a majority of households to engage in subsistence production mainly under free-range systems. Due to their importance, unexploited potential and the need to maintain biodiversity while feeding the ever-increasing population, the current IC productivity should be enhanced considerably. Within breed selection is an option that has not been widely utilized, despite its potential to permanently and cumulatively increase productivity without adversely affecting genetic diversity. To implement effective selection programmes, potential populations, their production, reproduction and functional characteristics have to be described (FAO, 2015).

Fertility, embryo mortalities and hatchability are incubation traits that not only influences reproduction efficiency but also profitability in hatchery enterprises. Both genetic and non-genetic factors influencing fertility and embryo mortality, either singly or in combination, have an impact on hatchability (Grochowska *et al.*, 2019). Non-genetic factors that could influence incubation traits of IC in Kenya have not been comprehensively documented. This study aimed to describe fertility, embryo mortalities and hatchability characteristics of IC population reared intensively and explore the effects of hatch, ecotype, egg size and storage period on performance.

Materials and methods

Study site, chicken source and management

The study was carried out at the poultry research unit (PRU) of the Kenya Agricultural and Livestock Research Organization (KALRO) in Naivasha. Mature free-range chickens of both sexes were sourced from 16 counties grouped into western, arid and semi-arid lands (ASAL) and coast regions. The chickens were wing-tagged and quarantined for 60 days, after which each cock allocated between 5 and 7 unrelated hens from the same county and placed randomly in deep litter mating pens. Each pen was labelled with the cock number and county of origin and the chickens provided with about 130g per day of commercial layers' marsh and clean drinking water *ad libitum*.

Egg collection and incubation

Eggs were collected daily, labelled and stored at room temperature for at most 19 days before incubation in 9 hatch groups. Each egg in a hatch was weighed to the nearest 0.1g and fumigated before setting at 37.6^{o}C and 55% humidity. Each hatch was 1st and 2nd candled on day 7 and 18, respectively. Infertile and dead-embryo eggs recorded, and live-embryo eggs re-set. At 2nd candling, each live-embryo egg was placed in an individual compartment and transferred into a hatcher at 37.0^{o}C and 60% humidity. On day 22, hatched chicks and their egg-shell labels, and pipped and dead-in-shell eggs were recorded.

Statistical analysis

Adopting the South African egg grading standards (RoSA, 2020), incubated eggs were graded as small (33.1-43.0g), medium (43.1-51.0g), large (51.1-59.0g) and extra-large (>51.1g). Fertility was computed as (fertile eggs/eggs set)×100, early embryo mortality as (dead embryos at first candling/fertile eggs)×100, mid embryo mortality as (dead embryos at 2nd candling/eggs re-set on day 7)×100, late embryo mortality as (dead-in-shell/eggs re-set on day 18)×100 and hatchability as (hatched eggs/fertile eggs)×100. Data were subjected to ANOVA using the GLM procedures of SAS. The model was: -

$$y_{ijklm} = \mu + h_i + r_j + g_k + s_l + \varepsilon_{ijklm}$$

where y_{ijklm} is the dependent variable, μ is the overall mean, h_i is the i^{th} hatch group, r_j is the j^{th} ecotype, g_k is the k^{th} egg grade, s_l is the l^{th} storage period and ε_{ijklm} is the residual $(0, \sigma^2)$.

Significant means (P<0.05) were separated using Turkey-Kramer and data presented as lsm± se.

Results

The least squares means are presented in Table 1. Overall mean fertility was 81.9±0.02% with a range of between 73.9 and 91.8%. Early, mid and late embryo mortalities had means of 9.4±1.28, 5.9±0.87 and 29.2±1.92%, and ranges of 4.2 to 16.0%, mid from 0.4 to 12.1% and late from 19.3 to 38.9%, respectively. Mean hatchability was 58.2±2.02% and ranged from 46.4 to 71.5%. There were significant differences in fertility within hatch group, ecotype, egg grade and storage period but none on early embryo mortality. Mid mortality was affected by hatch group only while late mortality was influenced by egg grade and storage period. Whereas there were no significant variations within hatch group and ecotype, hatchability was affected by egg grade and storage period.

Discussion

The mean fertility was within the range (81.1 to 92.4%) earlier reported for IC in Kenya (Ndegwa *et al.*, 2002). Varying fertility rates ranging from 67.2 to 98.9% have been documented in the tropics (Rajkumar *et al.*, 2017; Zeleke *et al.*, 2020). The mean early embryo mortality (EEM) was comparable to 8.92% reported by Peñuela & Hernandez (2018), lower than 20.34% observed by Khan *et al.*, (2013), and higher than 4.5 to 4.7% reported by Zeleke *et al.*, (2020). The mean mid embryo mortality (MEM) was higher than 4.5 to 4.7% reported by Zeleke *et al.*, (2020) and lower than 9.04% reported by Khan *et al.*, (2013). The mean late embryo mortality (LEM) was comparable to 28.66% reported by Kumar *et al.*, (2013) and higher than 9.23% observed by Khan *et al.*, (2013). The mean hatchability was lower than the range of 62 to 76% reported for IC in Kenya (King`ori, 2011) and comparable to 54.76% reported by Khan *et al.*, (2013). Fertility, embryo mortalities and hatchability are influenced by breed, strain, ecotypes, and genotypes, stage of embryo development at oviposition, egg storage period and condition, flock age, egg size, nutrition, husbandry system and rearing technology, mating system, incubation temperature and humidity, and turning frequency and angle (King`ori, 2011). These factors could explain the variations with studies elsewhere. The wide range fertility, embryo mortalities and hatchability observed indicate potential for improvement through genetic or non-genetic interventions.

Significant differences in fertility between hatch group 1 and 7 on the one hand, and hatch group 5 on the other, may be attributed to possible feed quality fluctuations that either reduced fertilization or increased very early embryo mortality (VEEM) in hatch group 5 eggs. The low fertility of coast eggs as opposed to their western and ASAL counterparts could be due to genetic differences that probably affects physiological processes leading to either more fertilization failure or higher VEEM. Small eggs had the lowest fertility compared to medium and extra-large eggs. Low fertility in small sized eggs may be attributed to lack of sufficient nutrients and pores leading to VEEM that is mistaken for infertility. This was in agreement with Patra *et al.*, (2016) who reported low fertility for small sized eggs as opposed to medium and large eggs. Eggs stored for up to 7 days had better fertility than those stored for more than 14 days. Abioja *et al.*, (2021) observed a decrease in fertility with egg storage period. Egg storage for more than 7 days increases VEEM due to factors such as storage temperature and humidity, change in egg quality during storage, embryonic viability and embryonic metabolism (Grochowska *et al.*, 2019).

Table 1. Least squares means (±se) of indigenous chicken fertility, embryo mortalities and hatchability

Fixed effect	n	Fertility (%)	Early embryo mortality (%)	Mid embryo mortality (%)	Late embryo mortality (%)	Hatchability (%)
Hatch						
1	417	91.5±3.92^{a}	8.5±3.30^{ns}	6.3±2.16^{ab}	33.8±4.23^{ns}	54.9±4.68^{ns}
2	380	88.1±4.23^{ab}	10.2±3.57^{ns}	9.4±2.34^{ab}	36.6±4.58^{ns}	47.4±5.06^{ns}
3	161	72.7±5.29^{ab}	11.9±4.59^{ns}	11.0±3.01^{ab}	33.0±5.90^{ns}	51.6±6.50^{ns}
4	259	76.9±4.93^{ab}	17.0±4.26^{ns}	2.5±2.86^{ab}	32.2±5.60^{ns}	52.7±6.03^{ns}
5	280	70.4±4.13^{b}	16.4±3.72^{ns}	5.2±2.56^{ab}	28.8±5.01^{ns}	55.4±5.27^{ns}
6	245	84.8±5.34^{ab}	11.2±4.64^{ns}	0.4±3.13^{b}	25.6±6.14^{ns}	64.9±6.57^{ns}
7	259	90.0±4.15^{a}	5.7±3.58^{ns}	0.7±2.35^{b}	24.5±4.59^{ns}	64.0±5.07^{ns}
8	295	79.5±4.42^{ab}	8.2±3.81^{ns}	11.9±2.57^{a}	19.0±5.15^{ns}	62.4±5.40^{ns}
9	238	72.1±5.05^{ab}	8.8±4.50^{ns}	3.2±2.95^{ab}	33.8±5.77^{ns}	57.5±6.37^{ns}
Ecotype						
Western	541	84.7±2.92^{a}	11.8±2.51^{ns}	4.2±1.70^{ns}	27.8±3.32^{ns}	58.2±3.56^{ns}
ASAL	603	85.6±2.95^{a}	10.5±2.55^{ns}	5.7±1.70^{ns}	27.0±3.38^{ns}	59.5±3.61^{ns}
Coast	1,390	71.7±2.40^{b}	10.3±2.13^{ns}	7.0±1.40^{ns}	34.3±2.73^{ns}	52.6±3.02^{ns}
Egg size						
Small (33.1-43.0 g)	1,16	69.1±3.71^{c}	17.5±3.55^{ns}	4.3±2.41^{ns}	13.1±4.72^{c}	66.6±5.04^{a}
Medium (43.1-51.0 g)	1,049	83.6±2.73^{ab}	8.2±2.30^{ns}	5.3±1.51^{ns}	30.4±2.95^{b}	59.6±3.26^{a}
Large (51.1-59.0 g)	1,139	79.1±2.71^{bc}	9.6±2.31^{ns}	6.7±1.54^{ns}	30.4±3.02^{b}	57.0±3.27^{ab}
Extra-large (59.1-72.0 g)	230	91.0±3.50^{a}	8.3±2.96^{ns}	6.2±1.97^{ns}	44.9±3.92^{a}	43.8±4.20^{b}
Storage period (days)						
1 to 7	1,192	86.8±2.35^{a}	08.6±2.04^{ns}	4.3±1.34^{ns}	17.2±2.62^{b}	70.6±2.89^{a}
8 to 14	1,051	79.5±2.46^{ab}	12.0±2.16^{ns}	6.1±1.47^{ns}	30.5±2.91^{a}	54.1±3.07^{b}
15 to 19	2,91	75.7±3.54^{b}	12.1±3.07^{ns}	6.4±2.04^{ns}	41.4±3.99^{a}	45.5±4.35^{b}
Overall means						
Mean		81.9±0.02	9.4±1.28	5.9±0.87	29.2±1.92	58.2±2.02
(Range)		(73.9-91.8)	(4.2-16.0)	(0.4-12.1)	(19.3-38.9)	(46.4-71.5)

^{abc}within a fixed effect, least squares means in a column followed by different superscripts were significantly (P<0.05) different

^{ns}within a fixed effect, least squares means were not significantly (P≥0.05) different

Whereas EEM is mainly associated with failure of the embryo to resume development after post oviposition storage, MEM is usually linked to nutritional deficiencies or embryonic abnormalities (Abudabos *et al.*, 2017). The hatch differences in MEM observed in the current study could probably be due to fluctuating feed quality or incubation temperature and humidity across hatches. Lack of within ecotype significant differences in embryo mortalities at all stages agrees with Zeleke *et al.*, (2020) who observed no embryo mortality differences between eggs originating from Horro and Tilili regions of Ethiopia. Embryo mortality differences between breed, strain and genotype have been reported and attributed to stage of embryo development at oviposition and egg shell quality (Fathi *et al.*, 2022). Since any fluctuations in feed quality affected all birds equally, it may be speculated that chicken from the three ecotypes either lay eggs of comparable shell quality or at similar embryonic development stage. The influence of egg grade and storage period on LEM agrees with various studies. Molapo & Motselisi (2020) observed significantly higher LEM in large than in medium and small sized Koekoek eggs. Pokhrel *et al.*, (2018) reported influence of storage time on LEM with eggs stored for more than 7 days having the highest mortality. The high LEM in extra-large as opposed to small and medium/large eggs in the current study may be attributed to increased egg conductance due to increased porosity and pore sizes that resulted in excessive water loss during incubation (Onagbesan *et al.*, 2007). As mentioned above, the high LEM of eggs stored for more than 7 days may be ascribed to either a delay in the initiation of or slow rate of embryonic development post incubation.

Lack of significant differences in hatchability between hatch groups agrees with Abudabos *et al.*, (2017) who observed no differences in hatchability across hatches. Lack of significant differences within ecotypes was in agreement with Abdurehman & Urge (2016) who found no differences between highland, midland and lowland agro-ecologies in Ethiopia. The significant differences within egg grades was in agreement with Senbeta (2017) who observed differences in hatchability across egg sizes. In the current study, small and medium eggs had the highest hatchability and extra-large the lowest. This could be attributed to the low late embryonic mortality in small eggs as opposed to their extra-large counterparts. Eggs stored for up to 7 days had significantly higher hatchability than eggs stored for between 8 to 14, and 15 to 19 days. Molapo *et al.*, (2021) reported significant differences in Koekoek eggs stored for 3, 7 and 11 days. Hatchability is expected to be influenced by early, mid and late embryonic mortality. In our study, eggs stored for up to 7 days had significantly low LEM and higher hatchability than those stored for 8 to 14 days and 15 to 19 days that consequently had significantly low hatchability.

Conclusions and Recommendations

This study determined the mean performances and ranges of fertility, embryo mortalities and hatchability. It was revealed that all traits had wide performance ranges, and hatch group, ecotype, egg size and post-oviposition egg storage influenced various traits. There is potential for traits improvement through genetic or non-genetic interventions. Although fertility was acceptable, egg sizes and pre-incubation storage period affected hatchability. It is recommended that fluctuations in feed quality and incubation conditions, extra-large eggs (above 59g) and egg storage exceed 7 days should be avoided as they could depress fertility, increase embryonic mortalities and hence reduce hatchability. The IC genome need to be sequenced and genomic regions associated with incubation traits identified for inclusion in breeding strategies and improvement programmes.

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Ethical approval

The research protocol was approved by Egerton University institutional scientific and ethics review committee (Approval No. EUISERC/APP/214/2023).

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Phenotypic Characterization of Orma Boran Cattle in Kenya

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Abstract

Evaluation of phenotypic characteristics of cattle breeds is important for identification of diversity between and within breeds. This information assists in optimization of utilization and conservation of animal genetic resources. This study was carried out to assess the phenotypic characteristics of

Orma Boran cattle in Kenya. A total of 123 animals were used to assess the morphological and morphometric characteristics. Some of the morphological traits that were considered were hoof colour, hump shape, hair type curl, ear shape, facial profile, temperament and body hair coat colour, whose data was subjected to qualitative analysis. Majority of the cattle had non-pigmented hoof colour (60%), horn presence (98%), cervico-thoracic hump position (75%), straight hair type colour (100%), straight ear shape (96%), straight facial profile (100%) and docile temperament (68%). The main body hair coat colours were white (35%), light brown (13%) and red (11%). It is concluded that Orma Boran cattle have their unique characteristics which can be used for classification, selection and conservation of these cattle as an indigenous breed.

Keywords: *classification, morphological, indigenous, quantitative, utilization*

Introduction

Orma Boran (OB) cattle breed has been preferred in some regions in Kenya due to its unique attributes especially with regard to survival and adaptability. This breed is originally kept by the Orma people in Tana River County, Kenya, as documented by Irungu (2000). The breed was selected for trypanotolerance at ADC Galana ranch over a 12 year breeding program undertaken by KETRI (currently KALRO – Biotechnology research institute) from 1985 (Dolan, 1998). On-station work identified the breed to have a superior genetic ability in tolerance to trypanosome challenge compared to improved Kenyan Boran, higher birth and weaning weights (Dolan, 1998; Njogu *et al.*, 2005). Improved genetic material was disseminated to tsetse infested areas of Kajiado (Maichomo et al, 2005) and Busia (Gachohi et al, 2009) counties and the resulting progeny recorded high growth rates (Maichomo *et al.,* 2005).

The primary focus of OB conservation and dissemination was to enhance reclamation and effective utilization of tsetse fly infested areas by resident communities. To achieve this purpose, a nucleus breeding herd was re-established in KALRO – Beef research Institute, Nakuru County in 2016. Some gaps existed in terms of the breed characterization and the need to have it registered with the Boran breeder's society for ease of adoption in community breeding schemes. Phenotypic characterization gives information on identity and classification of the physical attributes, including body conformation and their biometric measurements (Pundir *et al.,* 2011; Pohler *et al.,* 2019). This data is useful in identification of diversity within and between breeds and informs how the genetic resources can be most suitably utilized (FAO, 2011). In addition, the information can be used as a basis for selection, improvement and conservation of local genetic resources (Adinata *et al.,* 2016). Farmer engagement gives insight on preferred traits attained from breed adaptation in a given environment and farmer/consumer needs to be considered in a breed selection program. Calculation of correlations between different traits is also important since they depict relationships between different characteristics (Adinata *et al.,* 2016). This study reports on the on-farm phenotypic characterization of the Orma Boran cattle breed.

Materials and methods

Study Area

Data was collected in Tana River County in Kenya, located between latitudes 0º0'53" and 2º0'41'' South and longitudes 38º30' and 40º15' East and with a total area of 38,862.20 Km^2. It receives an

average of 200-900 mm rainfall per year. The average annual temperatures ranges between 30-41ºC (Tana River County, 2013).

Sampling, data collection and statistical analysis

Data was collected and recorded based on FAO (2011) guidelines describing phenotypic characterization of animal genetic resources. Data on 16 morphometric and 31 morphological characteristics was collected from 123 animals (15 males and 108 females). Morphological traits were recorded based on visual appearance and morphometric traits were measured using a weighing band. The age of the animal was determined through teeth and horns examination. The morphological traits that were recorded include coat colour, horn, hump, head and ear characteristics. Collected data was managed in excel and analyzed using Statistical Package for Social Sciences (SPSS) version 20. Analysis was done on aforementioned attributes and mean comparison made between male and female cattle considering a 5% significance level. Frequencies were calculated for the qualitative traits.

Results

The qualitative characteristics for males and females are presented in Tables 1a, 1b and 1c. Majority (80% and 75%, respectively) of both males and females had plain body hair coat colour pattern. Body skin, muzzle, eyelid, hoof and anal area colour was mostly non-pigmented for both males and females at 60% and 63% respectively (Table 1a). All males and 98.1% of the females had horns, whose attributes on attachment, shape and orientation are detailed in Table 1a. Horn presence at herd level was 100% for males and 98.1% for females. All the males and females had hair type sheen that is glossy as opposed to dull, of medium length and straight curl. Majority of males had a straight ear shape, erect hump shape, cervico-thoracic hump positioning, straight backline profile and a docile temperament, at 93.3%, 86.7%, 60.0%, 86.7% and 53.3 % respectively (Table 1b). Majority of females had a straight ear shape, erect hump shape, cervico-thoracic hump positioning, straight backline profile and a docile temperament with 96.3%, 98.1%, 76.9%, 96.3% and 70.4%, respectively (Table 1b). There was a huge hair coat colour variations with white (35.0%), light brown (13%) and red (11.4%) as shown in Table 1c.

Table 1a: Body colour, muzzle, eyelid, hoof, anal area and horn characteristics of Orma Boran cattle (N = 123)

Variable	Sub-category	Male %	Female %	Total %	N
Body hair coat colour pattern	Plain	80.0	75.9	76.4	94
	Patchy	20.0	24.1	23.6	29
Body skin colour	Pigmented	40.0	37.0	37.4	46
	Non-pigmented	60.0	63.0	62.6	77
Muzzle colour	Pigmented	40.0	38.9	39.0	48
	Non-pigmented	60.0	61.1	61.0	75
Eyelid colour	Pigmented	40.0	39.8	39.8	49
	Non-pigmented	60.0	60.2	60.2	74
Hoof Colour	Pigmented	40.0	39.8	39.8	49
	Non-pigmented	60.0	60.2	60.2	74
Anal area Colour	Pigmented	33.3	34.3	34.1	42
	Non-pigmented	66.7	65.7	65.9	81
Horn Presence	Present	100	98.1	98.4	121
	Polled	0.0	1.9	1.6	2

Variable	Sub-category	Male %	Female %	Total %	N
Horn Colour	Pigmented	40.0	38.0	38.2	47
	Non-pigmented	60.0	60.2	60.2	74
	Polled	-	1.9	1.6	2
Horn Shape	Curvy	66.6	93.6	90.2	111
	Straight	20.0	2.8	4.9	6
	Pointed	6.7	0.9	1.6	2
	Straight	6.7	0.9	1.6	2
	Polled	0	1.9	1.6	2
Horn presence at herd level (HL)	Horned	100.0	98.1	98.4	121
	Polled	0.0	1.9	1.6	2
Horn Attachment HL (Fixed/Loose)	Fixed	100.0	98.1	98.4	121
	Polled	0.0	1.9	1.6	2
Horn orientation HL males	Upward	100	-	-	15
Horn Orientation HL females	Upward	-	92.6	81.3	100
	Forward	-	3.7	3.3	4
	Straight	-	1.8	1.6	2
	Polled	-	1.9	13.8	2

Table 1b: Hair, ear, hump, dewlap and facial, backline, rump profiles of Orma Boran cattle (N = 123)

Variable	Sub-category	Male %	Female %	Total %	N
Hair type sheen	Glossy	100.0	100.0	100.0	123
	Dull	0.00	0.00	0.00	-
Hair type curl	Straight	100	100	100.0	123
	Curly	0.00	0.00	0.00	
Hair length	Medium	100	100	100.0	123
	Long	0.00	0.00	0.00	123
Ear shape	Straight	93.3	96.3	95.9	118
	Rounded	6.7	3.7	4.1	5
Ear orientation	Erect	100	98.1	98.4	121
	Lateral	0.0	1.9	1.6	2
Hump Size	Small	33.3	73.1	68.3	84
	Medium	33.3	23.1	24.4	30
	Large	33.3	3.7	7.3	9
Hump Shape	Erect	86.7	98.1	96.7	119
	Drooping back	13.3	1.9	3.3	4
Hump Position	Thoracic	40.0	23.1	25.2	31
	Cervico-Thoracic	60.0	76.9	74.8	92
Facial/head profile	Straight	100	100	100	123
Dewlap size	Small	20.0	18.5	18.7	23
	Medium	40.0	66.7	63.4	78
	Large	40.0	14.8	17.9	22
Backline profile	Straight	86.7	96.3	95.1	117
	Slope down from withers	13.3	2.8	4.1	5
	Slope up towards rump	0	0.9	0.8	1
Rump Profile	Sloping	93.3	97.2	96.7	119
	Flat	6.7	2.8	3.3	4

Table 1c: Navel flap, sheath, scrotum, tail length, temperament and body hair coat colour characteristics of Orma Boran cattle (N = 123)

Variable	Sub-category	Male %	Female %	Total	N
Navel Flap	Absent	60.0	16.7	22.0	27
	Small	33.3	58.3	55.3	68
	Medium	0.0	19.4	17.1	21
	Long	6.7	5.6	5.7	7
Preputial sheath	Small	33.3	-	33.3	5
	Medium	46.7	-	46.7	7
	Long	20.0	-	20.0	3
Scrotum size	Small	6.7	-		1
	Medium	73.3	-		11
	Large	20.0	-		3
Tail length	Small	0.0	1.9	1.6	2
	Medium	6.7	3.7	4.1	5
	Long	93.3	94.4	94.3	116
Temperament	Tractile	46.7	28.7	30.9	38
	Docile	53.3	70.4	68.3	84
	Wild	0	0.9	0.8	1
Body hair coat colour	White	13.3	38.0	35.0	43
	Black	6.7	8.3	8.1	10
	Red	13.3	11.1	11.4	14
	Light brown	26.7	11.1	13.0	16
	Dark brown	6.7	0.9	1.6	2
	White with red marks	6.7	7.4	7.3	9
	White with red and black marks	6.7	13.9	13	16
	Black and white strips	6.7	0.9	1.6	2
	Other colours	13.4	11.6	8.9	11

Discussion

This study observed distinctive traits in the Orma Boran (OB) cattle breed. These include plain hair coat colour pattern that was dominant and similar to findings with indigenous cattle in Ethiopia (Gelaye *et al.*, 2022). Muzzle colour was mainly non-pigmented and in agreement with findings by Kebede *et al.*, (2017) whereby 79% of males had non-pigmented muzzle colour in Gofa cattle in Southern Ethiopia. Variance was however observed in Tigray region of Ethiopia with local cattle having pigmented muzzle (Gelaye *et al.*, 2022). Non-pigmentation in the body skin, eyelid, hoof, anal area, and horn colours was also dominant, albeit to varying levels in OB cattle, and in agreement with findings by Kebede *et al.*, (2017). Nonetheless, pigmentation dominance in these areas is recorded in some indigenous animals (Said *et al.*, 2017). Pigmentation is due to presence of melanin and variations in colouration is attributed to factors such as breed and environment in which these animals are found (Islam *et al.*, 2022).

Horn presence was predominant in 99% of study population, and in agreement with findings by Getachew *et al.*, (2014). While horned animals are considered attractive, it's also an adaptability trait for defense from their enemies (Gelaye *et al.*, 2022). The OB males had both curvy and straight horn shape, while females' horns were mainly curvy. This is in comparison with Raya-Azebo cattle

in Ethiopia found to have lyre horn shape (Mustefa *et al.,* 2020). Upward horn orientation (curving) is a unique characteristic of OB with 93% dominance and compares well with observation in Begait cattle in Tigray region, Ethiopia (Gebru *et al.*, 2017). The OB cattle had a dominant glossy hair type sheen (100%) that helps in reflection of sunlight (Teweldemedhn & Selam, 2020). Straight hair type (100%) of medium length can be considered advantageous for the OB animals since the host county of Tana River has high environmental temperatures and shorter hair length assists them in heat dissipation (Porto-Neto *et al.,* 2018). The ear shape was predominantly straight at 93% and similar to indigenous cattle in Oromiya regional state in Ethiopia (Annosse *et al.,* 2016).

Erect ear orientation and erect hump shape were also found prevalent in the OB. There were variations in hump size between males (small) and females (small, medium, large). A medium and erect hump is desirable especially for bull's suitability in draft use because it enables them to take pressure from the yoke and have reduced damage to the hides (Getaneh *et al.,* 2019). The hump position was mainly cervico-thoracic with 60% for males and 77% for females and compares well with Ogaden cattle (Mengesha, 2019). Distinctive straight facial profile in the OB is similar to that of indigenous cattle in Southwest Ethiopia (Gelaye *et al.,* 2022) but differs from those in the Western Zone that have a concave facial profile (Teweldemedhn & Selam, 2020). Medium sized dewlap was predominant in females (67%) while males had medium and large dewlap sizes in equal proportions (40%). Bekele & Kebede (2016) reported similar findings in Oromia region. Distinctive straight backline in the OB was similar to Raya-Azebo cattle but differed with Ogaden cattle in Ethiopia with backline sloping upward (Mengesha, 2019).

Most of the males (60%) did not have a navel flap while 58% females had small sized navel flap. Other studies have reported large and medium navel flaps for both sexes (Gebru *et al.,* 2017)**.** A large proportion of the bulls had medium and small sized preputial sheaths while the scrotum was medium sized. Scrotum sizes have been found to have a direct relationship with sperm quantity (Perumal, 2014). Majority animals had long tail which is advantageous as it helps them in keeping away flies and parasites that cause irritation (Gebru *et al.,* 2017; Mustefa *et al.,* 2020). Extremely long tails are however undesirable since the animals can be easily entangled in bushes during grazing. Docile temperament was dominant as observed in past studies in Kenya (Maichomo *et al.*, 2005). Temperament determines the ease with which animals can be handled and has also been found to have an effect on carcass qualities (King *et al.,* 2006). The docile nature of the OB breed was recorded as a desirable trait that enhanced adoption by the Maasai pastoralists due to their ease of handling by women and children (Maichomo *et al.,* 2005).

The OB breed displayed huge hair coat colour variations with the main colours being white (35%), light brown (13%) and red (11%). Farmers appear to prefer white colour which has adaptive advantage of repelling infra-red radiation in comparison to dark colours (Getaneh *et al.,* 2019), thereby putting a limit to negative effects of thermal stress on the animals (Oke *et al.,* 2022). This is helpful in breed adaptation because the area in which the Orma Boran cattle are found usually has high environmental temperatures throughout the year. This narrative was asserted by Irungu (2000) who reported that the Orma people selected their breeding animals based on some preferred characteristics which included body size and white coat colour. Getaneh *et al.*, (2019) also reported dominance of both white and red coat colours for Malle cattle breed in Southwest Ethiopia. Generally, the lighter colours (white, light brown, red) are more prevalent in indigenous cattle breeds compared to dark colours (black and its admixtures). The colour combinations also shows that the

coat colour for this breed is heterogeneous and can be an advantage to evade predators as they are not easily spotted.

Conclusion

It is concluded that Orma Boran cattle have distinctive features including: a straight facial profile, a medium sized dewlap, horns, small to medium erect hump sizes that are in the cervico-thoracic location. This breed has variations in coat colour with the dominant colours being white, light brown and red. Chest girth and body weight had a high and positive correlation and therefore chest girth can be used reliably to predict live body weight. The generated information can be used to inform decisions for Orma Boran cattle breeding and conservation.

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Evaluation of the Genetic Effect on the Growth of KALRO Improved Chicken in Kenya

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Abstract

In Kenya, the chicken sector is highly significant in terms of food security, nutrition, and economic development. Nonetheless, this industry has faced challenges due to poor chicken nutrition caused by irregular access and scarcity of high-quality feed ingredients, and the undeveloped genetic capacities of diverse chicken breeds. This genetic deficit has resulted in inadequate feed conversion efficiency, resulting in reduced growth and increased production expenditures, notably in terms of feed costs. The objective of this research was to assess how genetic factors influence the growth of two breeding lines of KALRO Improved Chicken (KIC) in comparison to a positive control. The investigation examined the growth rate, feed intake, and feed conversion efficiency within these three breeding lines. The study was designed using a Completely Randomized Design consisting of three replications with a total of 405 chicks aged day old to 4 weeks. The study results suggest that KC1 has a significantly higher live weight of 1484.78g compared to KC3=1328.7g and Positive control=1332.73 g up to 4 weeks, at P< 0.001. The positive control showed a significantly higher feed intake of 1479.23g as compared to KC1= 1459.66g and KC3 =1421.42 g. KC3 exhibited a significantly higher FCE compared to F2 and KC3.

Keywords; *KALRO Improved Chicken (KIC), growth rate, feed intake, and feed conversion efficiency*

Introduction

The global poultry industry stands as a critical pillar in the economy, making substantialcontributions to food security, nutrition, and economic growth. The sector generates around $300 billion annually and employs over 130 million people worldwide (Food Agriculture Organization, 2021). In low-income countries, it serves as an affordable source of animal protein and essential nutrients for vulnerable populations, aiding poverty reduction and food security (Marinda *et al.*, 2017).

Kenya's agricultural economy highly depends on the poultry industry, with an estimatedpopulation of 32 million chicken with indigenous chickens (IC) constituting 75% of this population (Kenya National Bureau of Statistics, 2021). Poultry farming in Kenyagenerates around 4% of the country's agricultural GDP (Olwande *et al.*, 2013a; FAOSTAT, 2014) providing essential income and nutrition for millions. In 2020, the country produced over a billion eggs and 50,000 metric tons of chicken meat, significantly enhancing food security and livelihoods (Kamau, 2021). With over 3

million people employed, especially small-scale farmers, the sector plays a vital role inalleviating malnutrition and enhancing food security, particularly in rural areas. Poultryexports, particularly eggs, have also contributed to foreign exchange reserves, underscoring the industry's economic and social importance (Kajiya *et al.*, 2020).

Selective breeding has emerged as a pivotal genetic strategy to enhance chicken growthtraits. Vigilant selection of superior breeds with desirable characteristics has led to improved growth rates, feed efficiency, and carcass quality (Tallentire *et al.*, 2016). Pedigree selection, progeny testing, and marker-assisted selection have further enhanced growth potential, elevating the economic value of chicken production (Saxena & Kolluri, 2018). Despite their resilience, ICs suffer growth limitations, prompting KALRO to develop novel lines KIC1, KIC2, and KIC3 to enhance feed efficiency and augment growth and production. Despite IC resilience, they suffer growth limitations, prompting KALRO to develop novel lines KIC1, KIC2, and KIC3 to enhance feed efficiency and augment growth andproduction.

Nonetheless, there is a shortage of information concerning the genetic implications of KALRO's Improved Chicken (KIC) lines. This study seeks to fill this void by investigating the genetic influence on growth, particularly delving into how specific genotypes affect growth rates, feed intake, and feed conversion efficiency. By yieldingvaluable insights, the study strives to assist small-scale farmers and stakeholders in thepoultry industry, thus facilitating well-informed decision-making and progress within the sector. Through the examination of genetic impacts on the growth performance of Improved Indigenous chickens, this research actively contributes to the advancement of the poultry field.

Materials and methodsStudy site

On-station studies were conducted at KALRO Kakamega, which is located in Kakamega town along the Kisumu to Webuye highway. Kakamega County is situatedat 37° 75'E 20°15'S and 1585m asl, experiences mean annual temperatures of 25°C andbimodal rainfall (1850 to 1916 mm).

Sampling strategy

A sample of 405 day old chicks were randomly selected from the Non-Ruminant Research Institute of Kenya Agriculture and Livestock Research Organization (KALRO) in Kakamega County. The selection employed a random sampling method, ensuring equal chances for each chick's inclusion in this study (Kothari, 2013). This approach guaranteed a representative and unbiased sample, minimizing potential bias or systematic errors. The chosen sampling strategy facilitated a reliable and impartial assessment of the genetic impact on KIC breed in Kenya.

Management of the Experimental Birds

Upon hatching, chick weights were measured using a digital ken trac weighing balancefollowed by placement in brooding area containing wood shavings as litter. The brooding period spanned from day one to four weeks, using three brooders with distinctgenotypes. For optimal comfort, a circular brooder with a 6 to 7 feet diameter was recommended for 135 chicks during the University of Georgia Cooperative Extension'sgrowing phase. All chicks were offered a Standard Chick mash diet from the KALRO Kakamega feedmill. A starter ration (20% CP and 2800Kcal/kg ME) was provided to chicks for 4 weeks. Routine management practices and vaccinations were administered, ensuring optimal health, including vaccinations against Newcastle Disease and infectious bursaldisease. (National Research Council, 1994).

Data collection

Data was collected through weekly weighing of birds, accompanied by weekly collection and weighing of feed remains to estimate the feed intake. Weights and feed amounts were recorded in grams for accuracy.

Data Analysis

Data on growth, feed intake, and FCE were subjected to Descriptive statistics analysisusing the SPSS Software to determine the coefficient of variation on the three breedinglines subjected to the study parameters.

Results and Discussion

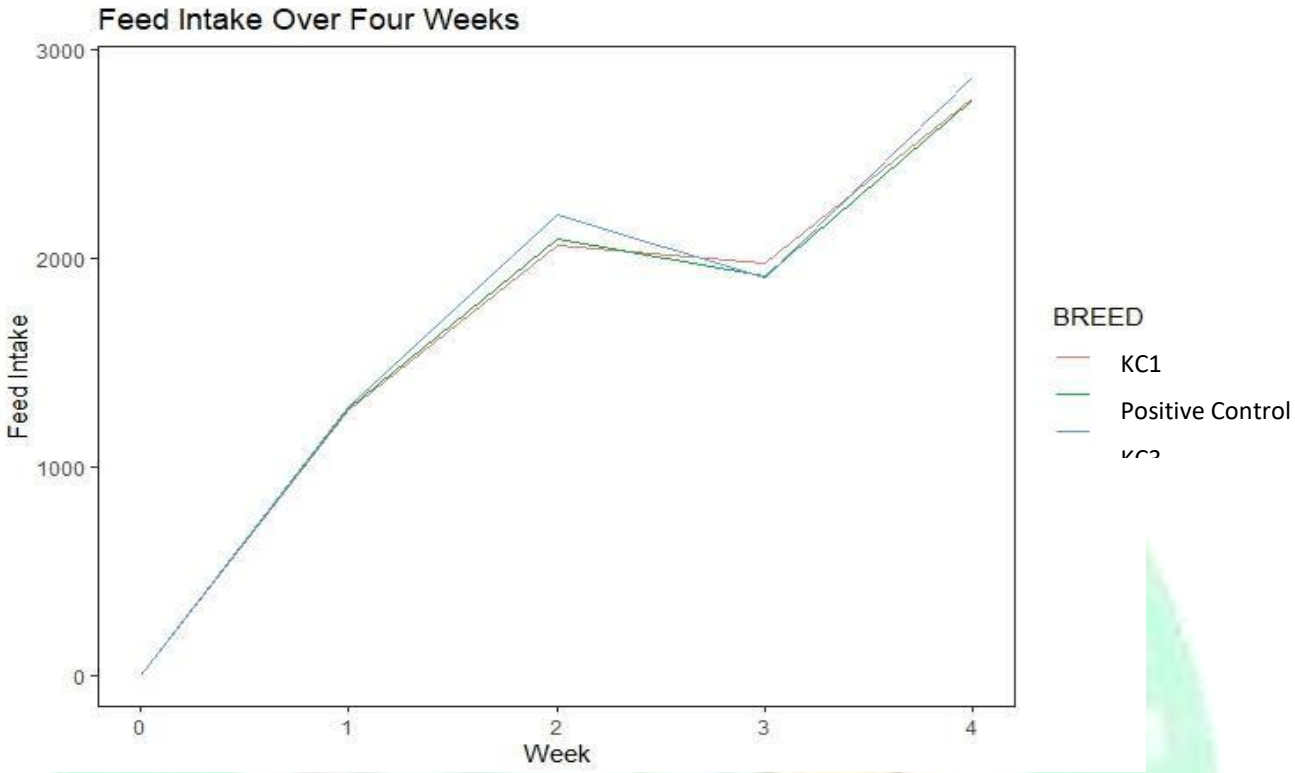
The performance metrics measured during brooding were the chicks live weight gain and feed intake. Data on FCE was calculated by dividing the total amount of feed consumed (feed intake) by the flock with the weight gained. This is analyzed by calculating the coefficient of variation between the three breeding lines of Chicken.

Live Weight and Feed Intake

The table below shows the mean live weight of the birds after feeding them for 4 weeks.Live weight of KC1 is higher with an average of 1484.78g, Positive control =1332.73g, and lower for KC3=1328.71g. This shows, after feeding the birds, KC1 had a faster growth rate compared to KC3 and the positive control. The feed intake is higher for the positive control with an average of 1479.23g followedby KC1=1459.66g and KC3=1421.42g. According to the study results KC3 has a higherfeed intake compared to KC1 and positive control.

Table 1: Live weight per breed, and feed intake

Frequency			Mean	Standard Deviation	Column N %	Maximum	Minimum
Liveweight	KC1	45	1484.78	945.15	33.3	3370.00	.00
	KC3	45	1328.71	836.98	33.3	3040.00	.00
	Positive Control	45	1332.73	838.49	33.3	3090.00	.00
	Total	135	1382.07	871.51	100.0	3370.00	.00
Feed Intake	KC1	45	1459.66	974.81	33.3	2769.90	.00
	KC3	45	1421.42	1009.99	33.3%	28 71.30	.00
	Positive Control	45	1479.23	984.68	33.3%	2760.60	.00
	Total	135	1453.44	982.82	100.0%	2871.30	.00



Growth

KC1 and the positive control show a consistent increase in live weight over weeks, with some fluctuations while KC3 seems to have a higher growth rate during early development stages while KC1 had a higher growth rate as the weeks approached 4. At week 2 with the reduction of feed intake, a stunted growth was recorded. This wasdue to Ascites which mostly affects fast growing chicken especially broilers. But in thiscase, KC3 was mostly affected in the 3 breeds because of its trait of faster growth rateand thus led to reduction of feed intake between weeks 2 and 3 which depressed feed intake and affected its growth and live weight. The energy and protein content of the Chick mash was reduced in the feed to reduce ascites in the chicks and also limited feeds was given to the chicks.

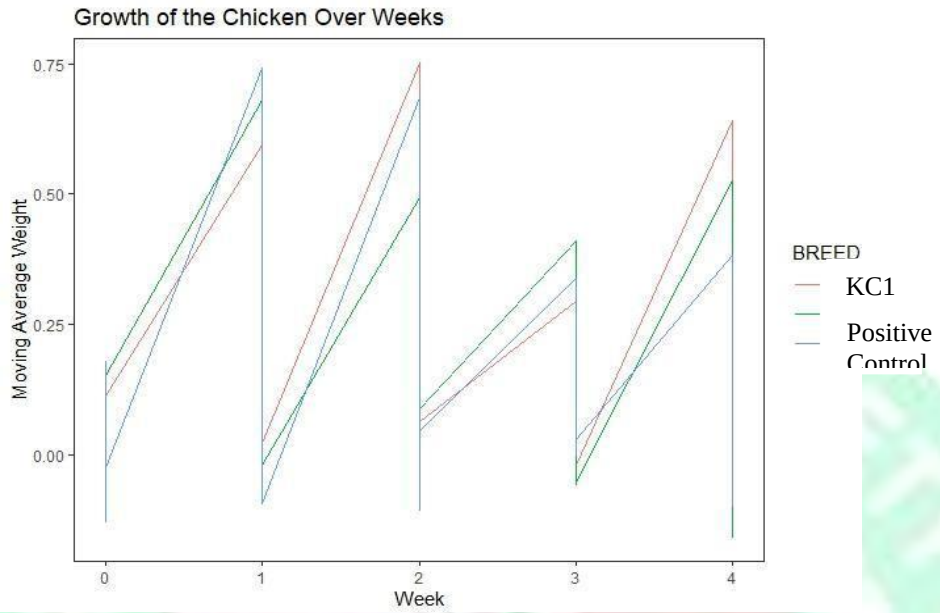


Figure 1: Growth Rate in 4 weeks

Feed Conversion Efficiency

The figure below shows that KC3 has a higher Feed Conversion Efficiency compared to KC1 and the positive control. FCE seems to be more stable in KC3 as opposed to KC1 and the positive control.

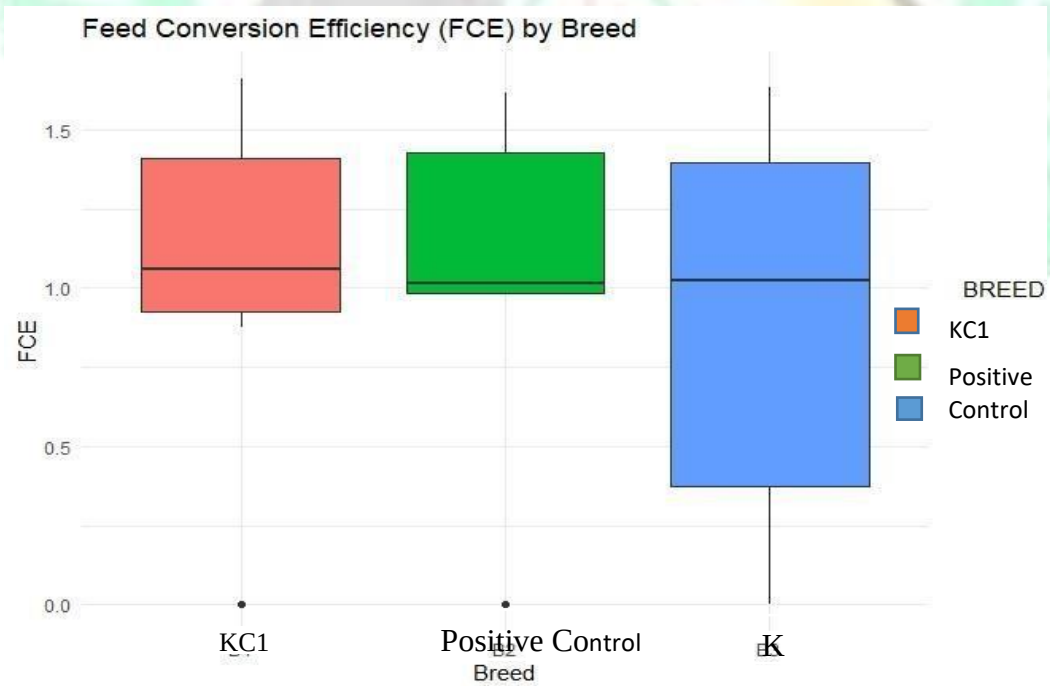


Figure 2: Feed Conversion Efficiency (FCE) by breed

Conclusion

KC1 has the highest growth rate in the 3 breeds while KC3 shows a higher FCEcompared to KC1 and the positive control.

Recommendations

The results recommend both KC1 and KC3 because KC1 has a higher live weight compared to KC3 and the positive control while KC3 has a higher feed conversion efficiency. According to the study results KC3 will be more economical and profitableto rear since it attracts low feed intake and high feed conversion efficiency.

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Effect of Total Mixed Ration Supplementation of Transition Cows on Reproductive Indices of Friesian Dairy Cows

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Abstract

The transition dairy cows are challenged by various stresses such as decreased dry matter intake, liver dysfunction, increased inflammation, and oxidative stress, particularly in subtropical regions. These might increase the need for total mixed ration supplementation. To examine whether supplementation would help transition dairy cows to achieve greater reproduction performance including reduced days to postpartum heat and reduced insemination to conception; a total of 30 incalf Friesian dairy cows of body condition score ranging from 2-4 and of parity ranging from 2-4 were enrolled in this study and divided into two groups: Test cows (n=20) were each supplemented twice daily from 30 days prepartum to 60 days posr-partum with total mixed ration feed-blocks (feed block composition: Brachiaria grass (60%), Dolichos lablab flour (20%) Lemon rind (5%), Bentonite clay (5%) ,and Molasses (10%)). Control cows (n=10) were not supplemented. The results showed supplementation reduced: gestation period by an average of 6 days, postpartum heat exhibition by an average of 30 days and number of insemination to conception to 1.5 as compared to the control The results were highly influenced by body condition score and parity. Application of the results to dairy cow management regimes would reduce calving intervals.

Keywords: *Transition cow, reproductive indices*

Introduction

A transition period in dairy cows is full of stress caused by physiological, metabolic, and nutritional changes (Joksimović-Todorović and Davidović; 2012). These stresses have an influence on reproductive indices thus significantly affecting profitability (Block; 2010). The transition period is characterized by decreased dry matter intake and liver dysfunction (Trevisi *et al*.; 2012). Therefore, the postpartum period constitutes an important period that affects dairy cows' fecundity (Drackley and Cardoso.2014). The onset of normal ovarian cyclic activity is one of the most important events for dairy cow to regain her maximum breeding potential following parturition. To attain a recommended calving interval of 12 months (Migbnesh, 2022), cows should conceive within 85 days after parturition. This requires normal cyclicity within few weeks after calving. The interval in several herds could be reduced by breeding cows on first heat after 45 days postpartum and/or next to first examining the cows for normal reproductive tracts. Feeds influence days open (Santos *et al., 2009*). The objective of this study was therefore to determine the influence of total mixed rations (feed blocks) on postpartum reproductive indices.

Materials and Methods

Study Site

KALRO -Lanet (0° 27' 09' S and 390 38' 45' E (Oliveira, 2018), is located in Nakuru County, Kenya at an elevation of 1600 meters above sea level. The area has a bimodal rainfall pattern with an annual mean rainfall of 800mm ranging from 534 to 1,049mm and 83% relative humidity. Temperature ranges between 8 to 20^{o}C (Pratt and Gwyne, 1977). Soils are deep sandy loam with good water holding capacity with pH range of 5.5 to 6.5 (Mwangi *et al.*, 2017).

Experiment

Thirty seven-month incalf Friesian cows were enrolled for the study. Twenty cows were put into Test group were supplemented with 2 kg of complete meal feed blocks at milking. They were supplemented with 4 kg of complete meal feed blocks postpartum. The control group was not supplemented. Parities, milk production, and body conditions were recorded. Five milliliters of milk was collected thrice a month from each cow postpartum by aseptically stripping 10 mls of evening milk into sterile milk container. The milk was preserved using sodium azide tablet. The milk was analyzed for progesterone using radioimmunoassay technique (FAO/IAEA, 1999) to determine postpartum cyclicity and conception

Determining Feed Nutritional Composition

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 (2006) method. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to Van Soest *et a*l (1991).

Statistical analysis

Data collected was analysed using SAS (2010).

Results

There was significant difference in nutritive values of Dry matter, crude protein, nutrient detergent fibre and ash with feed block having higher values (Table 1). Forage values are similar to those obtained by Smith *et al.,* (2006). Average values for NDF as indicated below reflect the good pastures used, and are suitable in enhancing rumen function (Russel *et al.*, 1992).

Table 1: Mean±SD of Nutritional Values of Forage and Feed block

Nutritional Component	Forage (%)	Feed block (%)
Dry Matter	36.8±2.5	86±3.7
Crude Protein	4.7±2.2	16.8±1.1
Neutral Detergent Fiber	41.7±6.7	45.7±9.5
Acid Detergent Fiber	28.6±2.5	30.4±9.5
Acid Detergent Lignin	4.7±1.6	11.1±0.6
Ash	9.1±0.8	9.4±2.1
Total aflatoxin (ppm)	-	7.4±0.3

Effect of supplementation on reproductive indices

Supplementation significantly impacted on pregnancy period (pg), days to visible heat and insemination to conception with the test group cows having lesser: pregnancy period (278.35±1.23), days to visible heat (50.35±1.39) and insemination/conception (1.35±0.11) (Table 2). Pregnancy period agreed with the finding of Norman *et al* (2009) who reported an average gestation period of a Friesian dairy cow as days 279.4 ± 5.7. Reduced number of inseminations to conception agreed with the finding of Gillah *et al* (2014) who reported that Concentrate supplementation pre calving reduced calving interval of lactating crossbred cows.

Table 2: Means and standard error (Means ± SE) of reproductive indices

Parameters	Supplementation	No of observation	Mean ± SE (days)	P Value
Pg period	No	10	284.10±1.79	0.000***
	Yes	20	278.35±1.23	
	Total	30	281.23±1.10	
Days to Visible heat	No	10	62.70±1.97	0.000***
	Yes	20	50.35±1.39	
	Total	30	56.53±1.21	
Insemination/conception	No	10	2.70±0.15	0.000***
	Yes	20	1.35±0.11	
	Total	30	2.03±0.09	

*** 1% significance level

Effect of Parity on reproduction

Cow parity impacted on BCS at calving (P<0.05), calf sex (P<0.05) and P4 at estrus(P<0.05) with significant difference between the treatments occurring at parity 1 (Table 3). Parity 1 showed minimal performance and this could be due to high nutrient partitioning for growth than for reproduction. This finding agreed with the finding of Inchaisri *et al.,* (2010) who reported minimal reproductive performance of first parity cows.

Table 3: Means and standard error (Means ± SE) of Effect of parity on body condition score

Parameters	Parity	No of observation	Mean ± SE	P Value
BCS at calving	First	10	1.40±0.12	0.000***
	Second	10	1.20±0.12	
	Third	5	2.00±0.18	
	Fourth	5	3.00±0.18	
	Total	30	1.90±0.08	
Calf sex	First	10	0.70±0.14	0.000***
	Second	10	0.50±0.14	
	Third	5	0.00±0.20	
	Fourth	5	0.20±0.20	
	Total	30	0.35±0.89	
P4 at estrus	First	10	1.20±0.11	0.000***
	Second	10	1.20±0.11	
	Third	5	1.00±0.15	
	Fourth	5	1.00±0.15	

Total	30	1.10±0.07

*** 1% significance level

Effects of BCS at Calving on reproductive indices

Body condition score less than 3 took more days (59.93±1.84) to show heat and most number of inseminations to conception (2.21±0.18) whereas body condition score 3 and above took less days (47.20±3.07) and less insemination to conception (1.18±0.20) ((Table 4). This could be due to the fact that lower parity cows have lower energy balance for growth as they cannot consume adequate energy in the diet. This finding agreed with the finding of Sharma *et al* (2018) who reported postpartum BCS of experimental cows to be significantly higher (P<0.05) in pluriparous cows as compared to primiparous.

Table 4: Means and standard error (Means ± SE) of BCS at Calving on reproductive indices

Parameters	BCS at Calving	No of observation	Mean ± SE	P Value
Days to Visible heat	Less than 3	14	59.93±1.84	0.000***
	Above 3 but less than 4	11	50.82±2.07	
	4 and Above	5	47.20±3.07	
	Total	30	52.65±1.38	
Insemination/ Conception	Less than 3	14	2.21±0.18	0.000***
	Above 3 but less than 4	11	1.18±0.20	
	4 and Above	5	2.20±0.30	
	Total	30	1.80±0.13	

*** 1% significance level

Conclusion

Supplementation with total mixed ration feed blocks positively enhanced reproductive indices. There was favourable interaction between body condition score at calving and parity on reproductive indices for supplemented cows.

Recommendations

The results should be applied to dairy cow management regimes to reduce calving intervals and increase profit from dairy farming.

Further Work

Parity and body condition score should be used as important traits in performance of dairy cattle.

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Upscaling Climate Smart Livestock Germplasm in ASAL Counties of Kenya

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Abstract

Adoption and utilization of climate smart cattle breeds for beef production in ASALs has enormous potential to enhance resilience of livelihoods and production systems. However, limited access to appropriate breeds and their management packages is a challenge. The aim of this project was to avail climate smart germplasm in ASALs communities by designing and implementing a three-tier community based breeding system. Tier 1 comprised of on-station nucleus herd for multiplication and dissemination of climate smart genotypes to Tier 2. Tier 2 comprised of satellite multiplier farmers recruited from target counties of Isiolo and Marsabit counties aimed at multiplying and disseminating genotypes to Tier 3. Tier 3 comprised of the community (farmers). 10 and 8 multiplier farmers recruited from Isiolo and Marsabit County respectively were supplied with 39 breeding stock comprising of 16 heifers and 23 breeding bulls. Capacity building on appropriate beef production technologies and management practices was done to the multiplier farmers. The on-station nucleus herd had 574 cattle at the beginning of the year 2020 during project inception. By the end of the year, 220 cows had calved down. In the year 2021, a total of 192 calves were born and an additional 230 in the year 2022. A total of 39 cattle comprising the breeding stock were supplied to Tier 2 while CIGs were supplied with 8 cattle from the breeding stock. By December 2022, the breeding bulls supplied to multipliers in Tier 2 had sired a total of 130 calves while heifers had produced 30 calves. Prolonged drought slowed down multiplication rate at Tiers 2 and 3 but now recovering after the rains. It was concluded that the project was viable and once the community breeding system has been adopted, ASALs community will benefit from the upscaled climate smart cattle breeds.

Keywords: *Climate smart germplasm, Nucleus herd, Three-tier community based breeding system.*

Introduction

Livestock production significantly contributes to Kenyan economy with up to 10% of National GDP and 40% of agricultural GDP (USAID, 2011; Tully 2014). The ASAL counties of Kenya cover approximately 80% of Kenya's landmass and produce over 70% of livestock products estimated at KES 70 Billion (GOK, 2010; Harun,2014), with estimated $ 4.5 billion per year (Tully, 2014). Beef cattle production in ASALs of Kenya is the main economic activity providing employment and household incomes (FAO, 2005). However, one the biggest challenge besides perennial feed challenge during dry seasons (Gachuiri *et al.*, 2017) is shortage of appropriate climate smart beef breeds to replace the local beef breeds which are associated with slow growth rates, low meat and milk production and slower reproduction rates (Kidake *et al.*, 2016). Demand for beef and milk is continuously increasing (Bosire *et al.*, 2017; Rademaker *et al.*, 2016) and is expected to continue rising as the population increases. Pastoral extensive production system limits dissemination efforts on appropriate beef breeds and establishment of community based breeding programs for improvement of the local breeds. The Government through research institutions has bred improved climate smart breeds and as such interventions to enhance adoption should be addressed. Promotion of adoption of cattle breeds that have been improved on resilience to climate change and increased productivity will result to increased meat and milk output and household incomes for all value chain actors. Vulnerable groups, women and youth will also benefit from diversified activities emanating from the value chain. Establishment of community based breeding schemes will empower the communities to sustainably keep quality breeding stock.

Materials and Methods

Experimental Site

On station germplasm multiplication (tier 1) was done at Kenya Agricultural and Livestock Research Organization (KALRO), Beef Research station, Lanet, Nakuru, Kenya. The project started by on – station livestock germplasm multiplication to form a nucleus herd (Tier 1). The existing breeding stock was divided into different herds where natural mating system was adopted by placing superior breeding bulls at a mating ratio of 1:50 per herd. A total of 37 cows and 24 heifers were selected from the breeding stock and subjected to estrus synchronization (ES) and subsequent artificial insemination using semen from superior bulls. ES was used to shorten calving interval to support natural mating in an effort to bolster offspring production. Stakeholders target counties officials were sensitized on the proposed project and workshops were conducted where a three tier breeding scheme comprising of the nucleus herd (Tier 1), satellite multipliers (Tier 2) and farmers (tier 3) was developed. Satellite multipliers were identified and recruited from the two project target counties of Isiolo and Marsabit with the help of county government officials. At tier 1(on station nucleus herd) elite germplasm were produced and supplied to the selected multipliers at Tier 2. The multipliers task was to multiply the germplasm and eventually avail them to farmers (Tier 3) and the cycle continues. A total of 18 multiplier satellite farms were recruited, 10 from Isiolo and 8 from Marsabit County. Ground truthing was done on the selected farms to assess their potential to multiply the germplasm after which a total number of 39 breeding stock comprising of 22 bulls and 17 heifers was supplied to the two counties as shown in tables 1.

Table 1: Supply and distribution of livestock germplasm to multiplier farms in Isiolo and Marsabit Counties.

ISIOLO COUNTY		MARSABIT COUNTY	
Multiplier farm	**No of animals supplied**	**Multiplier farm**	**No of animals supplied**
Beca farm	1 heifer	Roba CIG	3 bulls, 5 heifers
Elibit farm	1 heifer	Wato farm	1 bull
Rose farm	1 heifer &1 bull	Lenaepe farm	1 bull
Hassan farm	1 bull	Korkora farm	1 heifer & 1 bull
Eiton farm	1 heifer &1 bull	Lekapan farm	1 heifer & 1 bull
Amnaj farm	2 bulls	Loperdes farm	1 bull
Vision farm	2 bulls	Wario CIG	1 heifer, 3 bulls
Fila farm	1 heifer & bull	Jamaa dairies	1 bull & 1heifer
Invems farm	1 heifer &1 bull		
BDD farm	1 heifer & 1 bull		

On- farm follow – up trainings, study tours and technical backstopping were conducted to support the offtake of the project. Data collection tools were designed and were used to collect data in follow-up trainings. Technology exchange platform was formed to enable interactions and discussion on technical issues among the stakeholders. The platform provided a channel for technology transfer and feedback exchange. A whatsup group was created to provide platform among the stakeholders. Monitoring and evaluation (M&E) activities on multipliers farms were done on monthly basis followed by data collection and technical backstopping. Training materials were continuously reviewed and updated.

Results

The average yearly herd size after annual sales from 2017 to 2022 is shown in table 2. The figures comprised of the on- station nucleus herd. From the figures it was evidence that herd size increased dramatically during the project period of 2020 to year 2022.

Table 2: Average yearly herd size at on- station tier 1 from 2017 to 2022

Year	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
No of livestock heads	589	691	770	860	935	987

The potential of tier 1 in germplasm multiplication determines the sustainability of the project. A forecast projection of germplasm multiplication within a period of five years from 2022 to 2027 is shown in figure 1. A trend line was drawn to give an idea on which direction the germplasm multiplication was taking in the coming five years.

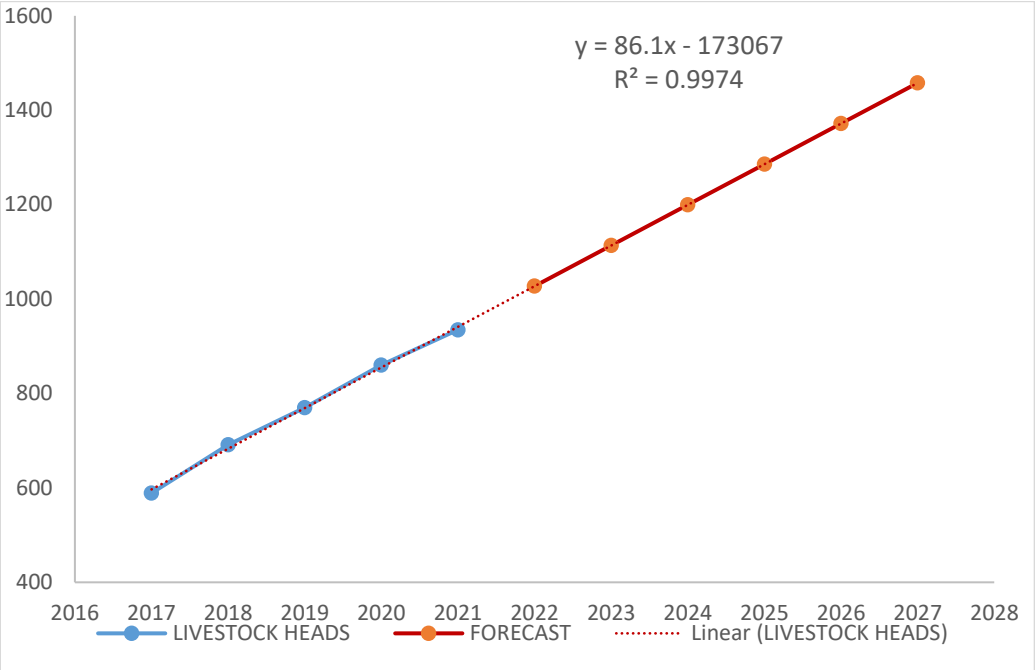

Figure 1: Forecast projection of germplasm multiplication from 2022 to 2027

Within a period of five years the on - station tier 1 might be able to achieve a population of over 1400 herds of breeding stock. This can be verified by using the equation y = 86.1x – 173067, R^2 0994. The figures comprised of the on- station nuclear herd. Table 3 below shows the performance of natural mating in tier 1 from 2020-2022. From the table, a steady increase was observed during the project period of 2020 to year 2022.

Table 3: Performance of natural mating in tier 1 from 2020-2022

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
No of calves	151	70	95	115	146	146	170	222	230	235

The figure 2 shows increasing trend of calves born from year 2014 to 2022. A sharp curve was observed during the project period of 2020 to 2022.

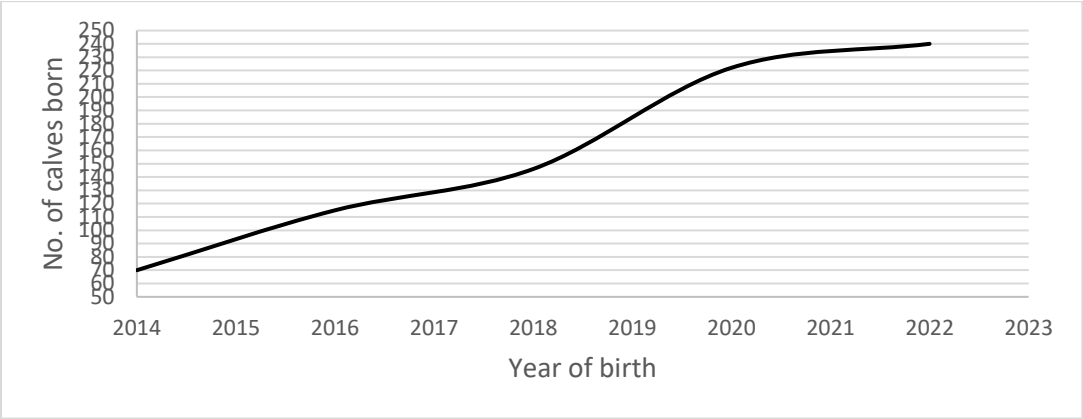

Figure 2: Increasing trend of calves born from year 2014 to 2022

At tier two, a monitoring and evaluation of the project one year after the inception indicated that out of 39 breeding stock supplied, 70 offspring were obtained in tier 2 (satellite multiplier farms) while 68 offspring were availed to tier 3 farms as shown in table 4.

Table 4: Livestock M& E data capture matrix

Name of multipliers	County of Multipliers	No of animals availed	No. of offspring after multiplication	No. of animals availed to Tier 3
Beca farm	Isiolo	1	-	0
Rose farm	Isiolo	2	-	0
Elibit farm	Isiolo	1	-	0
Hassan farm	Isiolo	1	-	0
Petro Eiton	Isiolo	2	2	7
Amnaj farm	Isiolo	2	8	6
Vision Farm	Isiolo	2	3	11
Fila farm	Isiolo	2	2	15
Invems Agencies	Isiolo	2	-	0
BDD investment	Isiolo	2	-	16
Godana Wato	Marsabit	2	-	0
Roba C IG	Marsabit	8	5	0
Lenaepe farm	Marsabit	1	18	10
Korkora farm	Marsabit	2	15	3
Lekapan farm	Marsabit	2	-	0
Amina Loperdes	Marsabit	1	14	0
Hussein Wario	Marsabit	4	3	0
Jamaa dairies	Marsabit	2	-	0
	TOTAL	39	70	68

Discussion

The herd size and calves born in tier 1 increased dramatically during the project period of 2020 to year 2022. This could have contributed to addition of breeding bulls in the nuclear herd to enhance natural breeding. On station nucleus multiplication (tier 1) involved use of natural mating systems where superior breeding bulls were purchased from commercial ranches and placed in herds at a mating ratio of 1:50. During the project period, estrus synchronization & artificial insemination was done to shorten calving interval to support natural mating in an effort to bolster offspring production hence increase in herd size and the calves born. Expected calving in tiers 2 and 3 was not achieved due to prolonged drought that occurred during the project period. This led to lack of livestock feeds hence starvation, reduced fertility, reproduction and mortalities. Farmers relied on commercial feeds which were inadequate. Insecurity was a problem for the entire period of the project. Invasion of livestock by predators and inadequate veterinary services/supplies led to loss of animals.

Conclusion

Through the community based beef cattle breeding schemes, the project envisioned a multiplier effects horizontally and vertically along the beef value chain where other farmers not directly involved with the project benefited through technology spillovers. Through multiplication and availing improved, efficient and adaptable beef breeds with high feed conversation ratio and high meat output to the targeted ASAL Counties. This will improve livelihoods in ASALs while reducing greenhouse gas emissions. The project will thus lead to resilience of beef production based on economic activities and production systems to the negative effects of climate change.

Recommendations

The project recommends a continuous multiplication and availing of improved, efficient and adaptable beef breeds with high feed conversation ratio and high meat output to improve livelihoods in ASALs.

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We acknowledge the Kenya Agricultural and Livestock Research Organization (KALRO) for logistical facilitation, Kenya Climate Smart Agriculture Project (KCSAP) for funding the livestock germplasm multiplication project entitled *'Germplasm multiplication of improved Boran cattle, Orma Boran and their crosses for ASAL'* in which this study was extracted. Beef Research Centre research team assisted in the research work. Satellite multipliers from both Isiolo and Marsabit counties for their collaboration and willingness to conduct germplasm multiplication in their farms. County Government officials for their grassroot assistance in project planning and implementation.

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ANIMAL HEALTH FOR SUSTAINABLE FOOD SYSTEMS

Kentec - Kenya Tsetse and Trypanosomiasis Eradication Council: Tsetse and Trypanosomiasis control in Kenya

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Abstract

Kenya has a long history of tsetse infestation and with it a heavy economic loss. African Animal Trypanosomosis (AAT)/*Nagana* transmitted by tsetse flies is endemic in the Country and Human African Trypanosomiasis (HAT)/sleeping sickness caused by *Trypanosoma brucei rhodesiense* was present in the past in the Western part of Kenya until the year 2009 when the last case was reported. To control tsetse flies and trypanosomiasis, a total of 3,486,433 cattle were treated with insecticide, 13,420 insecticide treated targets deployed, 2,317 tiny targets deployed and 342 zero grazing units were installed with LPF in the intervention areas to date. Tsetse flies monitoring in those areas resulted in average of flies trapped per trap per day (FTD) of 4.54 for *G. pallidipes*, 0.21 for *G. longipennis*, 0.68 for *G. austeni*, 0.86 for *G. brevipalpis*, 0.87 for *G. fuscipes* and 2.14 for *G. swynnertonni*. The AAT monitoring resulted in average prevalences of 1.567% for *T. vivax*, 1.428% for *T. congolense* and 0.2096% for *T. brucei* from 16,496 animals screened. The HAT surveillances were carried out within the reporting period where no positive case was reported. In the implementation of European Union (EU) funded project Controlling and progressively Minimizing the Burden of African Trypanosomosis (COMBAT), Kenya has adopted the Progressive Control Pathway (PCP) in staging the progress of AAT reduction which informs the stages at which Counties are in. Out of the 47 Counties in Kenya, 25 have been categorized in Stage 1 Early, 7 Counties in Stage 1 Advanced, 10 Counties in Stage 2 Early and 5 Counties in Stage 2 Advanced. The vastness of tsetse infested areas with difficult terrains and transboundary nature of tsetse and trypanosomiasis (T&T) are some of the challenges faced. Advancing collaborations with Stakeholders at the National, Regional and International level in the implementation of tsetse and trypanosomiasis (T&T) control activities is crucial to the sustainability of the achievements made so far.

Causes of Cattle Mortality Under Free- Range System of Production: A Case Study of Beef Research Institute - Lanet, Kenya

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Abstract

Health of the beef cattle is a vital factor that permits the animal to perform to its highest capacity. Cattle Mortality affects beef cattle performance, and is a threat to cattle productivity, thus having enormous economic and welfare impacts on farmers. This study aimed at investigating the causes and factors associated with the mortality of beef cattle, and the measures which can be put in place to prevent future occurrences of the mortalities. Data was collected from post-mortem reports from the livestock records office at Beef Research Centre – Lanet for the years 2014 to 2019. The sample size consisted of 116 cattle which were categorized into six age groups of <6months, ≥6months, <1year, ≥1<2 years, ≥2<5 years, ≥5<8 years, ≥8 years. The collected data were entered into Microsoft Excel sheet and analyzed by Chi-square analysis using SPSS, (version 26.0). The results showed that, the major causes of death reported over the five-year period were ECF, Colibacillosis, Viral septicemia, Colisepticemia and Pneumonia. To test whether factors such as; sex, age, birth weight, parity, and season had a significant association with the cause of death a Chi-square analysis was performed. The results showed that; age of the cattle, season of death, and sex were significantly associated with the mortality causes of the cattle at Beef Research Centre - Lanet. Tick-borne diseases were the major causes of mortalities.

Keywords: *Beef Research Institute, cattle, mortality*

Introduction

Cattle are a source of food, particularly protein for human diets and they provide income, employment, transport, can serve as store of wealth, they also provide draft power, organic fertilizers for crop production milk, hides and fat (Perry *et al.*, 2005; Rushton, 2013). Kenyans in the rural areas derive a range of financial benefits from livestock keeping, including the provision of credit, insurance and as a means of sharing risk (IGAD, 2021). According to the Kenya National Bureau of Statistics (KNBS), the value added by livestock to the agricultural sector of the Kenyan economy was 318.971 billion Kenya shillings (Ksh) in 2009, of which 197.018 billion Ksh was from cattle milk and Ksh 53.960 billion from cattle offtake. This means cattle contributes 78.7 % of the total livestock contribution to GDP (IGAD, 2011). Optimization of animal production is therefore of paramount importance to both Kenyan economy and food security of the nation

However, there are constraints that cattle keepers are facing which hinders the optimization of livestock production. The major constraints in cattle production were diseases, lack of feeds and problems of provision and delivery of livestock services (Emongor *et al.*, 2007), with diseases of cattle being the most significant and responsible for most mortality cases.

According to Mureithi *et al*. (2015) diseases and parasites are among the most severe factors that impact livestock production and productivity. Diseases that reduce production, productivity and profitability are associated with the cost of treatment, disruption of local markets, international trade and exacerbate poverty on rural, local and regional communities. Livestock diseases can cause direct losses (mortality, stunted growth, reduced fertility and changes in herd structure) and indirect losses (additional costs for drugs and vaccines, added labour costs and profit losses due to denied access to better markets and use of suboptimal production technology) in revenue (Rushton and Knight,2015). Disease control strategies should be in place in all animal production enterprises; be it small scale or large scale farms to ensure increase in productivity.

Currently, the country's demand for meat exceeds production and thus, there is a projected growth of the sector. In anticipation of this growth, potential production constraints, such as animal health, need to be identified, (Ndiritu, 2020). Efficient production and limited losses are important for the farmers to realize maximum benefits from their enterprises. In order to minimize these losses, the causes of mortality and the associated risk factors need to be controlled appropriately.

Materials and Methods

Study design

The study used data from 116 post-mortem reports from Regional Veterinary Investigation Laboratory, Nakuru kept at the livestock records office. The records were from carcasses obtained from center during a period of 6 years from 2014-2019. Information on animal identification number, date of birth, sex, birth weight, parity, age at death, date of death and cause of the death were recorded. The data of animals in which post –mortem was carried out and with complete information was included in the study. Approximately 99% of the cattle had their carcasses diagnosis made through postmortem examination while the rest were inconclusive due to decomposition.

Data analysis

The collected data were compiled entered into Microsoft spread excel sheet and analyzed by Chi-square analysis using SPSS, (version 26.0) software in the light of the objective of study to determine factors associated with cattle mortality causes.

Chi-square (χ^2) analysis: For Chi-square analysis the distribution factors including sex of the cattle, age of the cattle, breed of the cattle, season of death, birth weight of cattle, and parity were made in columns while the cattle mortality causes (disease) were in rows. The Chi-square analysis for analyzing the categorical data is by comparing observed frequencies and expected frequencies as shown in the following formula;

$$\chi_c^2 = \sum \frac{(O-E)^2}{E}$$

Where,

O= Observed values

E= Expected Values

c = Degrees of freedom

Results and Discussions

Descriptive statistics

The major reported causes of death and monthly pattern are shown in figure 1, with the Tick-borne diseases (TBDs), specifically ECF, being the main cause of death at 31.9%. The other common causes are Colibacillosis, Viral septicemia, Colisepticemia and Pneumonia at 10.34%, 10.34%, 10.34% and 8.62% respectively.

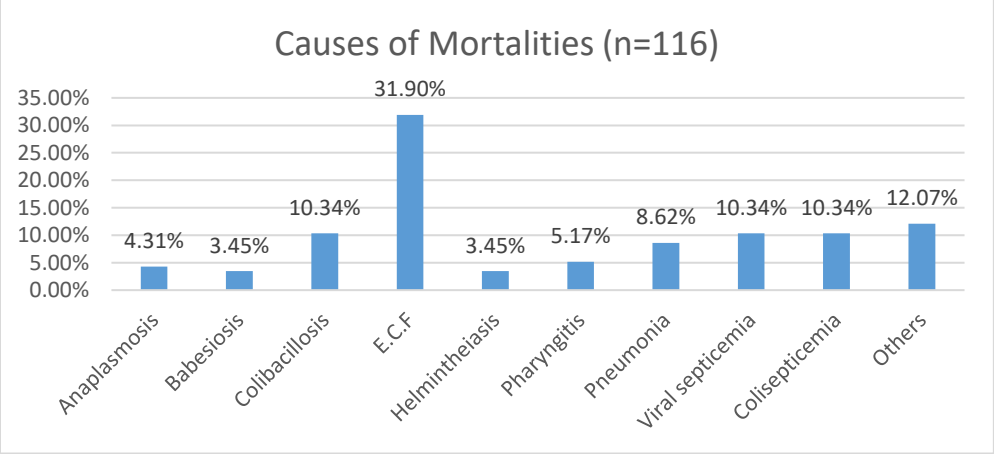

Figure 1: The common causes of cattle mortality in Beef Research Centre, Lanet

Factors associated with the mortality of beef cattle

Season of death

The Chi-square analysis over cattle mortality causes with respect to season of death, showed that the season of death had a significant (P<0.01) relationship with the causes of mortality. High overall mortality was observed in January to April season (56.03%), followed by September to December season (25%) and May to August (18.97%). This might be due to stress of high temperatures and scarcity of feeds during the dry periods, thus more efforts should be put to ensure that the cattle are provided extra rations during the period. This results are in agreement with findings of Banga *et al.* (2013).

	Season of death				χ^2
Causes of Death	**Jan-Apr**	**May-Aug**	**Sep-Dec**	**Total**	
Anaplasmosis	3	2	0	5	64.879***
Babesiosis	2	0	2	4	(0.000)
Colibacillosis	5	3	4	12	
E.C.F	36	0	1	37	
Helmintheiasis	2	0	2	4	
Pharyngitis	2	0	4	6	
Pneumonia	6	1	3	10	
Viral septicemia	4	3	5	12	
Colisepticemia	0	7	5	12	
Others	5	6	3	14	
Total	65	22	29	116	

*****1% Significance level**

Sex of cattle

The analysis shows that sex of the cattle had a significant effect of (P<0.05) in relation to the causes of mortality. Females had a high mortality rate as compared to males, the findings are in agreement with Hillary (2015) who found out that estrogen hormones in females affects the expression of virulence factors thus making them more prone to diseases hence high mortality, but results contradicts findings of Motus *et al.* (2017) that male cattle had a higher mortality risk than females

	Sex of cattle			χ^2
Causes of Death	**Female**	**Male**	**Total**	
Anaplasmosis	1	4	5	18.092**
Babesiosis	3	1	4	(0.034)
Colibacillosis	8	4	12	
E.C.F	30	7	37	
Helmintheiasis	3	1	4	
Pharyngitis	4	2	6	
Pneumonia	6	4	10	
Viral septicemia	3	9	12	
Colisepticemia	6	6	12	
Others	9	5	14	
Total	73	43	116	

**5% Significance level

Age of cattle

Age had a high significant (P<0.001) effect on mortality causes. Young stock of less than six months had a high mortality rate as compared to the older animals, this could be as a result of low immunity during the early stage, this is in agreement Chaudhary *et al.* (2013) calves had highest mortality (16.09%) due to poor management problems followed by 2.48% cases of digestive diseases.

	Age Category of cattle							χ^2
Causes of Death	**<6 months**	**≥6 Months< 1 year**	**≥1 < 2 years**	**≥2 < 5 years**	**≥ 5 < 8 years**	**≥ 8 years**	**Total**	
Anaplasmosis	4	1	0	0	0	0	5	79.499***
Babesiosis	0	0	0	1	3	0	4	(0.001)
Colibacillosis	5	3	1	2	0	1	12	
E.C.F	5	3	0	15	9	5	37	
Helmintheiasis	0	0	1	1	1	1	4	
Pharyngitis	3	0	0	0	1	2	6	
Pneumonia	5	1	2	1	0	1	10	
septicemia	5	1	5	1	0	0	12	
Colisepticemia	3	1	1	1	5	1	12	
Others	6	0	0	3	3	2	14	
Total	36	10	10	25	22	13	116	

***1% Significance level

Birth weight of cattle

The Chi-square analysis over cattle mortality causes with respect to birth weight, showed that the birth weight had no significant effect on the causes of mortality.

	Birth weight of cattle	χ^2

Causes of Death	≤ 20 Kgs	>20≤25Kgs	>25≤29Kgs	Above 29 Kgs	Total	
Anaplasmosis	0	2	3	0	5	23.735
Babesiosis	0	3	0	1	4	(0.645)
Colibacillosis	1	3	6	2	12	
E.C.F	1	15	18	3	37	
Helmintheiasis	0	2	2	0	4	
Pharyngitis	1	3	2	0	6	
Pneumonia	1	5	4	0	10	
Viral septicemia	0	5	6	1	12	
Colisepticemia	0	3	5	4	12	
Others	1	6	7	0	14	
Total	5	47	53	11	116	

Parity

The Chi-square analysis of analysis over cattle mortality causes with respect to parity, showed that parity had no significant effect on the causes of mortality.

	Parity							χ^2
Causes of Death	**First**	**Second**	**Third**	**Fourth**	**Fifth**	**Sixth**	**Total**	
Anaplasmosis	2	1	1	1	0	0	5	41.588
Babesiosis	1	1	0	1	1	0	4	(0.617)
Colibacillosis	4	3	1	3	1	0	12	
E.C.F	7	14	7	5	4	0	37	
Helmintheiasis	1	0	3	0	0	0	4	
Pharyngitis	2	1	1	1	1	0	6	
Pneumonia	5	2	1	0	1	1	10	
Viral septicemia	6	4	0	1	1	0	12	
Colisepticemia	5	2	2	3	0	0	12	
Others	5	3	3	3	0	0	14	
Total	38	31	19	18	9	1	116	

Conclusion

Tick Borne Diseases were the major causes of mortalities. The other dominant diseases were Colibacillosis, Viral septicemia, Colisepticemia and Pneumonia. Age, sex, season of death and season of birth were significantly associated with the causes of mortalities. Mortalities were high in calves as compared to adult cattle, probably due to increase in immunity as the cattle grows older. High mortalities were experienced in females than males this was due to virulence factor found in females. The Jan-April season of both death and birth had a greater contribution to mortality causes this was attributed to stress and inadequate feeds.

Recommendations

Proper vaccinations and good management especially on the calves and during dry seasons should be put in place to control the mortality rate. Measures to control the animal diseases should implemented in all livestock farms to prevent future losses.

Acknowledgment

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Prevalence of Gastro-Intestinal Helminthes in Beef Cattle at Beef Research Institute, Lanet, Kenya

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Abstract

A study was conducted to ascertain the prevalence of gastrointestinal helminthes in beef cattle at KALRO Lanet. A total of 59 fecal samples from each cattle rectum were collected in well-labelled sterile polythene bags and brought to the parasitology laboratory for examination and analysis. All feacal samples were analyzed for the presence of gastrointestinal (G.I) helminthes using both floatation and sedimentation methods. The data collected was from samples from cattle from 2017 through to 2022. The data was entered into Microsoft excel for analysis, where parameters such as age, breed, sex and season were taken into consideration. Out of the 59 cattle samples used, 33 (55.9%) were positive for G.I. helminthes infection, while those unaffected were 26 (44.1%). Nine different types of helminthes were identified. Out of these helminths, *M. digitatus* was high with a prevalence of 25%, followed by *O. radiatum* (8%), *S. laryngeus* (7%), *Schistosoma* (7%), *Strongyloides* and *F. cobboldi* at 3% each, *S. japonicum* and *B. phlebotomum* had the least prevalence of 2% each. The findings revealed that Boran cattle breed had the highest prevalence (40%) and brown swiss cattle the lowest (2%). The prevalence of helminthes was highest among females at 59% than males (41%). It was also found that, the occurrence of G.I. helminthes infection was highest among cattle below one year at 51% and lower for those above the age of one year. In conclusion, the prevalence of gastrointestinal helminthes was slightly higher and this has a negative impact on both animal production and public health. To mitigate these negative effects of helminthes, appropriate anthelminthic regime and control measures is encouraged.

Key words: *Gastrointestinal, helminthes, parasitology, prevalence*

Abstract

A study was conducted to ascertain the prevalence of gastrointestinal helminthes in beef cattle at KALRO Lanet. A total of 59 fecal samples from each cattle rectum were collected in well-labelled sterile polythene bags and brought to the parasitology laboratory for examination and analysis. All feacal samples were analyzed for the presence of gastrointestinal (G.I) helminthes using both floatation and sedimentation methods. The data collected was from samples from cattle from 2017 through to 2022. The data was entered into Microsoft excel for analysis, where parameters such as age, breed, sex and season were taken into consideration. Out of the 59 cattle samples used, 33 (55.9%) were positive for G.I. helminthes infection, while those unaffected were 26 (44.1%). Nine different types of helminthes were identified. Out of these helminths, *M. digitatus* was high with a

prevalence of 25%, followed by *O. radiatum* (8%), *S. laryngeus* (7%), *Schistosoma* (7%), *Strongyloides* and *F. cobboldi* at 3% each, *S. japonicum* and *B. phlebotomum* had the least prevalence of 2% each. The findings revealed that Boran cattle breed had the highest prevalence (40%) and brown swiss cattle the lowest (2%). The prevalence of helminthes was highest among females at 59% than males (41%). It was also found that, the occurrence of G.I. helminthes infection was highest among cattle below one year at 51% and lower for those above the age of one year. In conclusion, the prevalence of gastrointestinal helminthes was slightly higher and this has a negative impact on both animal production and public health. To mitigate these negative effects of helminthes, appropriate anthelminthic regime and control measures is encouraged.

Key words: *Gastrointestinal, helminthes, parasitology, prevalence*

Introduction

In Kenya, cattle are among the most prominent domesticated livestock that serve as valuable assets in the agricultural sector since they provide animal protein, milk, employment, hide, and skin for leather production and beef during festive seasons. Meat is one of the most important livestock products, although there could be losses due to various diseases including helminth infections. Helminths are known to be a major constraint to ruminants' well-being and productive performance. Helminths are parasitic worms and are major enteric parasites affecting important ruminants like cattle, sheep, and goat. They cause great economic loss in livestock in Africa, and can be categorized as either direct or indirect losses (Maichomo et al., 2004). Indirect losses associated with helminth infections include the reduction in productive potential such as decreased growth rate, weight loss, diarrhea, anorexia, and sometimes anaemia. The occurrence of helminths is influenced by predisposing factors such as grazing habits, climate, nutritional deficiency, pasture management, immunological status, vector, presence of intermediate host, and the number of infective larvae and eggs in the environment. It is important to control internal parasites through better management as in developed countries, and knowledge on prevalence of these parasites is mandatory. There is limited knowledge on the common gastro-intestinal parasites in different cattle breeds at BRI Lanet. This study focused on determining the prevalence of gastro-intestinal parasites in beef cattle at KALRO Lanet and determination of factors affecting susceptibility of cattle to helminths.

Methodology

Study area

The study was conducted at Beef Research Institute (BRI) Lanet. Geographically, the area lies on latitude 0° 18¢W and longitude 36°09¢E, 1920 metres above sea level in Lanet Location, Dundori Division of Nakuru North Sub County. It is about 16 km South East of Nakuru City. The Centre occupies 1,418 hectares of land (BRI Annual report, 2014), of which 20% is in ecological zone three and 80% in ecological zone four (Jaetzold et al., 2010). The rainfall pattern at Lanet is bimodal with an annual mean of 800mm and a relative humidity of 83%. The mean minimum and maximum temperatures are 10°C and 26°C respectively.

Collection and analysis of fecal samples

There are different cattle breeds in the Institute which include Boran, Orma Boran, Sahiwal, Friesian, Ayrshire and cross breeds. Deworming is done after every three months using albendazole which is a broad spectrum anti-helminthic. The study was conducted using 59 cattle.

A total of 59 fecal samples from each cattle rectum were collected in well-labelled sterile polythene bags and brought to the parasitology laboratory for examination and analysis. All feacal samples were analyzed for the presence of gastro-intestinal helminths using both floatation and sedimentation methods, as described by Cheesbrough. Floatation methods were carried out to detect cestode and nematode eggs as they are lighter. In contrast, the sedimentation method was carried out to detect the trematode eggs as they are heavier. For the floatation method, approximately 1.0g of the fecal sample was scooped and transferred into a suitable clean universal test tube. Five (5) ml of saturated salt solution was added, and the mixture was emulsified and sieved into another clean test tube. This is then covered with a clean grease-free microscopic slide, avoiding the air bubbles and over flooding. The slide was removed by inversion and covered with a clean glass coverslip. Each of the samples was examined under the microscope with X10 and X40 objectives, respectively. For the sedimentation method, approximately 1.0g of the fecal sample was transferred into a suitable clean universal test tube. 5ml of distilled water was added, and the mixture was emulsified. The mixture was sieved into another clean test tube, and more distilled water was added and allowed to be settled on a bench for one hour. The supernatant was discarded, and distilled water was added allowing it to settle for an hour. A Pasteur pipette was used to drop the sample to the Centre of the clean grease-free microscopic slide and examined under the microscope with X10 and X40 objectives, respectively.

Data collection and analysis

Desk top review of secondary data from the parasitology laboratory was used. The data collected was from samples collected from cattle from 2017 through to 2022. Parameters such as age, breed, sex and season were taken into consideration. The data was entered into Microsoft Excel, cleaned and analyzed.

Results

Table 1 presents the prevalence of gastrointestinal helminthes. The findings of the study reveal a wide occurrence of G.I. helminth parasites in cattle at BRI Lanet. Out of the 59 cattle samples used, 33 (55.9%) were positive for G.I. helminths infection, while those unaffected were 26 (44.1%). Seven different types of helminths were identified. Out of these helminths, *M.digitatus* was high with a prevalence of 25%, followed by *O. radiatum* (8%), *S.laryngeus* (7%) *Schistosoma japonicum* (7%), *Strongyloides* and *F.cobboldi* at 3% each, *S.japonicum* and *B.phlebotomum* had the least prevalence of 2% each.

Table 1: Prevalence of gastrointestinal helminths obtained among cattle at BRI-Lanet, Kenya.

	Helminth spp	Frequencies	Prevalence
1	*Bunostomum phlebotomum*	1	2
2	*Mecistocirrus digitatus*	15	25
3	*Oesophagostomum radiatum*	5	8
4	*Syngamus laryngeus*	4	7
5	*Schistosoma japonicum*	4	7
6	*Strongyloides*	2	3
7	*Fischoederius cobboldi*	2	3
8	No helminths	26	44

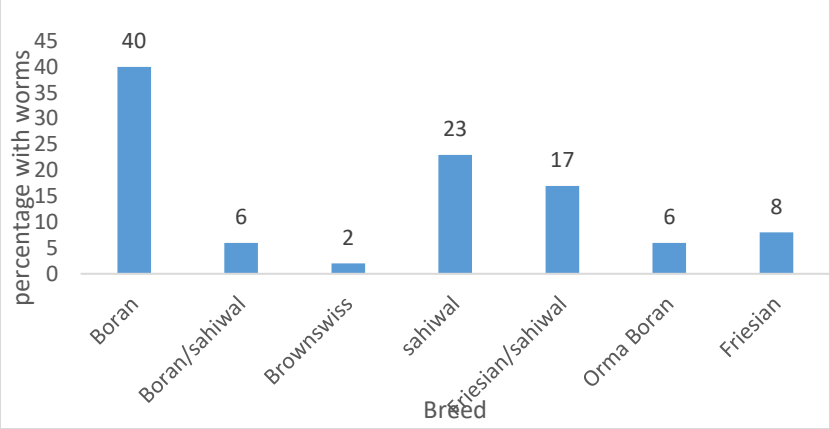

Figure 1: Susceptibility of cattle to worms categorized by breed

The prevalence of gastro-intestinal helminths were analyzed according to breeds as shown in Figure 1 above. The findings revealed that Boran cattle breed had the highest prevalence (40%) and brown Swiss cattle the lowest (2%). The other breeds had the following infection rates, Boran/Sahiwal (6%), Sahiwal (23%), Friesian/Sahiwal (17%) and Orma Boran (6%). The prevalence of G.I. helminths infection was further analyzed according to sex of the cattle sampled as shown in Figure 2. Out of the 59 samples, the prevalence was highest among females at 59% were while 41% were males.

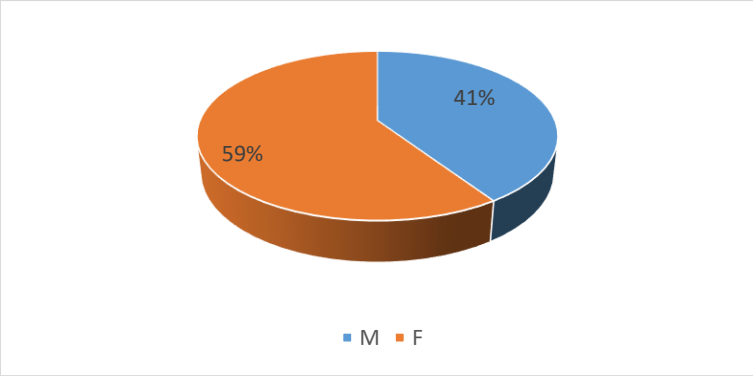

Figure 2: Susceptibility of cattle to worms categorized by sex of the cattle

Key-M-male, F-female

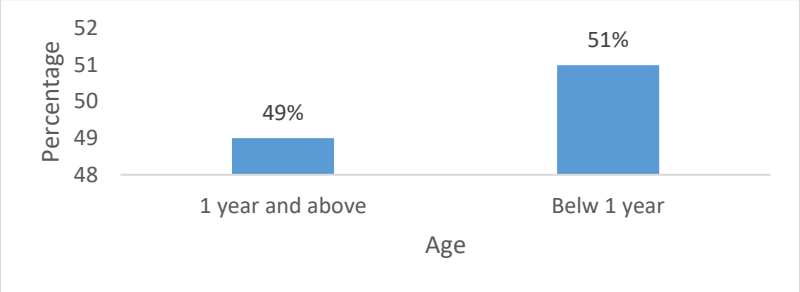

Figure 3: Susceptibility of cattle to worms according to age

The susceptibility of cattle to helminths was also analyzed according to age as shown in Figure 3 above. It was found that, the occurrence of G.I. helminth infection was highest among cattle aged one year and below (<1) at 51% and lower for those aged above one year.

Discussion

The results of this study showed that cattle at BRI Lanet are infected with a variety of gastrointestinal parasite species with a prevalence of 55.9%. This provided vital information on the burden of helminth infection in the farm. This finding agrees with the study done by Elele et al. (2013) that the prevalence of gastro enteritis of ruminants is usually high especially those kept under traditional methods of husbandry. Nematode infections were relatively high, as they accounted for 48.9% of the total helminth burden and trematodes 7%. High nematode infection has huge impact on livestock production since they result in reduced milk, meat, wool, hide products, and stamina of working animals (Nwosu et al., 2007; Ballweber, 2006). The previous studies reported by Hailu et al. (2019), Mir et al. (2013) and Nwigwe et al. (2018) reported trematodes was the most prevalent helminthes. The possible reason for the differences observed in the prevalence of the gastrointestinal helminth parasites recorded in this study and that recorded by other researchers may be because of the differences in locations, management practices (Regassa et al., 2006; Waruiru et al., 1993) and period of investigation The findings further reveal that female cattle have a slightly higher likelihood of being infected compared to males (Females 59% and males 41%). A similar study was done by Elele et al. (2013) and found that male cattle were more likely to be infected with helminths than the female. This may be attributed to the aggressiveness of male animals when feeding and thus likely to pick up more ova of helminths from the pasture. In terms of breed, the difference in infection rates may be attributed to the different numbers of cattle used in the study.

From the analysis, it was found that the occurrence of gastro-intestinal helminths was higher in cattle below the age of one year. This could be attributed to the fact that young animals tend to be aggressive and therefore graze everywhere. In the process, they end up picking infective stages of the helminths. The other reason is that calves are born with little immunity or natural resistance to worms and as the animal grows, the immunity becomes stronger and is able to resist. Compared to yearlings and younger animals, cattle aged ≥ 2 years carry lower worm burdens of stomach and intestine worms, and excrete fewer worm eggs for the size of their burden. This finding is in tandem with a study conducted by Colditz et al. (1996) in the Australian livestock industries, where susceptibility to infectious diseases in young animals was greater than in mature ruminants. It has also been found that the basis of host worm resistance is a more intensive immunological response to worm larvae, and that in some individuals, consequent gut inflammation is sufficient to lead to diarrhoea (Larsen et al., 1994; Shaw et al., 1999; Panti-May, et al., 2017).

Conclusion and Recommendations

The prevalence of gastrointestinal helminths was slightly higher and this has a negative impact on both animal production and public health. To mitigate these negative effects of helminthes, appropriate anthelminthic regime and control measures is encouraged. Finally, gastrointestinal parasites of cattle should be closely monitored to promote animal production and public health.

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Determination of Levels and Predictors of Mortalities in Cattle Beef in Kenyan Rangelands: Kaplan–Meier Method Approach

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Abstract

High health-related mortality has been frequently reported as the major impediment to cattle production. This study aimed at investigating the vital infectious diseases and non-infectious factors that account for the majority of deaths which is crucial in determining mortality control strategies. The study used the Kaplan–Meier method and truncated regression analysis using eight-year retrospective data spanning from 2014 to 2022. The results indicate infectious diseases as the most important cause of cattle mortality. The mean annual mortality rates are higher and the pre-weaning cattle mortality appeared to be one of the major constraints hampering the development of replacement herds. The risk factors considered for high mortality were the age and sex of the calve. The infectious diseases identified as the important causes of cattle mortality included bacterial, parasitic, and non-specific, while the non-infectious conditions included malnutrition, predation, shock, and traumatic injuries. The analysis provided an improved insight into animal-health-related factors which once addressed could reduce mortality and hence optimize animal husbandry performance. Interventions in cattle health, and husbandry are recommended to control pre-weaning calve mortality.

Keywords: *Kaplan–Meier method, truncated model, mortality rate, infectious diseases, Cattle, Kenya*

Introduction

Cattle are culturally the main livestock species amongst communities living in the rangelands of Kenya followed by goat and sheep, camel, and donkey in that order. The main cattle breeds kept in the rangelands are the Zebu and Boran which together contribute to a national market supply of 70% of the total beef production (Government of Kenya, 2012). However, desirable results are yet to be

observed, and this can partly be associated with the problems of herd health and adaptability which are partly attributed to the persistent exposure to multiple stresses of low quality and quantity feed, heat stress, high disease, and parasitic incidences, poor husbandry and breeding practices (Njarui *et al.*, 2011; Ngila *et al.*, 2016). The combined effect of these factors is high cattle mortality. Amongst the highlighted factors, high health-related mortality forms the major impediment to cattle production (Interbull, 2015). Since the dynamics of an animal population is the result of the balance between mortality and replacement, an appropriate understanding of either mortality (or survival) patterns is one of the keys to animal genetic evaluation for the reason of fundamental or applied goals and this forms the premise of this study.

There's a paucity of retrospective studies addressing the causes of death in cattle in Kenya, thus making it difficult for decision-making on control strategies. Neither assumption made in the previous studies under similar terrain (Perrin *et al.*, 2012; Rumor *et al.*, 2015; Struchen *et al.*, 2015; Molossi *et al.*, 2021; Credille, 2022) can be expected to hold in the more tropical regions of the Kenyan rangelands, where cattle are routinely subjected to long periods of nutritional stress and high disease incidences. Therefore, there is a need to document the causes of these mortalities and put in place measures to control deaths, since cattle form a considerable prospective opportunity for smallholder farming and income generation and may contribute significantly to poverty alleviation and food and nutrition security for communities living in these areas. Thus, in this study, we hypothesized an econometric relationship would be required to specifically address this information gap by estimating the cattle mortality rates as well as identifying the infectious and non-infectious factors associated with mortality which would be a target for determining mortality mitigation strategies.

Materials and methods

Study Areas and Animals

The study was conducted in an arid and range lands research station, Kiboko ranch, that lies between latitude 2° 10' and 2° South and longitude 37° 40' and 37° 55' East. The institute's mandates include developing, adapting, and up-scaling scientific research innovations, information, and knowledge geared towards sustainably managing the livelihoods of communities living in the arid and semi-arid lands of Kenya. The institute is located in agro-ecological zone V which is not ideal for arable agriculture but suitable for livestock production. The area receives a bimodal rainfall pattern, and the vegetation is mainly bushy grassland with scattered acacia and commiphora trees. The soils are mainly sandy loams. The study animals were Small East African Zebu and Boran crosses.

Data collection and analysis

A retrospective approach was used where mortality data was extracted from the cattle registry. This register compiles information on cattle herds (identification number, sex, and age, date of death/birth, and autopsy findings (conducted by a qualified veterinary surgeon). The records were initially recorded on paper by animal health technicians on daily basis and transferred to the Microsoft (Ms) Excel sheet for storage and further analysis. The study used this database to categorize the daily number of live and dead cattle between the years 2014 and 2022.

Infectious factors were categorized as protozoan (anaplasmosis, babesiosis, ECF, trypanosomosis), bacterial (pneumonia, enteritis, septicemia/toxemia, enterotoxaemia, scours, anemia, CBPP, metritis, pyometra, sinusitis, myocarditis, etc), parasitic (haemonchosis and haemonchus),

Rickettsial diseases (heartwater/cowdriosis) and other conditions (such as bloat, calculi, uremia, hardware disease, hepatitis, senescence, percadisise, trauma and viral conditions like rabies), and non-specified disease causes. Non-infectious causes included shock (hypothermic and cardiogenic), traumatic injuries, predation, plant poisoning, malnutrition, dystocia, premature birth (abortions and stillbirth), and postnatal/congenital defects. The sample comprises 96 observations, with minimal outliers which were omitted during analysis.

Data analysis was twofold; employing the Kaplan-Meier method and econometric model approach using Ms Excel and STATA statistical software. Under the Kaplan-Meier method, the study involved computing the probabilities of cattle mortality at a certain point in time using the widely used Kaplan-Meier nonparametric method (Kaplan and Meier,1958; Adelöf, *et al.,* 2021). The survival probability of cattle at any particular period (C_p), was calculated using the formula provided below;

$$C_p = \frac{Number\ of\ cattle\ living\ at\ the\ start + Birth - Number\ of\ cattle\ that\ died}{Number\ of\ cattle\ living\ at\ the\ start + Birth}$$

Since the herd size is dynamic and births are experienced at any time, this means that any births become a part of the study later. In some cases, there is often a shorter observation period and those cattle may or may not experience death in that short stipulated time. However, we cannot exclude those cattle since otherwise, the sample size of the study may become small. The Kaplan-Meier method allows us to compute survival over time despite such difficulties associated with situations (Goel *et al.,* 2010; Grzesiak *et al.,* 2022). The total probability of survival till that time period was calculated by multiplying all the probabilities of survival at all-time intervals preceding that time (by applying the law of multiplication of probability to calculate cumulative probability) (Kaplan and Meier,1958; Grzesiak *et al.,* 2022). Then, the probability of cattle dying (cumulative mortality) is 1 (one) minus the probability of cattle survival (cumulative survival). Cattle which were sold out were not counted as "at risk", hence were considered "censored" and are not accounted for, in the denominator.

$$\text{Annual mortality} = \frac{Deaths}{Total\ heard\ at\ start + births}$$

The second phase of analysis involved the determination of the effect of various causes on cattle mortality. Since econometric models offer estimates of actual values for forecasted variables and indicate both the direction and magnitude of change, then it was found appropriate to determine the effect of infectious and non-infectious factors on cattle mortality for uncensored data. In this paper, the outcome measure of interest was mortality, defined as any death of a study animal occurring during the period of observation and attributed to an infectious and non-infectious disease cause. The independent variables included infectious factors being the protozoan, bacterial, parasitic, rickettsial diseases and other conditions, and non-infectious factors categorized as shock, traumatic injury, predation, plant poisoning, malnutrition, dystocia, premature birth, congenital/postnatal defects, non-specified causes. Truncated regression of the normal distribution was performed to identify risk factors for cattle mortality. This model type was selected because sample truncation is a pervasive issue in quantitative animal sciences, particularly when using observational data (Abot 2020; Ouédraogo *et al.,* 2022). Truncation reduces the variance compared with the variance in the untruncated (Heckman, 1979; Dongfang *et al.,* 2017). A truncated regression is one in which the values of the explanatory variables are observed only if the value of the dependent variable is

observed and, thus following Greene (2010) and Reinhammar (2019), a truncated regression (at zero) was specified as;

$$y_i = X_i'\beta + \varepsilon_i, i = 1, \ldots, n$$

$$\varepsilon_i \sim iidN\ (0, \sigma^2)$$

Where y_i and x_i are observed number of livestock death and risk factors causing mortality respectively, the truncated form below for $y_i > 0$. The factors related to infectious and non-infectious diseases were considered independent variables (x_i) and livestock death as a dependent variable (y_i). Term ε_i is the random error associated with random shocks, not under the control of economic agent *i*, and in this case capture weather changes or any economic adversity. The X-vector parameter estimate for mortality level ($\widehat{y_i}$), is expected to have a positive sign, which implies the corresponding variable would increase the level of cattle mortality rate. The analyses were carried out using the maximum likelihood estimation (MLE) procedure. The use of the MLE technique applies because the error terms nested on these equations are assumed to follow a certain distribution, and our goal is to obtain the "most likely" estimate rather than one which minimizes the sum of squares as is the case with ordinary least squares.

Results and Discussions

Kaplan–Meier estimates

The Kaplan–Meier versus common estimates for mortality are displayed in Table 1. Looking at Table 4, the cattle production cycle was taken as eight-year-round twelve intervals, conforming to the times of death of the 339 cattle. The year-round average number of cattle was about 399, while a total of 876 cattle exited the herd through death or sale. Based on the Kaplan–Meier functions, the cumulative survival decline could be observed and this translates to an increase in the cumulative mortality for the entire period of about 50.2% against the reported 66.2% when the common method of annual mortality estimation is used. However, the average all-cause mortality rate estimated using the common method was 0.0735 (7.35%) per 100 animal risk years. The proportion surviving of cattle per year seems to be relatively high and ranges from 0.848 (84.8%) to 0.976 (97.6%). Comparable survival probability for cows culled for different reasons was observed in Grzesiak *et al.*, (2022) study.

Table 1. Kaplan-Meier estimate for cattle

Years	Total Herd	Births	Sale	Deaths	Kaplan-Meier method			Ordinarily method
					Proportion surviving on this day (p)	Cumulative survival ($p * p_{t-1}$)	Cumulative mortality (CM)	Annual mortality
2014	462	70	1	51	0.9044	0.9041	0.0959	0.0959
2015	541	50	14	24	0.9594	0.8674	0.1326	0.0406
2016	552	105	103	84	0.8721	0.7565	0.2435	0.1279
2017	468	65	133	81	0.8481	0.6415	0.3585	0.1521
2018	321	53	67	9	0.9759	0.6261	0.3739	0.0241
2019	298	75	37	22	0.9411	0.5892	0.4108	0.0591
2020	305	81	50	17	0.9551	0.5632	0.4368	0.0441
2021	323	108	2	33	0.9234	0.5201	0.4799	0.0766
2022	386	39	70	18	0.9576	0.4981	0.5019	0.0424
Cumulative		**646**	**477**	**339**				**0.6623**

Note: CM = 1-cumulative survival
Source: Authors' construction

Age-specific mortality rate

The statistical analysis of mortality rates recorded in cattle production between 2014 and 2022 was skewed and showed a clear influence of age and sex as shown in Table 2. A higher mortality rate was reported in the young ones (calves and weaners). Early mortality for calves during the first six months of their lifetime accounted for 30% of the total mortalities and was particularly high in female calves.

The highest proportion of mortality period (55.1%) was experience during calf-to-weaningperiod. Similar high mortality of about 67% for calves within a week after birth with the cause of death most frequently recorded as unspecific was reported by Bunter *et al.*, (2013). However, there was no significant difference in the number of deaths within the 1-5-year period. The high mortality of calves during the first one year reported in the present study means the ranch cannot raise enough stock to replace the loss, let alone expand the herds, and, therefore, more attention to calf management is a critical concern. This is because a reduction in calves' mortality would translate into an increase in herd size and consequently the increase in male and culled off-take.

Overall, the result showed high female mortality which was also inversely related to age. Since the herd composition differed somewhat between the sexes (with more females being maintained for herd expansion while males are frequently selected for off-take), the high female mortality rates could thus reflect these differences. The low mortality observed in males might also be attributed to regular culling of males upon attaining one year of age to maintain a limited number of males for breeding purposes. A similar result was observed in a study conducted by Mlimbe *et al.*, (2020).

Table 2: Mortality prevalence by age categories

Age category	Proportion (%)	Male (%)	Female (%)
Calves (≤6 months)	30.0381	45.5696	54.4304
Weaners (7 to 12 months)	25.0951	45.4546	54.5455
Heifers/bulls (1 to 2 years)	9.5057	72	28
Mature (2 to 3 years)	9.5057	68	32
Mature (3 to 5 years)	8.3651	72.7278	27.2727
Mature (5 to 8 years)	15.5894	97.5609	2.4391
Mature (8 years and above)	1.9011	80	20
Total proportion (in %)	100	38.7833	61.2167

Source: Authors' construction

Econometric estimation of the causes of livestock mortality

To investigate the direction and magnitude of the various infectious and non-infectious factors that cause cattle mortality, the truncated model was fitted. The truncated regression analyses examined all possible interactions among variables with death as the dependent variable (Table 3). The estimates of sigma square (σ^2) are significantly different from zero at a 1% level of significance, implying a good fit of the specified distribution assumptions of the error term and the Wald Chi-square value showed that statistical tests are highly significant ($P < 0.01$), suggesting that the model had strong explanatory power. The results are presented in Table 3.

Table 3. Predictors for cattle mortality and percentage contribution (proportion)

Variable	Coeff.	Percent proportion	Ranking
_cons	-0.00344±0.0277	-	-
Diseases	0.9965±0.0063***	64.7273	1
Dystocia	0.9831±0.0873***	0.7273	6
Premature birth	1.0016±0.03795***	2.9091	4
Postnatal defects	0.47057±0.2331**	0.3636	7
Shock	1.00697±0.02439***	3.2727	3
Malnutrition	1.0475±0.01476***	20.3636	2
Injury	0.9543±0.0455***	2.1818	5
Predation	0.9815±0.0366***	3.2727	3
Plant poisoning	1.0139±0.0543***	2.1818	5
/sigma	0.1192±0.0111***	-	-
Wald chi2(9)	135324.28***	-	-
Log-likelihood	41.0796	-	-

Sources: Author's own

Regarding covariant variables included in the model, the results as indicated in Table 3 are robust and all had the expected positive sign. The disease-related factors were identified as the major cause of mortality in the cattle production of the study area. In the present study, the magnitude of cattle mortality attributed to diseases is 0.996 which is statistically significant (at a 1% level), and the contribution to the overall mortality is about 65%. The high risk associated with diseases indicates that the most important area of intervention in reducing cattle mortality should be health management.

Among the non-infectious conditions associated with cattle mortality, malnutrition tops the list followed by shock and predation. This finding is in tandem with the findings of Fentie (2016), who found malnutrition (which was presented as a feed shortage) as one of the major problems causing mortality in young stock across all species. Accordingly, the high disease-related mortality rate observed can be aggravated by the effect of malnutrition in terms of feed and milk shortages that could compromise the immunity of young ones and expose them to diseases. Exposure to predators and plant poisoning, and traumatic injuries had a marginal effect on cattle mortality. Similarly, to Fentie's (2016) findings, the contribution of predators (hyena, cheetah, etc.) and injury (physical damage) in herds where young and adult animals share the same barns were important causes of mortality.

Having confirmed that disease-related syndromes were the main cause of mortality, an attempt was made to identify which particular disease conditions proportionally contributed to mortality in cattle. The findings of this analysis are displayed in Table 4.

Table 4: The main disease that causes cattle mortality

Variables	Cases	Proportion	Rank
Protozoa	32	17.9775	3
Bacteria	73	41.0112	1
Parasite	3	1.6854	6
Rickettsia diseases	26	14.6067	4
Other diseases	6	3.3708	5
Non specific	38	21.3483	2

Source: Author's own

The results revealed that bacteria majorly represented by pneumonia, enteritis, septicemia, enterotoxaemia, and calf scours were the major diseases in cattle, followed by protozoan diseases comprising of anaplasmosis, East Coast Fever (ECF), babesiosis, and trypanosomiasis. The percentage proportion mortality as a result of bacteria was 41%, and 18% was parasite-related. An in-depth study by Kocho (2007) also observed parasites across the different sites of Southern Ethiopia were not significantly different ($P>0.05$) which depicts that it is was not a major cross-cutting impediment to the livestock production in the region. Among the diagnosed diseases, rickettsia infections majorly represented by heartwater (or cowdrosis) disease also had the highest contribution which means its effects should be reduced to the bare minimum. Heartwater has been reported throughout sub-Saharan Africa (Uilenberg, 1983) and in Mozambique, Asselbergs *et al.*, (1993) observed that the disease does occur throughout the country and mainly during the rainy season.

Conclusion and Recommendation

This study has investigated levels and predictors of mortality in cattle production with an aim of identifying the main causes of death and the risk factors associated with infectious and non-infectious diseases. The all-cause mortality rate was estimated at 7.35% per 100 animal risk years with an annual cumulative mortality of 50%. Mortality attributed to infectious diseases was estimated at 65%. This study also revealed that mortality in calves is likely to be above 54%. The risk factors considered for high mortality were age and sex of the calves. The pre-weaning mortality of cattle appeared to be one of the major constraints hampering the development of replacement

stock. The critical time for higher cattle mortality was during the first six months of life-extending up to 12 months of age. Therefore, for an efficient cattle production system, survival of female calves is required for herd expansion and breed improvement, while that of male calves is important as a source of income from sales; so the mortality against pre-weaning, in general, should be reduced to the bare minimum.

Regarding infectious and non-infectious conditions influencing mortality, an econometric model was fitted and disease and malnutrition appeared to be the most important causes of cattle mortality. The model displayed that, bacterial diseases, parasitic conditions, and non-specific diseases were the most common challenges of raising cattle in the rangelands of Kenya. Overall, infectious diseases contribute to high mortalities in cattle production. However, many of the health problems of cattle can be controlled throughnutrition and recommended management practices. Modest interventions, for example, minimizing herd loss through disease control and protection against predators and proper feeding to curb the effect of malnutrition could potentially boost the flock's performance. Veterinary services should provide strategic disease prevention, control, and treatment measures. Future studies should investigate the effects of specific farm management practices on cattle mortality which together with the insights provided by this study will help in constructing a conceptually comprehensive stock-and-flow model of a representative cattle production system for Kenyan rangelands.

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Slaughterhouse Tap Water Quality: A Case of Kajiado County

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Abstract

The study determined the microbiological and chemical quality of tap water utilised for sanitation procedures, at 5 slaughterhouses in Kajiado county. While classical techniques for cattle and carcass inspection are done to control the transmission of parasites and notifiable diseases to consumers, the role of slaughterhouse water on impact to meat safety is poorly understood. From the standpoint of slaughterhouse-borne infections, meticulous care is required across all slaughter operations and resources to prevent illness and harm. Bacteriological analyses of water determined total and faecal coliform, *Escherichia coli (E. coli), Salmonella* and *Shigella* species and confirmed with biochemical assays. Chemical analyses determined pH, temperature, electrical conductivity (EC) and total dissolved solids (TDS), turbidity, Iron (Fe) and aluminium (Al), fluoride, nitrate, nitrite and ammoniacal nitrogen.

Out of the five samples, four (80 %) tested positive for presumptive coliform bacteria with Most Probable Number (MPN) indices ranging between 17 and >1609, three (60 %) were confirmed positive for E. coli, 1 (20 %) for Salmonella species while three (60 %) samples presumed as Shigella species were confirmed to be Pseudomonas aeruginosa. The five water samples had acceptable appearance, pH and turbidity, but temperatures exceeded the global safety limit of 15 ℃. Two samples exceeded guidelines in Fe (0.2 ppm), recording 0.35 ppm (M3) and 0.24 ppm (M1C), with the later also exceeding in EC (2500 µS/cm) and TDS (1000 ppm), attaining 2533 µS/cm and 1260 ppm respectively. One spring water (M1A) and one borehole water (M2A) sample had ammoniacal nitrogen and fluoride levels of 0.72 ppm and 2.05 ppm respectively, which were beyond the global

limits of 0.5 ppm and 1.5 ppm respectively. Aluminium and nitrate levels were low ranging from 0.027 to 0.059 ppm and 0.42 to 2.24 ppm respectively. Nitrites were not detected.

Faecal contamination of water intended for slaughterhouse hygiene and sanitation rises public health concern for the presence enteric pathogens and opportunistic infections. Sensitization of slaughterhouse management and local authority on the consequences of poor-quality potable water on meat safety, personnel health and slaughter operations should be prioritized. The study recommends the routine water quality monitoring between slaughter facilities and local government to verify quality and safety of water for use.

Keywords: *microbial water quality, potable water, Salmonella, slaughterhouse, water quality*

Introduction

Water is a fundamental resource in slaughterhouses, playing a vital role in many applications including hide washing, carcass washing, meat processing, hygiene and sanitation of personnel, disinfection and sanitizing of equipment and the facility (Dickson & Acuff, 2017). Underestimating the fundamental significance of microbial and chemical quality of water may have negative impacts on product and food safety, in addition to operations such as water management and equipment operation and maintenance (Bhagwat, 2019). Kajiado County lies in the arid and semi-arid zones, receiving an average annual rainfall of about 400 mm/year. The main sources of water include seasonal rivers, shallow wells, springs, dams, water pans and boreholes. Several local government subsidiary companies provide water and sewerage services in the county however, their services have not been streamlined to guarantee sustainable management of water and sanitation for the population. It's underdeveloped water supply systems contributes to frequent acute shortage of potable water for drinking and other functional uses, leaving only 36 % of the population having access to potable piped water. As of 2018, there had been no county-led routine water monitoring programs to assess the water quality of its surface, ground waters, nor of the water providing companies (Kajiado County, 2018) which allows instances of potentially severe microbial contamination to go unnoticed. The county's primary objective appears to be merely increasing water harvesting and distribution infrastructure with provision of safe water limited to health and learning institutions. With nearly 20 registered slaughter facilities across the county, the lack of reliable potable water for slaughter operations is a worrying concern.

Materials and methods

Tap water samples were collected from 5 slaughterhouses located in towns across Kajiado County, namely in Namanga town (M1A), Bissil (M1B), Kajiado town (M1C), Isinya (M2A) and Kiserian (M3). All the taps were located inside the slaughtering hall were utilized in all sanitation activities as well as carcass washing. The samples were stored in a cool box and chilled with ice packs and transported to the laboratory in 5 hours.

Multiple tube fermentation (MTF) technique was used for the presumptive determination of total coliforms using MacConkey Broth Purple (MAC) and faecal coliforms were determined by the differential coliform (Eijkman) test. Presumptive *E. coli* were streaked onto Eosin Methyl Blue (EMB) agar and presumptive *Salmonella* and *Shigella* colonies on pre-enriched (tetrathionate broth) were enumerated on Xylose Lysine Desoxycholate agar (XLD). Triple sugar Iron (TSI) test, Urease test and Motility Indole Ornithine (MIO) test were the biochemical confirmatory assays performed.

A portable multiparameter meter was used to measure water pH, electrical conductivity (EC), total dissolved solids (TDS) and temperature. Turbidity was determined by a Spectrophotometer at a wavelength of 882 nm. Fluoride, nitrate and nitrite were determined by an Ion Concentration meter each test having its own unique electrode. Total Fe and Al were determined by an Atomic Absorption Spectrophotometer with corresponding cathode lamps and flames while ammonia was determined as ammonical nitrogen (NH_3-N).

Results

The microbial presumptive results are summarised in Table 1. Only 1 (20 %) water sample (M1B) met the WHO guideline for total coliform scoring an MPN index of < 2. The other 4 (80 %) samples were positive for presumptive coliform bacteria with MPN index of 17, 130, 1609 and >1609 per 100 ml water sampled corresponding to M1A, M3, M2A and M1C respectively. 60 % (3 out of 5) of the samples, that is M1A, M1B and M2A tested positive for *E. coli*, 1 (20 %) was presumed as *Salmonella* while 3 (60 %) were presumed as *Shigella.*

Table 1. Presumptive total and faecal coliform, *Escherichia coli, Salmonella* and *Shigella*

SMS	Water source	MPN/100 ml	Faecal coliform (MAC)	*E. coli* (EMB)	*Salmonella* (XLD)	*Shigella/ Pseudomonas* (XLD)
M1A	Spring	17	-	+	+	-
M1B	Borehole	<2	-	+	-	-
M1C	Borehole	> 1609	-	-	_	+
M2A	Borehole	1609	-	+	_	+
M3	Borehole	130	-	-	_	+

MPN = Most Probable Number; MAC = MacConkey Broth, EMB = Eosin Methyl Blue, XLD = Xylose Lysine Desoxycholate media

Table 2 shows the results obtained from the confirmatory biochemical tests.

Biochemical tests	M1A	M1B	M1C	M2A	M3
TSI: slant / butt	NCC/A	A/A	K/K	K/K	K/K
TSI: H_2S production	H_2S	-ve	-ve	-ve	-ve
TSI: gas production	+ve	+ve	-ve	-ve	-ve
Urea	-ve	-ve	-ve	-ve	-ve
MIO: motility	+ve	+ve	-ve	-ve	-ve
MIO: Indole	+ve	+ve	-ve	-ve	-ve
MIO: Ornithine	-ve	+ve	-ve	-ve	-ve
Identification	*Salmonella*	*E. coli*	*P. aeruginosa*	*P. aeruginosa*	*P. aeruginosa*

KEY: H_2S = hydrogen sulphide production, NCC = No colour change, K = alkaline, A = acid, -ve = negative result, +ve = positive result

Water chemical quality results are summarised in Table 3.

Table 3: Sampled water chemical quality results

Sample	**Water source**	**Water pH (°C)**	**Ec (µS/cm)**	**TDS (ppm)**	**T (NTU)**	F (ppm)	Fe (ppm)	Al (ppm)	NH_3-N (ppm)	NO_3-N (ppm)	NO_2-N (ppm)
M1A	Spring	7.7 (23.7)	820	428	1.65	0.72	0.12	0.027	**0.72**	1.12	ND
M1B	Borehole	7.7 (25.7)	1884	953	1.1	0.78	0.02	ND	ND	0.42	ND
M1C	Borehole	7.9 (24.5)	**2533**	**1260**	2.11	1.33	**0.24**	ND	0.35	2.24	ND
M2A	Borehole	8.4 (23.4)	1920	979	2.1	**2.05**	0.11	0.059	0.49	1.40	ND
M3	Borehole	8.3 (26.1)	683	343	1.8	1.4	**0.35**	ND	ND	1.54	ND
WHO max. limits		**6.5-8.5 (15)**	**2500**	**1000**	**5**	**1.5 mg/L**	**0.2**	**0.2**	**0.50**	**10.00**	**1**

KEY: WHO = World Health Organization Guidelines on drinking water quality, Ec = Electrical conductivity, T = turbidity, NTU = nephlometric turbidity units, , F = fluoride, Fe = Iron, Al = aluminium, NH_3-N = ammonium, NO_3-N = nitrate, NO_2-N = nitrite, TDS = total dissolved solids

Discussion

Slaughterhouse water quality is paramount in facility sanitation and carcass hygiene. Total coliforms should not be present following treatment (WHO, 2022), and their presence in this study could suggest inadequate disinfection of the stored water sources and the distribution system. The presence of *Escherichia coli* in tap water across 3 slaughterhouses implies the possibility of faecal pollution of the spring and borehole sources. Similarly, the presence of *Salmonella* spp. in the water distribution in 1 slaughterhouse presents the potential dangers of these enteric pathogens to the slaughterhouse personnel, the food chain and ultimately to the beef consumers. *E. coli*, *Salmonella* typhi and other salmonellae particularly *S. enterica*, *S. bongori* and *S. dysenteriae* are classified among other pathogenic species of high significance in water-borne infections, with moderate persistence in water supplies. *Pseudomonas aeruginosa* was isolated across water taps of 3 facilities, but as of now, there is no evidence that regular uses of potable water sources contaminated with *P. aeruginosa* could be a source of infection in the general population. However, *P. aeruginosa* is a significant opportunistic pathogen to immunocompromised persons in hospital settings (WHO, 2022).

The 5 SMS in Kajiado get supplied with water from private suppliers of borehole and spring water and may not have direct control over the quality of water at source nor the treatment methods utilized. Only 1 manager (M3) out of the 5, declared that chlorination was the water treatment method utilized in their facility. Three declared that the water sources were treated but did not know the method, while one did not know the status of water treatment. This study supports the suggestion of Bhagwat *et al*, 2019, who found that water quality is frequently ignored in many food production and processing procedures. A study of meat and water quality across 18 South African poultry, pig and ruminant slaughterhouses reported that over 91 % of water samples tested positive for *E. coli*, contravening Government regulations (Ncoko *et al*, 2020). Similarly, an earlier study at a pig slaughterhouse in Indonesia reported that 33.3 % (n= 6) of its reservoir water tested positive for *E. coli* O157:H7 (Goma *et al*, 2019). Although the residual chlorine of M3 water sample was not determined at source, the considerably high MPN index is indicative of water contamination and inadequate chlorination.

The water sample temperatures had exceeded the national and WHO maximum levels by nearly 10 °C. As observed during the study, this may be partly explained by the exposure to direct sunlight of the overhead water storage tanks', which could warm the water during storage. Previous studies have implicated temperature to having the biggest impact on a network's water's microbiological stability (Mohammed *et al*, 2021). Increase in tap water temperature have been attributed to numerous factors including the prevailing weather, presence or absence of shade, installation depth of distribution pipes, type of soil and soil temperature, ground water levels, the presence of anthropogenic (subsurface) heat sources, and hydraulic residence times (Agudelo-Vera *et al.*, 2020).

Water pH is one of the most crucial operational water quality parameters affecting the corrosivity of piping and disinfection. Water samples from M2A and M3 had rather alkaline pH at 8.4 and 8.3. Water pH should ideally be lower than 8 to effectively disinfect with chlorine since more hypochlorous ions form at lower pH, increasing the antibacterial activity. However, pH below 7 is more likely to be corrosive (Bhagwat, 2019; WHO, 2022).

Water sample from M1C had the highest EC and TDS readings, as well as Fe levels that were beyond the worldwide recommendations. Presence of iron in potable water has been attributed to the corrosivity of cast and steel iron pipes, as well as the utilization of iron-based water coagulants that may result in film production and water staining (Bhagwat, 2019, WHO, 2022). In previous studies, old metallic water pipes that are susceptible to corrosion have been linked to an increase in the probability of chemical releases into water and, consequently increasing electrical conductivity (Mohammed *et al.*, 2021). Together, these findings imply that the elevated EC and TDS levels of the water sample are related to Fe ions, most likely via corroded piping. Oxidation products of Fe, manganese and arsenic are well known sources of turbidity in water. Similarly, high TDS concentrations cause severe scaling in water heating equipment (WHO, 2022).

Fluoride is commonly found in groundwater and may reach levels to the tune of 10 ppm. Fluoride levels higher than 1.5 ppm are associated with dental fluorosis and much higher levels of 3 to 6 ppm resulting to skeletal fluorosis. One borehole water sample (M2A) with reported 2.0 5 ppm fluoride. An earlier study in Kenya revealed a positive relationship between the depth of underground water sources and fluoride concentrations, where an increase in depth led to an increase in fluoride concentrations up to 1 to 5 ppm (Nair *et al.*, 1984). Like iron salts, aluminium salts are employed as water coagulants. The low to undetectable quantities of aluminium indicate that they might not be used in the water treatment process in Kajiado.

Ammonical nitrogen concentration at M2A (0.49 ppm) and M1A (0.72 ppm) bordered and exceeded the WHO guideline limit of 0.5 ppm. Groundwater naturally contains ammonia, usually at concentrations below 0.2 ppm (WHO, 2022). Ammonia is however a significant part of mammalian metabolism, and its presence in the spring and borehole water samples was suggestive of contamination by bacteria, human or animal waste. Nitrate and nitrite concentrations were below the guideline limit and undetected respectively. Generally, nitrites may be formed in water pipes by *Nitrosomonas* spp. when poorly oxygenated nitrate-rich water is stagnated in galvanized steel pipes, or when chloramines are utilized as a residual disinfectant (WHO, 2022).

Conclusion

Contamination of water intended for slaughterhouse hygiene and sanitation by faecally borne pathogens is a serious public health concern that should further rise concern to the possible presence of other microbial risks of faecal origin such as other pathogenic bacteria, viruses, protozoa, and

helminths. To eliminate or diminish the possibility of contaminating beef in SMS, adequate water safety plans should be implemented to avail potable water for sanitation, carcass washing and human consumption.

Recommendation

The result of this study calls for slaughterhouse management and local authority to be sensitized on poor quality potable water as sources of microbial pathogens and to prioritize the control of water quality with paramount importance. Secondly, the study recommends routine analysis of slaughterhouse water to verify quality and safety for use, with basic laboratory tests that can serve as indicators of possible hazards such as pH, conductivity, turbidity, colour and *Escherichia coli.*

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Beef Hygiene: Efficacy of Hot Water Washing in Reducing Escherichia coli

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Abstract

The study presents the findings of a laboratory trial that determined the extent of microbial reduction following carcass washing at varying water temperatures. Beef rib surfaces were inoculated with 7 log CFU/ml of standard Escherichia coli ATCC 25922, incubated for 1 hour at ambient temperature and washed with water at ambient temperature (control), and heated water at 70, 75, 80, 85, 90 and 95 ℃ for 10 seconds. Aerobic plate count (APC) on Plate count agar (PCA) was performed to determine background microflora, effect of treatment on inoculated area and effect of treatment on spreading of inoculum beyond treated area. Appearance was analysed by observing carcass colour, adipose damage, and sub-surface cooking in comparison to the control. Carcass washing with water at ambient temperature was largely ineffective in reducing microorganisms, achieving only 0.66 log reduction of E. coli. Hot water treatments resulted in 2 to 4 log reductions with a clear trend of increasing log reductions with increasing water temperatures. Hot water wash at 70, 75, 80, 85, 90 and 95 ℃ had log reductions of 2.6, 2.69, 2.82, 3.69, 3.98 and 4.0 respectively. Water wash treatments resulted in spreading of the inoculum beyond the inoculation area, receiving mean counts ranging from 3 to 4.87 log CFU/cm2. Hot water washes between 75 to 95 ℃ resulted in unacceptable rib cuts colour, melted fat and a cooked appearance. The prevailing practice of carcass washing with water at ambient temperature is inadequate in effectively reducing microbial contamination on carcasses, and at best serves to only improve the appearance of the carcass ahead of dispatch. Carcass washing with water heated at 70 ℃ for 10 secs resulted in a 2.6 log reduction of E. coli without affecting carcass appearance and adipose damage. This decontamination intervention can contribute to carcasses of acceptable quality if used in tandem with prior hygienic slaughter and meat handling procedures. Sensitization of slaughterhouse management and workers on appropriate carcass decontamination technologies should be prioritized. The study recommends hygienic slaughter and meat handling procedures to diminish faecal contamination of carcasses where carcass decontamination operations are inadequate.

Introduction

Contamination of beef carcasses may occur during various slaughter operations including flaying, evisceration, carcass splitting (Wambui, 2016), carcass washing (Dickson & Acuff, 2017) and during transportation and carcass storage (Kago, 2015). In many small and medium local slaughterhouses (SMS) in Kenya, beef carcasses are usually washed with water at ambient temperature to remove visible filth such as blood, bone splinters and ruminal contents. A recent study in Kajiado slaughterhouses reported manual washing of carcasses with water contained in buckets, and washing aided with rugs, brushes, and knives (Kimindu et al, 2022). While this is effective in improving the

visual appearance of the carcass, it is ineffective in reducing or eliminating microbial loads. Poor beef carcass hygiene may lead to high microbial counts of both spoilage and pathogenic microorganisms leading to poor keeping quality and meat safety concerns (Ameso *et al.,* 2017, Wambui, 2016). A study of five SMS in Nairobi and its environs reported increase in carcass microbial contamination with the progression of slaughter operations. APC at flaying ranged from 2.6 to 3.6 log CFU/cm^2 while those at dispatch ranged from 3.4 to 4.5 log CFU/cm^2 (Wambui, 2016). Contrary to this trend, microbial contamination reduced as slaughter operations advanced in slaughter facilities that employed carcass decontamination interventions by as much as 3 log reductions (Dickson & Acuff, 2017).

The economic implications of high aerobic counts are significant both globally and locally, with up to 29 % of meat retailers across Kenya reporting suffering losses from meat spoilage (Kenya Market Trust, 2019). To improve the microbiological quality of beef products, an effective intervention should be implemented on beef carcasses. In 1996, the Food Safety Inspection Service (FSIS) of United States successfully proposed the adoption and implementation of HACCP in all slaughter establishments and required the use of at least one effective antimicrobial treatment to reduce pathogens. Among decontamination interventions approved were chlorine, lactic, citric, and acetic acids, trisodium phosphate (TSP), and hot water washing (FSIS, 1996). Ten years later, the European Union, Regulation (EC) No. 853/2004 permitted using lactic acid washes in addition to potable water (hot water and steam pasteurization) to remove microbial surface contamination from animal-derived foods (European Commission, 2004). The Kenyan Standard, KS 317-1:2017 on beef and veal carcasses and meat cuts, specifies maximum microbiological limits but fails to address how to achieve these safety requirements. The standard together with the Meat Control Act CAP 356 only specifies the sanitizing of slaughter equipment and facility with hot water heated above 82 ℃ but not of carcasses (GoK, 2010; KEBS, 2017).

Carcass washing with potable water is a decontamination intervention routinely practiced globally in slaughterhouses and at meat processing plants (Sofos & Smith, 1998). The use of hot water has been shown to potentially reduce microbial counts on beef carcasses. Furthermore, this intervention, without additional chemical sanitizers and or advanced equipment makes it suitable for SMS that have low technological, skilled, and financial capacities (Castillo *et al.,* 1998).

To the best of our knowledge, thus far, the use of hot water washes has not been investigated in decontamination of beef carcasses across Kenyan SMS. Therefore, the study objectives were to utilize a laboratory trial to validate the efficacy of hot water washes at six temperature-time regimes of 70, 75, 80, 85, 90 and 95 ◦C for 10 seconds to reduce inoculated *E. coli* ATCC 25922 population on pre-rigor beef ribs, to determine the effect of washing on microbial spreading to non-inoculated areas and finally to determine the effect of treatment on carcass surface appearance,

Materials and methods

The beef samples were purchased from a slaughterhouse in Kitengela town. The slaughter method combined stunning and ritual (Halal) slaughter. Bleeding occurred on the floor after severing the main blood vessels of the neck to ensure rapid blood loss. The cattle were left to bleed on the floor until the paddling movements of the front and hind legs ceased. Flaying was partly done on ground by cutting off the feet and making an incision between the brisket and the belly to remove the gall blabber and inspect for gallstones. The carcass was then hoisted off the floor by shackling the achilles tendon of the hind leg and lifting the carcass manually with a chain suspended from the ceiling. In

hoisted position, flaying was completed manually by knives and pulling. The carcasses were then split, eviscerated, washed, and inspected. Washing was only done on some carcasses to improve the visual appearance by getting rid of blood, bones, soil and or ruminal contamination. The entire slaughter process occurred at ambient temperature. Carcasses that were passed as fit for human consumption were stamped by the meat inspector and cleared for dispatch. One hour after post-mortem inspection, 3 rib steaks totalling 6 kg were separated from three half carcasses, aseptically wrapped in sterilized aluminium foil, and stored in a cooler box. Transport time to the laboratory was 1 hour. Once in the laboratory, the steaks were refrigerated at 4 ℃ ahead of the experiment.

E. coli ATCC 25922 strain was obtained from the culture collection of Dr. G. Nduhiu, (PHPT, University of Nairobi) and were grown for 18 h at 37 ℃ in nutrient broth. Using a Spectrophotometer, the McFarland 0.5 standard obtained an absorbance reading of 0.081 at 600 nm. The *E. coli* inoculum standard was subsequently adjusted with 0.1% sterile saline water to achieve the same absorbance reading, which inferred a cell concentration of approximately 1.5 x 10^8 CFU/ml. Portions of 0.1 ml of the standardized *E. coli* ATCC 25922 were aseptically added into vials containing 0.9 ml sterile 0.1 % sterile saline water and were homogenised in a vortex mixer, resulting in an inoculum concentration of 7 log CFU/ml. This neat concentration (10^{-1}) was further diluted into ten-fold decimal dilutions up to 10^{-7} for plating on PCA.

Sample preparation was done according to (Castillo *et al.*, 1998), with a few modifications. The 3 rib steaks were cut into 14 pieces measuring 14 x 14 cm^2, needed for the duplication of the 7 water wash treatments at 70, 75, 80, 85, 90, 95 and control. Using a 100 cm^2 (10 x 10 cm^2) aluminium template, an inoculation area was demarketed by a food grade black edible ink. In rib cuts with an irregular top surface or with abundant adipose tissue, approximately 3 mm deep incisions were made by a sterile scalpel around the inoculation perimeter. Before inoculation, a dimension area above the inoculation area measuring 2 cm x 5 cm of each treatment duplicate were swabbed to determine the background microorganisms. The swabs were placed in sterile stomacher bags with closures to which 90 ml (inoculated area) and 9 ml (background and spreading) of sterile 0.1% peptone water was added and pummelled for 1 minute with a BagMixer® 400. A 0.1 ml of the inoculum was inoculated onto the exterior surface of the ribs and spread by a sterile spatula in a one-way crossing motion. Following inoculation, the samples were incubated at 25°C for 1 hour attachment period prior to the washing treatments.

The experiment used potable tapped laboratory water as the carcass wash, that was filled into a cleaned bucket fitted with a tap at its bottom. For each treatment, the tap was opened fully by turning the knob to its farthest end for 10 seconds. The control wash water temperature was determined to be 20.7 ℃ (69.2 ℉). The water was heated by an ANOVA Precision® immersion heater to the specific temperatures, starting from 70 ℃ and progressing to 95 ℃.

The rib treatments were ranked as either acceptable or unacceptable, based on the rib surface appearance in; (i) colour difference compared to the control, (ii) adipose damage and (iii) subsurface cooking. APC was determined by plating seven serial dilutions from 10 -1 to 10 -7 on PCA at 35°C for 48 hours.

Results

All carcass washing treatments resulted in a notable decrease in microbial load as summarized in Table 1. With an initial inoculum of 7.0 CFU/cm^2, the study observed a clear trend of increase in log reductions with increase in water wash temperatures. Water wash at

20.7 (control), 70, 75, 80, 85, 90 and 95 ℃ had log reductions of 0.66, 2.6, 2.69, 2.82, 3.69, 3.98 and 4.0 respectively. Since the mean background microbial counts were all lower than the levels of the inoculated standard *E. coli*, these counts appeared to have little impact on the bacterial counts after inoculation.

Similarly, wash treatments resulted in the spreading of the inoculum beyond the inoculation area. The mean counts of the inoculated standard spread to non-inoculated areas ranged from

3 to 4.87 log CFU/cm^2 in the hot water washes. The control had similar background and spreading counts. While these counts are significantly lower than the background microbial levels on the rib cuts (except for water wash at 70 ℃ that was higher), spreading of contaminant particularly pathogens due to inadequate carcass washing may pose a public health risk.

Table 1. Mean log (CFU/cm^2) reductions in E. coli ATCC 25922 affected by wash water temperature

Sample (CFU/cm^2)	95 ℃	90 ℃	85 ℃	80 ℃	75 ℃	70 ℃	20.7
Background Log B	7	7	7	7	7	7	4.699
Treatment Log T	3.000	2.398	3.301	4.176	4.301	4.398	4.041
Log reduction (B-T)	4.0	3.979	3.699	2.824	2.699	2.602	0.658
Spreading Log S	4.872	3	4.338	4.079	4.029	4.362	4.653

Hot water washes at 95 to 75 ℃ resulted in unacceptable carcass appearance of the rib cuts particularly in colour, fat melting and cooking appearance, as illustrated in table 2. The 70 ℃ water wash resulted in acceptable carcass surface quality similar to the control.

Table 2. Carcass appearance evaluation of ribs cuts across treatment

Sample (CFU/cm^2)	20.7	95 ℃	90 ℃	85 ℃	80 ℃	75 ℃	70 ℃
Colour	acceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	acceptable
Adipose	acceptable	unacceptable	unacceptable	unacceptable	unacceptable	borderline	acceptable
Surface cooking	acceptable	unacceptable	unacceptable	unacceptable	unacceptable	unacceptable	acceptable

Discussion

Ambient water wash was largely ineffective in microbial reduction with up to 0.66 log reduction of APC. Similar results were reported in Mexican slaughterhouses, that typically washed carcasses with water from its distribution system for 120 to 180 seconds at 2100 psi, having recorded up to 0.5 log reductions in APC (Carranza *et al.*, 2013). Hot water treatments resulted in 2 to 4 log reductions with a clear trend of increasing log reductions with increasing water temperatures. This log reduction is similar to that of comparable studies. Numerous studies have reported slaughterhouse practices of warm water washes from 48.9 to 50 ℃ at high pressure, 55 ℃ with lactic acid , and from 65 to 85 ℃ with low pressure, and even at 95 ℃ for 5 seconds with log reduction between 1.5 to 2.5 (Bosilevac *et al.*, 2006; Castillo *et al.*, 1998).

This study also reported the redistribution of bacteria from inoculation sites to adjacent areas, resulting in undesired spreading of contamination to other carcass surfaces. These results are like

those reported by Carranza *et al*, (2013) where ambient water wash alone and in combination with acetic treatments were able to reduce total and faecal coliforms but increased the APC and spreading of microorganisms. The redistribution of microorganisms following ambient and cold water wash has also been previously alluded by (Castillo *et al.*, 1998). An APC less than 6 log CFU/ cm^2 is deemed satisfactory by the Kenya Standard, KS 317-1:2017. All treatments (100%) had APC values that were lower than the guideline value, however, only the control and water wash at 70 ℃ resulted in carcasses of acceptable fresh appearance. Hot water washes have previously been associated with changes in muscle and fat tissue colour and appearance (Sofos and Smith, 1998). In this study, muscle tissue exposed for 10 seconds at 75 – 95 ℃ treatments resulted in noticeable cooking effect, change in adipose appearance and carcass colour, lowering the visual quality of the fresh carcasses. To achieve microbial reduction without compromising the fresh appearance of the meat tissue, several factors can be varied such as wash water temperature, pressure, application technique, initial microbial load, duration of inoculation, and exposure time of the treatment (Dickson & Acuff, 2017, Castillo *et al*, 1998)

Conclusion

Carcass washing with water heated to 70 ℃ for 10 secs resulted in a 2.6 log reduction of E. coli without affecting carcass appearance and adipose damage. This decontamination intervention can contribute to carcasses of acceptable quality if used in combination with good prior hygienic slaughter and meat handling processes.

Recommendation

Sensitization of slaughterhouse management and workers on appropriate carcass decontamination technologies should be prioritized. The study recommends hygienic slaughter and meat handling procedures to diminish faecal contamination of carcasses where carcass decontamination operations are inadequate. Similarly, the study recommends policy review to facilitate use of hot water for not only carcass decontamination but also for sanitizing of slaughter equipment and facility.

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

Profitability of Sheep Finished on Range Grass and Legume Diets in the Arid and Semi-Arid Lands of Kenya

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Abstract

The nutrient content of ruminant feeds, especially crude protein, in the Arid and Semi-Arid Lands (ASALs) is insufficient to support maintenance and influence production. Therefore, ruminant supplementation with protein rich leguminous feeds that are cost-effective and easily accessible is strongly recommended for optimum ruminants' production. In a completely randomized experimental design (CRD), a group of 15 mass selected dorper yearling sheep, average age of 10-13 months and average body weight of 21.7±1.5 kgs were assigned into each experimental unit. The animals were dewormed prior to the start of the experiment. A total of 5 test diets; African fox tail+ Cow pea, African fox tail+Desmodium, African fox tail+Dolichos lab lab, and African fox tail+Lucerne were fed for a period of 12 weeks, excluding acclimatization period of one week. The feeds were chopped and fed on an effective daily feed intake of 3% of the animal live body weight, dry matter basis, on a 3:1 grass and legume ratio. Water and mineral salt was provided *ad-libitum*. The results of a one-way analysis of variance (ANOVA) on comparison of the sample means of the different finishing diets showed an average daily weight gains (ADWG) of African fox tail+Cowpea (51.2±2.4g) and African fox tail+Dolichos lab lab (38.1±11.9g) as the leading. Grass as a single diet performed the least with an ADWG of 9.5±4.8g. There was a significant difference between the test diets at P=0.05 level. The economic analyses showed that the diets composed of African fox tail+Dolichos lab lab and African fox tail+Desmodium had the best profitable returns of Ksh 59,172.60 and Ksh 50,448.40 respectively for 100 units' sheep establishment. African fox tail+Lucerne diet was the least. However, for such an initiative, the initial live weight and breed of the sheep greatly influenced the final performance.

Key words: *Profitability, grass, legume, daily weight gain, ASALs*

Introduction

In Kenya, the livestock sub-sector contributes about 10% of the country's Gross Domestic Product (GDP) and consequently 50% of the agricultural labor force. The livestock population is distributed all over the country with arid and semi-arid lands (ASALs) which constitute about 84% of the country's land mass, hosting about 70% of the country's livestock (KCSAP/ELRP, 2023). Thus, making livestock keeping in the region the major economic activity. Ruminants in particular, rely heavily on roughages primarily derived from pastures, browse, fodder and crop-residues. The nutritional value of these feed sources is insufficient to support maintenance, let alone growth, milk and production. Thus, limiting the ruminant's reproductive abilities and production levels. This is demonstrated by poor daily weight gain, low meat production, low off-take rates, low conception and kidding rates, and high mortality (Behnke *et al.*, 2011). This has led to low food and nutritional security, and consequently low livestock sub-sector potential impact on the country's economy. Accordingly, there is a need to greatly increase animal production and productivity. In the ASALs, crude protein has been found to be the most restrictive nutrient, particularly during dry seasons.

Therefore, supplementation is strongly recommended if ruminants are to be optimally productive. Dietary supplements are known to increase consumption by increasing nitrogen supply to the rumen microorganisms. This has a beneficial impact on rumen microbial population and efficiency (Matthews *et al.*, 2019). For smallholder ruminant producers in Kenya, protein source concentrates are either unavailable or too expensive. Availability of economical and easily accessible feeds that are high in both quantity and quality is a crucial factor in sustainable livestock production (Ephrem *et al.*, 2015). Therefore, supplementing ruminants with legumes which are less competitive in the human food system is desirable. This study's objective was to determine the profitability of finishing ruminants and in particular dorper sheep in the ASALs using African fox tail grass and Cow pea, Desmodium, Dolichos lab lab, and Lucerne legumes feed diets.

Materials and Methods

Experimental animals, selection, management and treatment

Mass selection method was used to handpick 15 dorper sheep yearlings with an average age of 10-13 months determined using recorded reports from farmers based on birth history and an average body weight of 21.7±1.5 kgs. The sheep were set for a feeding trial under on-farm feedlot system. The utilized feeds were established on-farm and harvested at flowering stage (Kamalak et al, 2011), conserved by baling and stored during the October, November and December 2021 (short rains) and March, April and May 2022 (long rains) seasons. The yearlings were dewormed, and acclimatized for 1 week to the experimental diets and individual pens. A completely randomized experimental design (CRD) was used to group 15 mass selected dorper yearling sheep, average age of 10-13 months and average body weight of 21.7±1.5 kgs and assigned into each experimental unit. A total of 5 treatments of African fox tail grass and selected legume diets were availed as follows; African fox tail (control), African fox tail+Desmodium, African fox tail+Lucerne, African fox tail+Cow pea, African fox tail+Dolichos lab lab. The feeds were chopped and offered on an effective daily intake of 3% of the animal live body weight, dry matter (Holden et al, 2023) on a 3:1 grass and legume ratio (Abreu, et al, 2004). The diets were divided into two halves and offered twice a day. Water and mineral salt was provided *ad-libitum* for a period of 12 weeks, between May to July 2023.

Study site

The study was conducted in Makueni and Taita Taveta, arid and semi-arid (ASAL) counties of Kenya, located in ecological zone IV. The zone has moderate climates and distinct seasons with a bimodal rainfall pattern experienced in March, April and May (long rains) and October, November and December (short rains) seasons, with an average annual rainfall of <700 mm (Government of Kenya, 2018). The short rains are more reliable (Government of Kenya, 2018).

Data collection and analysis

Data on the cost of production of the different feed crops was collected during the establishment periods. These included the cost of buying seeds, land preparation, planting, weeding, harvesting and labor. The average variable cost per unit of feed production (AVCf) was calculated as the average of the total variable cost incurred over the crop lifespan in seasons (n) over the estimated average yield per season.

$$\text{AVCf} = \frac{\sum_1^n \text{Cost per season}}{\sum_1^n \text{ yield per season}}$$

Measurements on the daily body weight were taken using an electronic weighing scale and entered in a Microsoft Excel work sheet. The average daily weight gain (ADWG) was determined as the difference between the final and initial/previous live body weight (LBW_i-LBW_0). The study used SPSS software version 22 to perform statistical analyses and Microsoft Excel for data visualization. A one-way analysis of variance (ANOVA) statistics was used to compare the sample means and test for significant differences between the treatments and LSD significance difference post hoc test used to separate significant differences ($P<0.05$). The results were presented in tables and graphs.

To determine the enterprise profitability, economic analyses were conducted under the different finishing diets as detailed on Table 1.

Table 1: Profitability economic analyses

Economic analysis	Formulae	Interpretation
Marginal revenue (MR)	$\frac{\Delta\text{Revenue}}{\Delta\text{Quantity}}$	Extra revenue achieved from the sale of one additional unit (LBWkg) of output
Marginal cost (MC)	$\frac{\Delta\text{Cost}}{\Delta\text{Quantity}}$	Extra cost incurred from producing one additional unit of output.
Gross margin (GM)	Revenue-VC	Net profits earned. Where VC is variable cost
Benefit cost ratio (BCR)	$\frac{\text{Revenue}}{\text{Cost}}$	Amount revenue earned for every shilling invested as cost. Viable where BCR>1
Return on investment (ROI)	$\frac{\text{GM}}{\text{Cost}}$	Amount of profit earned for every shilling invested as cost.
Break even quantity (BEQ)	$\frac{\text{TVC}}{\text{Price}}$	The quantity that is sufficient to at least recoup the total variable costs (TVC) invested

Results and Discussions

Animal performance

Table 2: Live weight gain

Diet	Initial weight (Kg)	Final weight (Week 12) Kg	Net weight gain (Kg)	ADWG (g)	Sig
a African Fox tail	21.7±1.5	23.3±2.8	0.8±0.4	9.5 ± 4.8^{d}	*
b African Fox tail+Desmodium	21.7±1.5	23.3±3.9	-0.8±2.2	-9.5 ± 26.2^{de}	*
c African Fox tail+Lucerne	21.7±1.5	22.8±1.7	1.3±1.2	15.5±14.3	NS
d African Fox tail+Cow pea	21.7±1.5	26.5±1.2	4.3±0.2	51.2 ± 2.4^{ab}	*
e African Fox tail+Dolichos	21.7±1.5	23.8±4.0	3.2±1.0	38.1 ± 11.9^{b}	*

**Means in the same row with different superscript differ significantly at the 0.05 level, NS= Not significant*

African fox tail+Cow pea or African fox tail+Dolichos lab lab diets respectively had the highest net average daily weight gain (ADWG). Generally, African fox tail grass as a single diet resulted in the

lowest average daily weight gain (ADWG) as shown in table 2 and demonstrated in Figure 1. As the average daily weight gain (ADWG) increases, the crude protein requirements increase (Ephrem, 2015).

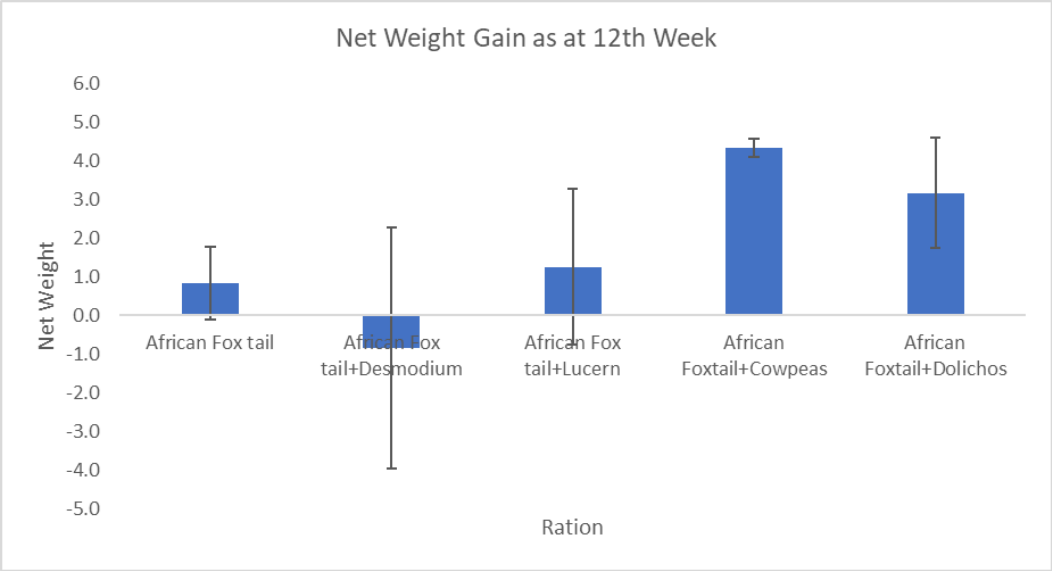

Figure 2: Live weight gain

The net weight performance within the treatments was varied with a ranged confidence interval and high margin (at 95% confidence level). The net weight gains under the lower limit performance was negative as shown in Figure 1. An increased selection intensity is critical to make selection decisions for traits desired in the herd (New et al, 2020).

Profitability

Table 3 presents the unit cost of feed production (cost of producing one kg of feed)of feed production

Table 3: Unit cost of feed production

Type	Crop	Seasonality	AVCf_bale (15kg) (KES)	AVCf_kg (KES)
Grass	African fox tail	Perennial	94.0	6.3
Legume	Dolichos lab lab	Annual	144.2	9.6
Legume	Cow pea	Annual	149.1	9.9
Legume	Lucerne	Bi annual	198.8	13.3
Legume	Desmodium	Perennial	72.8	4.9

Generally, perennially growing crops had the least unit cost of production. This is due to one-off costs of production incurred only in the first season and not recurrent in the subsequent seasons. Lucerne legume had the highest unit cost of production. The cost of growing the feeds was relatively cheaper than the market buying price of KES 250 (15-kg bale of grass hay) and KES 350 (15-kg bale of legume). On-farm production of the feeds thus minimizes the cost of production and

maximizes on the profits. Feed quality is also guaranteed. Table 4 presents the marginal gross margin results.

Table 4: Marginal gross margin (MGM)/profit derived from weight gains

Diet	MGM (Ksh)	
	Mean	Upper Limit
African fox tail	-38.2	526.5
African fox tail+Desmodium	-49.2	726.8
African fox tail+Lucerne	-452.5	-117.1
African fox tail+Cowpea	435.2	680.2
African fox tail+Dolichos lab lab	33.0	826.1

Note: Considering the direct cost of feed production only (most significant) and selling price of ksh 200 per kg live body weight.

The net GM under the mean performance was negative. African fox tail+Dolichos lab lab and African fox tail+Desmodium diet showed the best profitable returns. African fox tail+Lucerne diet were the least profitable due to its higher unit cost of production of the legume.

Table 5: Break even quantity (BEQ)

Diet	Total MR	Total MC				Profitability		
	Price KES200/kg LW	Cost of feed	Cost of labor	Constant AC (labor)	Other costs (10%)	Average Cost	BEQ	BCR (>1)
African Fox tail	840.5	526.5	15,750.0	225.0	75.1	826.6	70.0	1.0
African Fox tail+Desmodium	1,217.7	490.9	15,750.0	583.3	107.4	1,181.6	27.0	1.0
African Fox tail+Lucerne	585.4	702.5	15,750.0	15.8	71.8	790.1	1,000.0	0.7
African Fox tail+Cow pea	1,299.2	619.1	15,750.0	543.1	116.2	1,278.4	29.0	1.0
African Fox Tail+Dolichos	1,436.8	610.8	15,750.0	656.3	126.7	1,393.7	24.0	1.0

African fox tail grass single diet and African fox tail+Lucerne diet had the highest break even quantities. This indicated that they were less profitable as higher units were required to operate under an efficient scale.

Table 6: A profitability case at 100 units

Diet	Total MR		Total MC				Profitability		
	Price 200ksh/kg LW	TR	Cost feed	Cost of labor	Other costs-10%	TVC	BCR	GM (Non discounted)	ROI
African Fox tail	840.5	84,046.0	52,647.5	15,750.0	6,839.7	75,237.2	1.1	8,808.8	0.1
African fox tail+Desmodium	1,217.7	121,769.6	49,087.5	15,750.0	6,483.8	71,321.3	1.7	50,448.4	0.7
African fox tail+Lucerne	585.4	58,541.0	70,252.9	15,750.0	8,600.3	94,603.2	0.6	(36,062.2)	-0.4
African fox tail+Cow pea	1,299.2	129,923.5	61,907.5	15,750.0	7,765.8	85,423.3	1.5	44,500.2	0.5
African fox tail+Dolichos lab lab	1,436.8	143,683.5	61,078.1	15,750.0	7,682.8	84,510.9	1.7	59,172.6	0.7

TMR= Total marginal revenue, TVC= Total variable cost

African fox tail+Dolichos lab lab and African fox tail+Desmodium diets showed positive and highest returns respectively, with a benefit cost ratio (BCR) of 1.7 and return on investment (ROI) of 0.7. This implied that, there was a positive return on revenue and profit for every shilling invested. The cost of feed production translated to an estimated average of 70.8% of the total cost of production.

Conclusion and Recommendations

On-farm feed production was more cost efficient than buying from the market and thus more farmer profit maximizing. A cost effective legume selection was also an essential consideration for the enterprise. Additionally, the breed and genetics of the animal influences feed efficiency, carcass merit and economic benefits significance. Thus it's fundamental to select the right breeds whether buying the animal or raising it from home.

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Enhancing Rural Livelihoods in ASALs through Feedlot Finisher Ration Commercialization for Dorper Sheep Early markets

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Abstract

In the Kenyan context, intensive small ruminant rearing and feedlot finishing farms are limited. This may be attributed to lack of sheep and goat finishing formulae in the market, coupled with lack of expertise. The current study was designed to have twofold objectives: i). To validate On-farm the On-station developed and tested small ruminant grass-legume based finisher rations, among the Dorper sheep keepers in Narok County. ii). To carry out organoleptic evaluation and meat quality two finisher rations under validation. The study site was in Ntulele sub-county, Nturumeti ward in Narok County. The experimental design was a completely Randomized Design (CRD) with Rations 6 and 8 as treatments, and sole grass grazing (farmers practice) as the control. All the treatments were replicated 10 times, with each sheep serving as a replicate. One CBO with 30 members, namely Anti-Female genital mutilation, Aids and Poverty eradication Organization (AFAPO) was purposively selected for this technology validation feeding trial. Three groups of sheep (10 sheep in each group) were identified *viz* TR0 as the Control (farmers practice without supplementation), TR6 (Ration 6) and TR8 (Ration 8) as the 2nd and 1st best-bet rations developed On-station respectively. Collective group feeding was adopted in this study. The response variable in this study was as follows: Growth performance measurement (average daily weight gain (ADG) and final market weights. Organoleptic evaluation and farmers' perception on the meat quality based on the new Dorper sheep finisher ration was also evaluated in the study. A Linkert scale and simple semi-structured questionnaire was used to collect this data respectively. A significant (p<0.044) difference in final market weight was observed among the treatments in week 12 finishing period. Treatment Ration 8 had the highest mean weight (45.8 kg), followed by Treatment 6 (40.8 kg), while the Control group had the lowest mean weight (38.1 kg). The final mean market weights of treatments TR8 and TR6 were statistically similar, while the mean live weight of the control group (38.1 kg) was different from these two treatments in week 12. Roasting assessment (Organoleptic evaluation) indicated carcass on Ration 8 (TR8) was well-marbled, tasty, and juicy on roasting. The ribs were appealing to the taste buds of the selected roasted meat eaters. These characteristics are good for barbeque preparation. Further the study showed that carcass on Ration 6 (TR6) was tasty, soft, and tender with less fat cover on roasting, and best for marination andstew preparation. Carcass of the sheep in the control treatment was less fatty, less tender, and had tough roasted meat. These meat attributes tend to burn upon roasting due to low fat cover. All the meat sampling was based on roasted meat alone. Fried and/or boiled meat was not sampled. The general rating of the meat quality indicated the carcasses on feed trials had better meat quality when compared to the control treatment group. In conclusion, the rearing period from birth to marketing of Dorper sheep can be shortened from 2-3 years old to about 6-7 months only. In turn, the farmer will increase the rate of returns and farm enterprise profitability.

Keywords: *Feedlot, Dorper sheep, Finisher Rations, ASALs*

Introduction

Kenya is currently a net importer of meat and meat products and this situation will get worse as income and urbanization grows. Sheep contribute to food production, rural employment and gross national product by converting roughages into meat, wool and skin. There is an increasing demand for mutton for domestic and export markets. Under the existing production systems, the slaughter weight of sheep and goats in the country is low and age at which it is usually achieved is much higher (>3 years). There is high demand particularly from the youth of a market-oriented production system for livestock-based enterprises that reduces the age at slaughter while increasing the market weight of marketed animals. Such a system which involves finishing and/or raising small ruminants for meat under feedlot system, coupled with high plane of nutrition and genetic potential should be cost effective.

The major advantage of this system is that the farmer would for example, rear the animals only for seven months (in case of Dorper sheep) and not for 2-3 years in extensive grazing. The farmer will get handsome profit after seven months, which is far from sheep reared for a long time up to 3 years under extensive grazing system. Shorter periods of rearing reduce the risk of mortality before selling, theft or loss due to drought. It would also ensure that a "flying herd" agribusiness that sources immature weaner lambs from the more arid rangeland and finishing them on better rangelands is achieved. However, intensive feedlot rearing of small ruminants is a fairly new concept in Kenya and has not been adequately emphasized by the authorities. There is a need for enhancing local production of small ruminants through intensive rearing to ensure quality meat supply. Experiments conducted elsewhere have proven that sheep and goats reared on well-balanced diets have a capacity to reach market weight fast enough to offset the cost of rearing (Mushi, 2004). However, fattening rations for small ruminants are not available in the Kenyan markets, from the feed manufacturers.

Thus, fattening of small ruminants through utilization of well formulated diets using locally available feed resources will help improve growth performance of small ruminants and timely availing of the stock to the market. A profitable and cost-effective grass-legume based finishing ration was developed and tested for finishing of small ruminants mainly in Kenya's arid and semi-arid lands (ASALs) as one way of commercializing livestock production in these dry areas. The current project was aimed at On-farm validation of small ruminant finisher ration technology among Dorper sheep keepers in Narok County.

Materials and Methods

Study sites

On-farm participatory validation feeding trial for Dorper weaner sheep was carried out in Ntulele sub-county, Nturumeti ward in Narok County. Narok County is situated in the Southern part of the great Rift valley. It lies between latitude: -1.086342 and Longitude: 35.8767012: Elevation: 1882m/6175feet above sea level. It borders Tanzania on the South, Nakuru County to the North, Bomet, Nyamira and Kisii counties to the North West, Kajiado to the East and Migori County to the West. Narok County experiences a bimodal rainfall pattern, whereby long rains fall between February and June and short rains between August and November. Rainfall amounts range from 2,500 mm in the wet season to about 450 mm during the dry season, with an annual average of 771 mm.

Farmer identification and recruitment process

The strategic Dorper sheep front-line farmers were purposively selected for the technology validation research work On-farm. Anti-Female genital mutilation, Aids and Poverty eradication Organization (AFAPO) CBO with 30 membership was purposively selected for the validation study. The recruitment criteria were as follows: The farmer must have at least 30 entire male Dorper sheep herd, and must be willing to participate in the On-farm validation research. The recruited farmers were also expected to meet some infrastructural and technical capacity requirements for recruitment. The expected infrastructural requirement was land ownership (of >10 acres) and water availability. In addition, the recruited Dorper sheep farmer was vetted to ensure that he/she has the ability to adhere to set production and husbandry standards, including biosecurity measures. A simple memorandum of understanding (MoU) was drawn between the research team and the selected CBO group members. This was to serve as a functional and simple legal framework that will be adopted in identifying and recruiting strategic Dorper sheep front-line farmers for the validation research work in the target County.

Feed formulations for On-farm data validation

The TWO best-bet promising Dorper sheep finisher rations (TR6 and TR8) that were developed from the previous controlled On-station feeding trial were formulated and stored On-station for subsequent delivery and use in the On-farm technology validation. Feedsoft® Professional feed formulation software (10.1 Edition) was used in formulating the experimental TMR rations for On-farm technology validation feeding trial. The main feed ingredients used in the feed formulations were as follows: Protein sources: Cotton seed cake, sunflower cake and Lucerne hay; Energy sources: Wheat bran, maize germ, Whole maize, Molasses and Rhodes grass hay; Other feed additives: Minerals and mineral premixes, and aflatoxin bidder. All the ingredients were weighed using a digital weighing scale based on specific test rations, and mixed manually on a black polythene paper gauge 60. The Energy and Protein concentrates were purchased from large scale Agro-dealers (Crop ways Feeds Ltd) in Thika. The roughages (Rhodes grass and Lucerne hay) for TMR formulations were purchased from Dairy Research Institute, KALRO Naivasha. The roughages were chopped into about 1-2 cm chop length using a motorized forage chopper prior to manual mixing with selected energy and protein concentrates as indicated above.

On-farm experimental design and treatments

The design of the On-farm participatory feeding experimentation was a completely Randomized Design (CRD) with Rations 6 and 8 as treatments, and sole grass grazing (farmers practice) as the control, with all treatments replicated 10 times. AFAPO CBO was selected for the technology validation feeding trial. The selection criteria for the farm will be: At least the farmer to be a Dorper sheep keeper with a minimum herd of about 30 Dorper sheep herd, and willingness to participate in the study. In this farm, three groups of sheep (10 sheep in each group) were identified for the data validation feeding trial. The experimental sheep were donated by the selected CBO members. The two best-bet rations developed and tested in the previous On-station feeding trials was validated On-farm in this study. The treatments comprise of Ration 1 (Control (farmers practice without supplementation (5.0 MJ Kg^{-1} DM; 7.0 % CP), TR2 (the 2^{nd} best-bet ration developed On-station

(TR6 (10 MJ Kg^{-1} DM; 16% CP), and the 1st best-bet ration (TR8 (11 MJ Kg^{-1} DM; 14% CP). Proximate analysis was done to determine the nutrient content of the control rations.

Experimental animals' management, Feeds and Feeding regime

A total of 30 entire male weaner Dorper sheep were selected for the On-farm feeding trial. These experimental animals, aged 3-4 months post-weaning for the On-farm data validation were donated from the selected members of AFAPO CBO. The rations under validation were as follows: Ration 1 (Control (farmers practice without supplementation (5.0 MJ Kg^{-1} DM; 7.0 % CP), TR2 comprising of the 2nd best-bet ration developed on-station (TR6 (10 MJ Kg^{-1} DM; 16% CP), and the 1st best-bet ration (TR8 (11 MJ Kg^{-1} DM; 14% CP). The chemical composition of the control groups was determined during the feeding trial. The experimental animals were kept on a preliminary adaptation period of ten days. This was aimed at acclimatizing the animals to the new environment, housing and test diets. The animals were managed in an intensive feedlot system, with a 2-hour sunlight allowance between 9 and 10 O'clock in the morning hours. The animals were fed daily about 3% of their LBW according to Tegegne, (2016). The offered feeds were adjusted to allow for 5% feed refusals during the acclimatization period. The animals were weighed weekly, after an overnight fasting. The formulated test diets were offered twice a day at 8:00 and 16:00 h in two equal portions. Water and mineral salts were provided *ad libitum*. The feeding experiment lasted for 90 days (3 months) On-farm.

Description of the experimental animals housing and management

The experimental animals were ear-tagged and quarantined for a period of 10 days. During this period, all the animals in the feeding trial were treated with a broad-spectrum antiparasitic agent (Ivermectin) against internal and external parasites. They were also vaccinated against sheep pox, pasteurollosis and blue tongue. Animals were housed in three groups according to the test rations-(TR0 (control), TR6 and TR8) in semi-permanent stalls (0.70 m X 1.70 m, whose construction was supported by the EU AgriFI project. The experimental animals were kept in an intensive feedlot system of feeding. Two paid family identified labor were sourced from experimental region. They were fully responsible for the On-farm data collection on growth performance (weekly weight measurements) and other daily routine management of Dorper sheep in the experiment. The identified persons were trained on expected data collection aspects. This would guarantee a sense of job commitment for a successful data collection On-farm.

Data Collection

Growth performance measurement, Organoleptic evaluation and meat quality grading

The response variable in this study were as follows: Growth performance measurement: weekly weight gains and final market weights. Means of initial, weekly and final market weight data was collected. Organoleptic evaluation and farmers' perception on the new Dorper sheep finisher ration-based mutton quality also formed an integral part in this study. A participatory technology ranking of the tested best-bet finisher rations for Doper sheep at farm level was done using a Likert scale (scale 1-5) in the measurement of perceptions, opinions and attitudes of farmers and other stakeholders towards various Dorper sheep finishing rations-based mutton quality. These were the two test treatments and the control diet, as dictated by performance (outward physical appearance, growth performance and meat quality (Ankur et al, 2015). A simple semi-structured questionnaire

and a Linkert scale was used for collecting this kind of a data according to the procedures described by Ankur et al. (2015). Three sheep from each of the three treatments were purchased by the project from the experimental sheep in the three groups (TR0, TR6 and TR8) in the project, slaughtered, and the meat quality evaluated. Pieces of roasted meat were placed in three different categories as per the different rations (Rations 6, 8 and the control). Five people were asked to taste and fill a simple questionnaire indicating; tenderness (palatability), juiciness, sweetness meat taste, fatness and leanness according to procedures described by Smulders, (1986).

Statistical analysis

The collected data were subjected to analysis of variance (ANOVA) using General Linear Model (GLM) procedure of statistical analysis system (SAS, 2003) with (test rations) as the main effect in the model and the animal performance (weekly and final slaughter/market weight) as the dependent variables. Least significant diffrence (LSD) was used for means separation.

Results and Discussions

The performance of weaner Dorper sheep as influenced by finisher rations is presented in Table 1. A covariate is a variable, such as entry live weight, that is measured alongside the main treatment factor. It is a potential source of variation that is taken into account to assess its influence on the response variable viz live weight (kg) for wk1-wk12). The *p*-value associated with a covariate was 0.052, which suggest that there was no significant effect between the covariate (Entry weight) and the live weights over the 12-week study period.

A significant ($p<0.044$) difference was observed among the treatments in week 12. Treatment Ration 8 (TR8) had the highest mean weight (45.8 kg), followed by Treatment 6 (40.8 kg), while the Control group had the lowest mean weight (38.1 kg). The final mean market live weights of treatments TR8 (45.8 kg) and TR6 (40.8 kg) were statistically similar (Table 1), while the mean live weight of the control group (38.1 kg) was different from these treatments in week 12.

Youths (15-34 years old), form 35% of the Kenyan population, and have the highest unemployment rate of 67% (KNBS, 2019). There is therefore need to empower these vulnerable groups by promoting livestock research technology agribusinesses aimed at improving their economic status. Due to increasing levels of poverty, these youths have been reported to engage in other criminal activities such as drug abuse, violence and burglary. Kenya's current poverty rate is 33.4%, where 4.4 million people are acutely food insecure due to frequent droughts as exacerbated by climate change. Dorper sheep breed adapts well to harsh climatic conditions and matures faster than other ordinary sheep such as black-head Persian and/or merino sheep. These traits can be tapped in an agribusiness model and science, to contribute to better production, better nutrition, better environment and better life and livelihoods in Kenya's drylands.

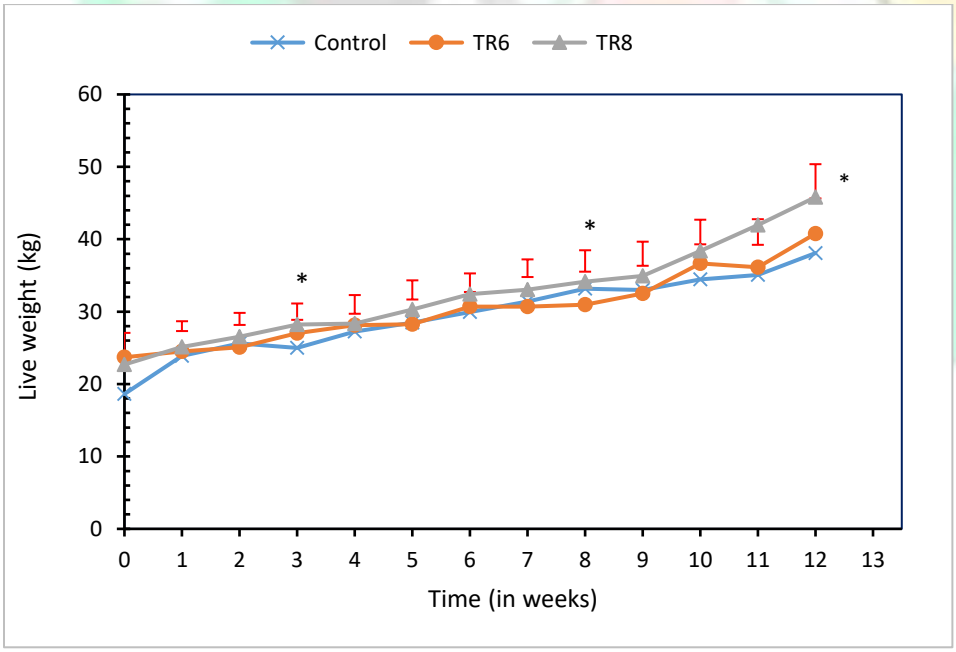
However, livestock production in Kenya has been adversely affected by drought in terms of quality and quantity of feeds. This has led to low level of productivity, high mortality, reduced market value and community stagnation out of poverty. The developed finisher ration for Dorper sheep is able to reduce the rearing period to attain a market weight of 45-50 kg within 6-7 months, instead of 36 months (3 years) rearing period. According to Tegegne (2016), with intensive sheep fattening on concentrate-based Total mixed rations (TMR) the highest daily gains and optimal feed conversion efficiency were achieved. The purchase of stock and the cost of feeding is the major economic

outlays in sheep fattening agribusiness, thus the feeds should be cost-effective (Kokeb et al., 2020; Anja, 2019; Assefa, 2020). In tropics dressing percentage with respect to slaughter weight has been reported to range from 45 to 55% (Gelgelo, 2017). This is in agreement with findings of current studies whose dressing percent ranged from 45-51% (Table 2).

Table 1: The Influence of Finishing Rations on weekly Live Weight gain (kg) of Dorper Sheep

Time	Control R0	Treatment R6	Treatment R8	p-value	LSD $_{(0.05)}$	CV (%)
Entry weight	18.6 a	23.7 a	22.7 a	0.052	4.1	19.7
Wk1	23.9 a	24.5 a	25.1 a	0.159	1.4	5.0
Wk2	25.6 a	25.1 a	26.5 a	0.117	1.7	5.9
Wk3	25.0 b	27.0 ab	28.2 a	0.018	2.3	7.6
Wk4	27.2 a	28.1 a	28.3 a	0.643	2.6	8.4
Wk5	28.5 a	28.3 a	30.3 a	0.149	2.6	8.3
Wk6	29.9 a	30.7 a	32.4 a	0.099	2.6	7.5
Wk7	31.4 a	30.7 a	33.0 a	0.073	2.4	7.0
Wk8	33.2 ab	30.9 b	34.2 a	0.042	3.0	8.2
Wk9	33.0 a	32.5 a	34.9 a	0.188	3.3	9.0
Wk10	34.4 a	36.7 a	38.4 a	0.061	3.4	8.4
Wk11	35.1 a	36.1 a	40.0 b	0.196	3.5	8.8
Wk12	38.1b	40.8ab	45.8 b	0.044	4.7	10.5

Means followed by the same letter within a row are not significantly different according to Fisher's protected least significant difference test
L.S.D = Least significant difference; C.V = Coefficient of variation



**Significant at p<0.05*

Figure 1. Effect of Finishing Ration formulae on the Live Weight (kg) of Dorper Sheep over a 12-week finishing period

Organoleptic evaluation and Meat Quality assessment of experimental sheep as influenced by Finishing ration

The lamb on outdoor grazing (control (TR0) reported a heavy worm infestation that is zoonotic in the nature-hydatidcyst (*Taenia hydatigena*. This depicts poor animal health and husbandry practices that can be associated with extensive out door grazing, including poor worm control on both livestock and dogs. All outdoor grazed livestock must be dewormed using appropriate dewormers as recommended and advised by the Veterinarian or Para Veterinarian. This is a variable cost that negatively affect the farm profitability.

The lamb under the control treatment lower live weight and poor kill-out yield, an implication of inadequate mineral and nutritional balance during the feeding regime to allow for balanced fat and muscle deposits. This is also corroborated by the poor conformation at the loin that had very poor fat distribution.

The lamb on TR8 had a kill-out yield of 51% had well-distributed intramuscular and subcutaneous fat cover depicting high feed conversion efficiency and probably a high protein and energy ratio (Table 2). All excess fatty acids from digestion were converted to adipose fat that was well distributed including the heavy omentum fat layering.

The lamb on TR6 had a 50% kill-out yield, and had lean meat, good fat distribution, and well-marbled, and low subcutaneous fat cover. This could be attributed to a high protein ratio in the diet with a moderate energy level. The animal was also still growing, and this justifies the meat's tenderness and leanness.

The higher the kill out yield the better the profits to the farmer. In terms of overall rating, the carcasses on test feed trials had better meat quality as compared to the control treatment group.

Table 2: Carcass meat grading

Treatment	Body Conditionn	Live wt (kg)	Dead Wt (kg)	Kill out %	Age (Months)	Marbling & loin thickness	Final Met Grade	Worms	Tenderness& at distribution
Control	Fair	40	18	45%	7	Poor	Mutton grade 2	Hydatid cysts and Stilesia hepatica recovered	Tougher meat and Poor fat distribution
Ration 8	Good	43	22	51%	8	Good	Mutton grade 1	Nil	Very Good Fat distribution and tender
Ration 6	Good	44	22	50%	7	Good	Lamb Grade 1	Nil	Good fat cover and very tender

Roasting Assessment

Carcass on Ration 8 was well-marbled, tasty, and juicy on roasting. The ribs were appealing to the taste buds of the roastedmeat eaters. These meat traits are good for barbeque preparation (Atsbha et al, 2021). Carcass on Ration 6 was tasty, soft, and tender with less fat cover on roasting. These characteristics are best for marination andstew preparation. The control carcass had Less fatty, less tender, and tough roasted meat. This is a disadvantage as it tends to burn upon roasting due to low fat cover. This sampling was based on roasted meat alone. Sampling of fried o boiled meat is recommended for future studies.

Figure 2: Ration 8 carcass

Figure 3: Marbling on the ribcage of Ration 8

Figure 4: Carcass from the control

Figure 5: Carcass of lamb on Ration

Conclusion and recommendations

Current research findings from this research work concludes that the rearing period from birth to marketing of Dorper sheep can be shortened from 2-3 years old to about 6-7 months only. In turn, the farmer will increase the rate of returns and farm enterprise profitability. Experimental animals on ration TR 8 reached the targeted market/slaughter weight of >50 kg within 6-7 months old. Rations 6 and 8 emerged as most performing in terms of growth performance and orgaleptiptic evaluation/meat quality. However, ration 6 would be more expensive due to high CP levels (16%). Thus ration 8 (CP 14%; ME (MJ/kg DM) is recommended for dissemination and commercialization among smallholder pastoral Dorper sheep keepers in the ASALs.

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Economic Analysis of Beef Cattle Production at Beef Research Institute at Lanet, Kenya

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Abstract

Beef production can a profitable venture if farmers, especially the pastoralists, could commercialize the enterprise, rather than the subsistence production they undertake. A study was conducted with an objective to evaluate economic viability of the beef cattle enterprise; a case of Beef Research Institute, Lanet Farm. Data on costs and benefits was obtained from the Institute's livestock, accounts, supplies and procurement records. The Institute keeps different breeds and specializes in improved Boran and its crosses. To evaluate the worthiness of the enterprise in the farm, this study computed the Net Present Value (NPV) and Benefit-Cost Ratio (BCR) .Results showed that, the livestock inventory change for 2021 was KES. 17,530,000, and the NPV was KES.36, 453,678 with a BCR of KES.3.60. Both the NPV and BCR demonstrates that the beef cattle venture is economically feasible. The production system and of the beef cattle breeds kept was also found to play a key role in determining profitability of the enterprise. This study recommends continuation of the beef cattle enterprise by the Institute.

Keywords: *Input Supply, Beef Cattle, profitability*

Introduction

Beef is a high-quality source of protein that also can provide highly desirable eating experiences, and its demand is increasing globally. Sustainability of the beef industry requires high on-farm efficiency and productivity, and efficient value-chains that reward achievement of target-market specifications (Greenwood, 2021). Beef contributes upto 20 percent of the total meat share consumed globally (OECD-FAO, 2021). Beef statistics in the year 2020 projected the world production to be 67.8 million tonnes, while in Africa and Eastern Africa, the production was estimated to be 5.9 and 1.9 million tonnes, respectively (FAOSTAT, 2022). Kenya currently produces 244,217 tonnes of beef, which reflects a 54 percent increase since 1961 (FAOSTAT, 2022).

Currently, there are new technological developments driving consumption patterns in the beef value chain such as feed lot finishing, organic beef production, quality improvements, marbling technology (Casperson *et al.*, 2020). In developing counties, the main challenges are experienced in efforts to increase production to meet local demand as well as improving quality to enable participation in the export and niche markets. This paper presents the findings of a study conducted at KALRO's Beef Research Institute, to evaluate the economic viability of the beef cattle enterprise.

Methodology

This study area was carried out at the Beef Research Institute (BRI) Headquarters, Lanet Centre. BRI is situated on latitude 0° 18¢W and longitude 36°09¢E, 1920 metres above sea level in Lanet Location, Dundori Division of Nakuru North Sub County (Figure 1). It is about 16 km South East of Nakuru City. The Centre occupies 1,418 hectares of land, (BRI Annual report, 2014), with 20% falling in agro-ecological zone three and 80% in agro-ecological zone

four. The rainfall pattern at Lanet is bimodal with an annual mean of 800mm and a relative humidity of 83%. The mean temperatures range between 10° - 26°C.

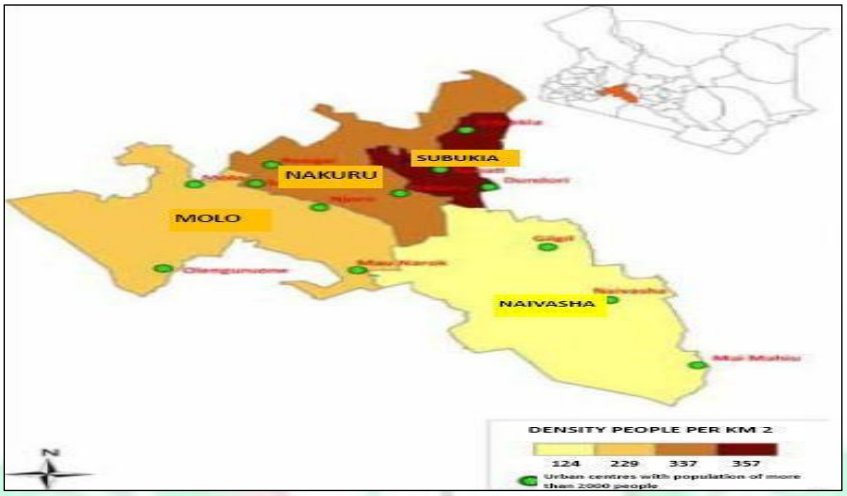

Figure 3: Map of Nakuru County, Kenya showing the location of study area Kalro-Lanet at Nakuru Ward(GPS.Lat -0.2858760,Long 36.18777200,Elev 6446ft)

The objective of the study was to evaluate the economic viability of the beef cattle enterprise. The Net Present Value (NPV) and Benefit-Cost Ratio (BCR) were used to evaluate the worthiness of the enterprise in the farm, the following methods were used; The data used in the study was sourced from the Centre's livestock records, accounts, supplies and procurement and pasture/fodder departments. The data was cleaned, organized and analyzed using Ms Excel analytical software.

Results and Discussion

Along with its research mandate, the BRI-Lanet undertakes farm enterprises for revenue generation as appropriate in aids (AIA), to fund research and development activities at the Centre. The major enterprise is the beef cattle enterprise among the others. Table 1 presents the off-take prices from the beef cattle enterprise, as obtained at the time of the study.

Table 1: Prices of outputs from the beef cattle enterprise

Type of output	Unit of sale	Selling price (KES)
Mature steer	**Kg liveweight**	**180**
Registered Breeding bull	Animal	240,000
Non-registered Breeding bull	Animal	120,000
Breeding heifer	Animal	80,000
Culled animal per	Kg liveweight	150
Manure	Tons	1500
Mineral salt	50-kg pack	2000

Source: BRI Account office 2022

Table 2 presents the mean cost of inputs used in the beef cattle enterprise.

Table 2: Mean cost of inputs used in the enterprise

Description of inputs in the farm	*Unit*	*Mean cost (KES)*
Casual labour	Man days	600
Semi-permanent labour (interns)	Man days	1000
Casual labour charges	Man days	250
Treatment drugs	Monthly	10,000
Acaricides	Monthly	77,850
Feeds	Monthly	5000
Miscellaneous	Monthly	4000

Source: BRI Account office 2022

It is important to note that, the selling price of registered breeding bulls was the highest in the enterprise. Boran cattle registered in the Kenya Stud Book are eligible (under the Breeding Society rules) for live export and as parent stock for embryo and semen extraction. The Society handles export protocols and holds an annual Breed Show and Sale in Nairobi where the top bulls are offered for sale (KALRO, 2022).

Table 3 presents the composition of the beef cattle herd at BRI Lanet for the period 1st January – 31st December 2021.

Table 3: Composition of the beef cattle enterprise in 2021

	1st January 2021	**31st December 2021**
Cows (which have calved once)	201	229
Bulls (aged ≥ 25 month)	20	26
Bulls (aged 8-24 months)	86	95
Female weaners (aged 8-24 months)	111	52
In-calf heifers	66	81
Castrated steers	70	59
Male calves (<7month)	93	59
Female calves	117	90
Culls	0	0

Source: Livestock BRI-Lanet 2021

Table 4 presents the change in inventory of the BRI beef cattle enterprise for the period January – December 2021.

Table 4: Change in livestock Inventory at KALRO-Lanet in 2021

Type of cattle (a)	**Number. on 1/1/2021 (b)**	**Number on 31/12/2021 (c)**	**Change (c-b)**	**PRICE (KES)**	**TOTAL (KES)**
Heifers (in-calf)	66	81	15	80,000.00	1,200,000.00
Cows (after 1st calving)	201	222	21	80,000.00	1,680,000.00
Bulls (over 25month)	20	25	5	120,000.00	600,000.00
Bulls (8-24) Months***	86	95	9	120,000.00	1,080,000.00
Female weaners (8-24month)***	111	52	59	120,000.00	7,080,000.00
Steers (after castration)	70	59	11	70,000.00	770,000.00

Male calves(<7month)*	93	59	34	80,000.00	2,720,000.00
Female calves**	117	90	27	80,000.00	2,160,000.00
culls****	8	0	8	30,000.00	240,000.00
Total					17,530,000.00

Source: Livestock BRI-Lanet 2021

The table 4 shows the change in livestock inventory from 1st January to 31 st December 2021 was worth KES. 17,530,000.The Farm policy does not allow sale of female calves (<7month), for the purpose of computing the worthiness of the farm and an arbitrary value is given of KES 80,000/=. Also does not allow sale of these categories of beef cattle but for the purpose of the computation of the worthiness of the farm the value given is KSH 120,000. The cattle removed or culled from a herd are due to factors including; age, performance, ill-health, lack of soundness, lack of available feed may be taken directly for slaughter, or for short duration finishing prior to slaughter depending on health and soundness.

Estimation of worthiness of Beef Farming under Extensive system

Table 5, shows the summaries of actual cash inflows from sale of beef cattle and expenses incurred in their management are used to calculate percentage of growth in revenues and expenses. Actual inflows and outflows considered in this case were from 2018-2019 financial year to the current year. From this data, it was estimated that revenues grew at an average of 34.3% and expenses grew at an average of 32.9 % per annum. This growth is what is used to estimate project flows for the next 5 years. The Kenya Central Bank current interest rate of 13% was used the discounting.

Table 5: Actual revenue generated and projected for beef cattle enterprise for the coming five years for BRI-Lanet

							34.30%		32.90%	
	Actual Revenue Collected				Projected					
Financial Year	**2018/2019**	**2019/2020**	**2020/2021**	**2021/2022**	**2022/2033**	**2023/2024**	**2024/2025**	**2025/2026**	**2026/2027**	**2027/2028**
Total cash in- flows	2,857,940	5,458,225	8,887,675	4,370,275	5,869,279	7,882,442	10,586,120	14,217,159	19,093,644	25,642,764
Total outflows	712,707	1,223,416	1,509,468	1,239,255	1,646,970	2,188,823	2,908,946	3,865,989	5,137,899	6,828,268
Net flows	2,145,233	4,234,809	7,378,207	3,131,020	4,222,309	5,693,619	7,677,174	10,351,170	13,955,745	18,814,496
Discount factor						1.135	1.288225	1.46213538	1.659523651	1.88355934
NPV						**5,016,405**	**5,959,498**	**7,079,488**	**8,409,489**	**9,988,799**
Discounted inflows						6,944,883	8,217,602	9,723,559	11,505,497	13,613,993
Discounted outflows						1,928,478	2,258,104	2,644,070	3,096,008	3,625,194
BCR						**3.60**	**3.64**	**3.68**	**3.72**	**3.76**
Net NPV	**36,453,678**									

Source of data: BRI-Lanet Account Office

From the analysis above, the NPVs are positive meaning that beef enterprise is a worthy enterprise and the returns are lucrative. Further to this, the BCR shows that, every shilling invested in the enterprise has a return of about KES.3.60.

This analysis shows that if more is invested in the beef enterprise in terms of number of cattle and land area, then KALRO stands to gain more. Further to this, investment into more value-added markets may also improve the returns to this enterprise.

Conclusions

Free range (Extensive) beef production systems is profitable. However, for the farmer to maximize profit there is need to follow the prescribed routine management practices. For the feedlot system the price of the beef cattle to fatten for three months should be relatively low in

order to competitively get a good selling price which will lead to having good profit, otherwise the unit operating cost is higher than for free range system. Across the board, the extensive models have higher profitability due to the lower costs of feeds compared to the intensive and the semi-intensive models (Kaberia, 2021). Further, in the extensive model, the farmer will be able to benefits from the economics of scale.

Recommendations

The study recommends free range (extensive) system for commercial beef production. This is where animals are kept on open pastures. The production system is economically feasible due to low unit cost and the economics of scale benefit. Further, the study recommends pasture based beef finishing system rather than using feedlots which the cost of production is extremely high, unless the farmer has a prime market for the finished product.

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Profitability of Dairy Farming Under Semi – intensive Production System: A Case Study of KALRO, Dairy Research Centre – Ol Joro Orok

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Abstract

The dairy industry accounts for 14% of Kenya's agricultural GDP. The subsector is important as it supports food security, employment, health and growth of industries in Kenya. The cost of production is a critical measure of estimating profitability of a dairy enterprise. A study was conducted with the aim of computing and analyzing the cost of production for the semi-intensive production system at KALRO Ol Joro Orok farm in Nyandarua County. Data was derived from costs and revenues obtained between January - December 2021. Variable costs comprised of feeds, drugs, minerals, labour and other consumables while revenue was derived from sale of fresh milk.

Results revealed that the annual average cost of production under the semi-intensive production system was KES 23.08 per litre of milk. The farm gate price for a litre of milk was Ksh 45. Feeding was the main component comprising 40% of the total production cost. Efforts towards producing dairy enterprise at least cost of feeds and feeding would greatly impact positively on dairy profitability. In addition, Intensive production of quality pastures and fodders per given area would not only increase the carrying capacity but would provide surplus for conservation into hay and silage, leading to even milk production throughout the year a phenomenal that earn farmers premium milk prices during the dry period. Well-fed cows are not only high milk producers but exhibit high conception rate leading to regular calving, low disease incidences and vet costs which enhance revenue. A well fed and health herd is fertile giving enough replacement stock and surplus for sale. Such a herd is capable of producing surplus milk, a stimulant for milk value addition. The findings imply that interventions with emphasis towards improving the feed, feeding and feed conservation for optimization of input costs should be prioritized. The estimate values are important for policy makers and development planners when making decisions related to costs and benefits of dairy enterprises as they enable them provide factual and realistic agribusiness advisories. In addition, the farmers will improve on the farm management and the economic performance. Policies which support the dairy sector such as removal of value added tax (VAT) in feeds should be enacted to create a conducive business environment to enable the dairy industry to flourish.

Keywords: *Semi-intensive, Gross margin, Cost of production*

Introduction

The dairy industry accounts for 14% of Kenya's agricultural GDP. It is significant in contributing to poverty alleviation, food and nutrition security in both rural and urban areas. The industry supports a range of actors including farmers, milk traders, processors, consumers and several service providers. It is regarded as a successful and vibrant industry due to the increasing domestic milk production, processing capacity, per capita milk consumption and export potential (Rademaker et al.) It supports the poor and smallholders who own one to three cows, who contribute about 80% of total milk production. Besides, it is estimated that the sub-sector employs two million people either directly or indirectly (Tegemeo Institute of Agricultural Policy and Development). There is potential for growth of the sub-sector domestically and regionally. For instance, Kenya's per capita milk consumption of 110 litres

per year is the highest in Sub-Saharan Africa and it is expected to rise to 130 litres per year by 2030 (MALF) . In addition, Kenya can easily tap into the demand within the Eastern and Southern Africa region, estimated at two million tonnes (SNV).

The annual consumption of milk in Kenya is increasing at a faster rate (5.8% vs 5.3%) than the milk production (Ministry of Agriculture Livestock Fisheries and Co-operatives); (Policy). The high demand for milk is because of the high consumption arising from rapid growth in the human population, and increased incomes and preference for quality food by the urban and the rising middle class citizens, as well as the increased rate of imports (3.5%) by the COMESA and other EAC countries. To meet this growing demand for milk and dairy products, smallholder dairy farmers need to increase the production of milk per animal.

Milk production at farm level is below 10 kg (*Smallholder Dairy Production in Kenya ; a Review*)(Muia et al.). The low milk production may be attributed mainly to the poor quality basal forages, sub-standard concentrates, and the low rates of supplementation with quality concentrates because of the high costs.

The semi- intensive system is practiced in areas of greater land availability, medium to high potential areas where there are less intensive practices of combined grazing and stall feeding or purely paddock grazing. It is characterized by grazing at daytime and stall feeding at night, the animals are supplemented during milking (Muia et al.)

Degree of intensification is a major factor in profit analysis in milk production. (Staal et al.). When intensification is increased the cost of production increases therefore profit per litres decreases. (Kibiego et al.). Fodder and feed make up the highest proportion of milk production costs (55-70%). According to (Gitau et al.) Production cost varies according to production system, location of farm in relation to market, input supply, labour, fodder availability, use of purchased feeds etc. Calculations are affected by the way family labour and land are calculated or included (Kibiego et al.) Incomes therefore vary with the season, location of farm, yields achieved, formal and informal milk sales and the value of by-products as manure (Staal et al.). This implies that the profits are different in various locations in the country. The intensive zero grazing system gives the highest cost of production because of high cost of factors of production. According to (Kibiego et al.), the smallholder zero grazing farmers had the highest returns on investment at 40.22% but the cost of producing a litre increased as intensification increased as it depends on high level of supplementation with purchased feeds.

High cost of production is particularly an important challenge and dairy producers have been raising concerns about it. (Economics and Library) estimated the cost of production in 2010 and found that purchase of concentrates was the largest share of variable costs. These authors further found that costs differed by production system, with the less intensive systems outperforming the more intensive ones in terms of economic performance. There are three main systems of dairy production in Kenya. These are intensive zero-grazing, semi-zero (mixed) and open grazing systems. (Kariyasa and Dewi)(Economics and Library) found that non-zero grazing systems were the most economically viable form of dairy production.

In one of the study areas, the intensive system of production returned negative gross margins. Despite the high costs of production, observations show that producer prices tend to remain relatively sticky even when production costs are on an upward trend. This has the effect of squeezing producers' profit margins and reducing incentives for dairy production. Measurement and estimation of the cost of production is important if a farmer wants to know whether or not the enterprise is profitable. While one can tell the milk price right away, it is often difficult to measure milk production costs and profits (Mburu and Wakhungu). The cost of milk production and its profitability is also affected by factors that determine farm-gate milk prices across the rural areas of Kenya (*Smallholder Dairy Production in Kenya ; a Review*). The choice of production and marketing strategies by farmers therefore, contribute to high costs

of production and low average productivity. As a result there has been continued interest from the public as well as policy makers in regard to profitability and competitiveness of Kenya dairy production. Therefore, an understanding of the costs and benefits of smallholder dairy farmers is an important pre-requisite for policy formulation, aimed at improving productivity levels and guiding enterprise decisions. Further, absence of farm records is a major hindrance to obtaining accurate cost of milk production at farm level. Cost of production helps in supporting farmers to improve farm management and economic performance. It also supports researchers and policy makers in identifying interventions to improve on farm profitability. It further assists processors and policy makers in setting milk prices and in identification of adequate farmer support interventions. The objective of this study was therefore to assess the cost of milk production under a semi-intensive system.

The specific objectives were to:

a) Estimate the cost of milk production and profitability under the semi-intensive system of production.
b) Identify the key factors that influence the cost of production.
c) To recommend strategies of lowering cost of production

Materials and Methods

The study was conducted at KALRO Dairy research centre, Oljororook and it involved collection and analysis of secondary data from the centre dairy herd. The centre climate is classified as cold with the average annual temperature and rainfall of 14.5 ^{o}C and 875 mm respectively and lies at 2383.82 M above sea level. The farm host an average of 30 milking cows composed of Friesians, Ayrshire and Friesian-Sahiwal crosses.

The cows graze on Kikuyu grass in the morning and are fed on maize silage, oat grass and other cut and carry fodder in the evening. During milking the cows are fed on concentrates based on their level of milk production (1kg: 4 litres of milk).

The data on cost and revenue in the dairy enterprise for the year 2021 was collected from the secondary data and it was analyzed and the variables of interest included cost of inputs viz. feeds, labour, drugs, minerals and consumables while the revenue was from sale of the milk.

Gross margin analysis was also done by subtracting the costs from revenue from every month. The cost of production was computed by dividing total cost with the number of litres that were produced in a month. Finally, the average cost of production was derived by adding all costs in the year and dividing by 12 to get the average annual cost of production.

Results

Table 1: Costs analysis for year 2021

Item Description	Total Costs	%Of The Items
Feeds	919,257.5	39.92
Drugs	434,805	18.86
minerals	108,347.5	4.70
consumables	178,089.5	7.72
Labour	466,395	20.23
silage	197,600	8.57
Total	2,304,494.5	100

Table 2. Annual cost of production, sales, gross margin and cost of milk production per kg (Ksh)

Month	Cost	Sales	Gross margin	Unit cost of production
January	185,890	244,567.5	58,677.5	22.9
February	238,512.5	260,502.5	21,990	27.1
March	229,340	253,297.5	23,957.5	25.4
April	239,540	227,877.5	-11,662.5	29.3
May	221,315	292,230	70,915	23.0
June	142,065	266,670	124,605	16.9
July	167,635	251,820	84,185	21.2
August	168,705	360472	191,767	15.3
September	177,342	373,973	196,631	15.0
October	154,420	343,912.5	189,492.5	22.6
November	174,030	292,185	118,155	28.3
December	209,520	273,712.5	64,192.5	30.0
Annual total	2,308,315	3,441,220	1,132,905	23.08

Discussion

Table 1 shows the feeds (concentrate) has the highest proportion of the cost .The results are in agreement with (Gitau et al.) Who found that fodder and feed make up the highest proportion of milk production costs (55-70%). Wambugu *et al*. Also estimated the cost of production in 2010 and found that purchase of concentrates was the largest share of variable cost. The cost of the production varied between months and this can be attributed to change in feeds availability, availability of quality pastures in the grazing fields which triggers an increase in the milk production among other factors. (Lukuyu et al.) Indicated that the cost can be affected by the seasons and other factors.

According to Mugambi *et al*. Milk production in smallholder farms could be increased by 16.3% through better use of available resources given the current state of technology without extra cost, while the cost of milk production could be decreased by about 4.4% without decreasing output

Conclusion

The study indicated that the semi-intensive production system has a positive gross margin and the cost of the production is relatively low compared to the studies on intensive systems. Gross margins can be improved further by embracing the pasture based system which will enable use of the available feed resources which are grown at a lower costs. Milk value addition and the sale of the breeding stock can further increase the revenue hence lowering the cost of the production.

More research on the cost of the production under different systems need to be carried in order to have updated and realistic information. Such studies will also assist dairy stakeholders in understanding the economic and production dynamics for them to make appropriate dairy agribusiness advisories.

Policy makers need to regularly evaluate the cost of the production to act as a guide in determining the profit margin within the farm as it is affected by several factors. This will act as a tool in determining profitability in the farm hence greatly assist the farmers. Policies which support the dairy sector such as removal of tax in feeds, Provision of milk coolers placed strategically for farmer use among other policies, should be enacted to enable the dairy industry to flourish.

Recommendations

i) Training of farmers on feeding strategies for improved productivity.
ii) Promote the feed conservation and training farmers on quality assessment and ration formulation from local feed resources
iii) Promotion of training programmes to spread dissemination of innovations and technologies in the dairy sector.
iv) Facilitation of the farmers with input subsidies by Government.
v) Mobilization of the farmers to form/join cooperatives to have more bargaining power on the price of the milk. The cooperatives should also be supported to embrace the value addition.
vi) Policy formulation and enactment which regulate the milk imports to prevent competition with the country milk products.
vii) Establishment of the guaranteed minimum price for the milk and its implementation to avoid farmer exploitation.

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Gendered Differences in Management of Cattle and Goat Diseases in Kajiado and Taita Taveta Counties, Kenya

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Abstract

Livestock diseases remain a major constraint limiting livestock production in Sub Saharan Africa and there is growing recognition of gender disparities in management of livestock diseases. In East Africa, women who keep livestock are less able than men to address animal disease constraints due to gender norms, which constrain their accessibility to veterinary services, animal medicines and information. Gender differences in management of cattle compared to goat disease in Kenya is not well understood. This paper takes the case of 508 randomly sampled female and male livestock keeping households in Kajiado and Taita Taveta counties to determine gender differences in management of cattle versus goat diseases, taking cognizance that men are more likely to own large livestock such as cattle compared to women who are more likely to own smaller species such as goats. Data was collected through a household survey and comparison of means using t-tests conducted to evaluate gendered differences in management of cattle and goat diseases. Among other results, the study revealed female-headed households were less likely to apply disease management strategies in cattle and goat production compared to their male counterparts. This paper recommends development and implementation of interventions that increase women's access to livestock disease management support as a potential strategy to enhance the impact of livestock production.

Keywords: *Cattle, goats, disease management, female-headed, male-headed*

The Level and Determinants of Profit Efficiency in Fodder Production: A Case of Southern Rangelands of Kenya

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Abstract

This study examines profit efficiency and factors influencing inefficiency in selected forage production in selected areas of Kenya by using the maximum likelihood stochastic profit frontier function. The findings revealed that forage production is profitable with an average profit efficiency of 76.22% and 86.57% for grasses and leguminous crops, respectively. The coefficients revealed variability, which confirms that the firms in the sample have different profit frontiers. For

coefficients that were significant but negative in terms of magnitude is a clear indication that such variables would result in a high decrease in return to scare with respect to profit margins and vice versa. The policy implication in forage production of these findings is that profit inefficiency can be reduced significantly by improving the cost of land preparation, land harrowing, and weed management, although other costs evaluated are also relevant.

Keywords: *Stochastic profit frontier function, profit efficiency, biomass, forages, Kenya*

Introduction

As a Sub-Saharan African country, the economy of Kenya is strongly influenced by agriculture which comprises crops, livestock, and fisheries. The livestock sector represents an important production activity providing about 88% of employment, yet the sector accounts for about 42% of the country's agricultural GDP (Manyeki *et al.*, 2019). Livestock farming is estimated to be practiced by more than 75% of the smallholdings in Kenya (Salami, et al 2010), with pastoralists keeping 80% of the country's livestock. Despite livestock keeping being the dominant economic activity among pastoralists who reside in the rangelands of Kenya, the production trends have been declining, resulting in less contribution to the agricultural GDP that can be traced to challenges associated with the nutritive value of the common forage species (Maweu et al 2023; Manyeki et al 2023). The solution to these challenge can be sought from the wide array of forage genetic materials available globally. Different fodder crop species have been promoted among smallholder farmers in Kenya and an estimated 55% of the farmers cultivate at least one type of fodder (SNV 2013). This paper contributes to limited information available on fodder profit efficiency measurement that could inspire local producers and communities to shift towards more sustainable fodder-livestock production systems.

In any agricultural-related enterprise, profit efficiency estimation establishes a vital information source intended for the economic agent and policymakers than other efficiency measures. Therefore, the profit efficiency of fodder production at household level has significant implications for the type of development strategies to be adopted in Kenyan rangelands where the primary livestock sector still dominates. Understanding profit efficiency levels and their determinants can greatly help pastoralists and policymakers in formulating efficiency-enhancing policies the fodder production. So, what is profit efficiency, and how can it be measured so that farmers and policymakers can gain insights and make effective plans for the betterment of fodder production as a commercial enterprise?

Three components can be utilized namely technical, allocative, and scale for the assessment of fodder profit (in)efficiency. Technical efficiency reflects the effectiveness with which a given set of inputs are used to produce output, while allocative efficiency reflects how different resource inputs are combined to produce a mix of different outputs, given their respective prices (Manyeki 2020). In the case of profit-maximization, there is scale inefficiency, if its yield level is not directly proportional to the output price and the marginal cost. However, when farmers find different prices for various aspects of the fodder products as was the case under pastoral cconditions then the production function model of quantity efficiency is not suitable and this directed the use of stochastic profit function to appraise farm-specific characteristics deviation and efficiency levels. According to Chen *et al.*, (2015), it is rare for a farm/firm to be on top of the list of all possible measures of performance. In this case, therefore, identifying the smallholder fodder-producing performance frontier across the relevant measures is an important task that is infrequently performed. Thus, this forms the premise of the present study that attempts to reveal the profit efficiency of fodder production by identifying farm-specific features that explain deviation in efficiency while assuming homogenous technology. This is because it is important to know the efficiency score and the determinants for fodder production as they are a major component in increasing the poor smallholder farmers' incomes and will enhance food security.

Materials and methods

Study area and data collection

The study was conducted in the counties of Kajiado, Narok and Taita Taveta where Kenya Agricultural and Livestock Research Organization (KARLO) in partnership with SNV Netherlands Development Organization agencies initiated research activities within the Integrated & and Climate Smart Innovations for Agro-Pastoralist Economies and Landscapes Kenya's ASAL (ICSIAPL) which ran for three (3) years starting from 1st January 2021–31st December 2023. The ICSIAPL project aimed at improving the livelihoods of agro-pastoralist communities through improved forage production and livestock husbandry, building on the commercialization of climate-smart innovations and sustainable landscape management. Due to the effects of climate change experienced in these areas, there was an urgency to use a wide array of appropriate genetic material and therefore twenty forage crop species were identified and promoted. The forage production varieties promoted were Brachiaria camelo, Panicum Maximum variety Massai, and Nutrifeed (Pennisetum glaucum hybrid), and two legumes including Cowpea (Vigna unguiculata), and Dolichos lab lab (Lablab purpureus) established in the Lowland region. Four grasses (Brachiaria cayman, Brachiaria cobra, Chloris gayana var. Ex-Tozi, and Panicum variety siambasa) and five legumes namely Desmodium (Desmodium intortum), Purple vetch (Vicia benghalensis), Lupin (Lupin albus), Velvet bean (Mucuna pruriens) and Sweet potato vines variety Ex-Mukurweini (Ipomea batattas) were established in the highlands regions. In addition, four grasses namely Boma Rhodes (Chloris gayana), Bush rye (Enterepogon macrostachyus), African foxtail (Cenchrus ciliaris), and Sugargraze (Sorghum bicolor), and two legumes including Sunn hemp (crotalaria juncea) and Lucerne (Medicago sativa)) were recommended for both regions.

In estimating the profit efficiency for forage production, there is a need to assign an economic value to important traits in forage production. Several important traits of forage include Seasonal Dry Matter (DM) yield, Quality, Silage DM Yield, and Persistency which are recommended for consideration (McEvoy, *et al.*, 2014). In this study, we opted for seasonal DM yield as the important trait that would influence profitability at the farm level. The DM Yield sampling was done from a total of 60 demo plots that were established in the three counties. Direct benefits of improved pastures through reseeding were estimated using the number of 15kg hay bales. Techniques used for valuing input included the cost of land preparation which comprised of land ploughing, harrowing and farrow opening; the cost of labour for sowing which is the wage rate of hired labour (in man-days); weed and forage management computed from the wage rate of hired labour and market price of herbicides; cost of planting material (seeds). On outputs, gross margin analysis was used and the revenue generated from sale of 15-kg hay bales. The valuation of both the inputs and outputs was estimated using prevailing market prices for the year 2023.

Stochastic profit efficient model

The concept of stochastic profit frontier measures the distance between the current profit of a firm and the efficient profit frontier and encompasses errors on the input side as well as on the output side. Literature distinguishes between standard profit efficiency and alternative profit efficiency depending on whether the hypothesis of perfect competition in the markets of inputs and outputs is assumed or not. Standard profit efficiency measures how close a firm is operating at its maximum profit given a price level for inputs and a price level for outputs, assuming perfect competition in these markets. This means that a firm takes as given the prices of inputs and outputs, and maximizes its profit by adjusting its quantities.

$$\pi = (p, w)\exp(v_\pi)\exp(-u_\pi), \quad (1)$$

where π is the profit variable, p is the price vector of the variable outputs (in this case the price of the 15-kg bale of hay), and w is the price vector of the variable inputs. The quantities of

inputs considered were transformed using natural logarithms and included the price of land ploughing (LogLP), price of land harrowing (LogLH), price of furrow opening (LogFO), price of labour for planting (logPla), price of planting materials (LogPM), and price of labour for weed management (LogWM). Term u_π presents the inefficiencies that reduce profit, and $v_\pi$represents random error. However, in practice, the assumption of perfect competition is not applicable in many farming situations, as farmers can exercise some discretionally market power in setting the price of outputs. Therefore, the alternative profit efficiency that measures how close a firm is operating to its maximum profit given its level of output was found to be appropriate. In this case, the alternative profit efficiency takes the quantity of output as given and the price of the outputs is allowed to vary freely and affect the profit of the farmer;

$$\pi = (y, w)\exp(v_\pi)\exp(-u_\pi), \quad (2)$$

where the variables are as defined in (1) and y is the vector of quantities of the variable outputs. Based on equation (2), the alternative profit efficiency of the farmer is defined as the ratio between the current profit and the maximum profit that a farm could achieve if it were perfectly efficient ($u_\pi = 0$). Although the basic assumption from the resource-based view is the heterogeneity of resources between farms, from the experimental point of view, we assume that all the farm sites within highland and lowland zones share the same technology; that is to say, they were homogeneous.

The next step involves the determination of the functional form of the stochastic frontier. One of the requirements for estimating the stochastic frontier is to specify its functional form. In this, the common assumption was that farmers are employing the same technologies, then the traditional frontier models proposed jointly by Aigner et al (1977) and Meeusen and Van der Broeck (1977) with a Cobb-Douglas logarithmic stochastic frontier model (Kibara and Kotosz 2022), was found appropriate and was specified as;

$$ln\,\pi_i = \beta_o \sum_{i=1}^{N} \beta_i\, ln\, Y_i + \sum_{i=1}^{N} \beta_i\, ln\, W_i + \nu_i - u_i, \quad (3)$$

where Y_i is the observed scalar variable output of farmer *i*, and $\boldsymbol{W_{ij}}$ is a vector of *J* inputs used by farmer *i*. In a traditional stochastic profit frontier modeling, profit-oriented inefficiency is calculated as a ratio of the observed profit to the corresponding optimal frontier profit, given the available technology;

$$Profit\ inefficiency = \frac{\pi}{\pi^*} = \frac{(y,w)\exp(v_\pi)\exp(-u_\pi)}{(y,w)\exp(v_\pi)} = exp(-u_\pi), \quad (4)$$

Here π is the observed profit and $presents$ the frontier output.

Results and discussion

Our focus was to analyze the levels and factor inputs that influence profit efficiencies in forage production under the rangelands condition that would give insight into the policy recommendations. In the case of cross-sectional data, the stochastic profit frontier model proposed can only be estimated if the inefficiency effect components u_i, are stochastic and have particular distributional properties (Battese and Coelli, 1995) – in this case, we assumed a half normal distribution. This implied that this stochastic profit frontier model can usually be estimated by maximum likelihood (ML) methods and the common practice under this scenario is to maximize the log-likelihood models. The systems of stochastic profit frontier models are estimated and presented in the section with the parametric imposition of maximum likelihood. Since all variables were normalized by their means and expressed in natural logarithms prior to estimation, coefficients can be interpreted as elasticities.

Determinants for (In)efficiency for Selected Grasses Species in lowland and highland regions

Table 1 shows estimates of the maximum-likelihood stochastic Cobb-Douglas logarithmic profit function. The table shows separate models for sugar graze, Nutrifeed, Camelo, Bush rye, and Foxtail for the lowland producers. Overall the empirical results are robust in the sense that the estimates for the majority of factor inputs employed across the profit frontier were significant at either 1%, 5%, or 10% levels, implying that differentiated patterns in input importance can be observed. The direction of the effect and the magnitude are important to note. The positive signs and negative signs indicate that the variable will reduce or increase profit, respectively. This suggests that the profit function is either downward-sloping with respect to negative signs or upward-sloping with respect to positive signs. Variables that are significant but negative in indicate that those variables would result in a decrease in return to scale with respect to profit margin and vice versa.

For instance, an increase in the cost of the planting materials (LogPM) seems to be the most important variable determining profit efficiency. This means that for a 10% increase in the cost of planting materials, the profit obtained from forage production will significantly reduce by 5.198%, 14.439%. 5.169%, 1.59%, and 0.0914% for Sugar graze, Nutrifeed, Camelo, Bush rye, and Foxtail, respectively. The contrary argument applies to the positive and significant variables. Bush rye seems top the list with respect to furrow opening (LogFO) and thus caution should be taken when making a decision whether to incur such costs, otherwise the status quo can be maintained. From Table 1, we also found that the average profit efficiency score for lowland grasses ranged from 0.6116 to 0.8046; it indicates that forage farmers in this region can raisetheir profits by 20 – 39% by applying factors that enhance profit inefficiency. This result is in line with similar research done in rice in Bangladesh by Rahman (2003) but of a different product from the one used in this study.

Table 1: Parameter estimation of the maximum-likelihood stochastic profit function for the Lowlands Grasses

Grass species	Sugar graze	Nutrifeed	Camelo	Bush rye	Foxtail
logLP	-0.5198***	-1.4439***	-0.5169***	-0.1590**	-0.0914*
	(0.6824)	(0.5796)	(0.0001)	(0.0092)	(0.1236)
logLH	-0.1404*	-0.9829***	-0.3994***	-0.1355*	-0.1046**
	(0.7001)	(0.5483)	(0.00005)	(0.0013)	(0.0984)
logFO	-0.1807**	-0.7414***	1.2534*	-4.4244***	-0.0375 (0.1469)
	(0.2919)	(0.2698)	(0.0002)	(0.0326)	
logPla	-0.1991**	-0.2177*	-3.1709***	-0.7990***	-0.0646*
	(0.3851)	(0.3211)	(0.0012)	(0.0099)	(0.2064)
logPM	-1.1497***	-0.5059**	0.4675***	0.5574***	-0.0336 (0.5252)
	(0.5197)	(0.5042)	(0.0018)	(0.0132)	
LogWM	-0.8804**	-0.5532**	-0.2957**	-0.2955**	-0.0427*
	(0.5026)	(0.4179)	(0.00003)	(0.0037)	(0.0348)
_cons	16.964*	-11.668	-18.946***	35.5852	11.5856
	(10.536)	(7.9527)	(0.0113)	(0.1524)	(5.1220)
Inefficiency score (IS)	0.3884	0.2018	0.1954	0.2757	0.2278
Efficiency =1-IS	0.6116	0.7982	0.8046	0.7243	0.7722

Note: Note: ***, ** and * == > significance at the 1%, 5% and 10%
Sources: Authors own computation using experimental data

Table 2 shows the maximum likelihood stochastic profit estimates scenario for grasses that were selected for the highland region. Similarly, the variables were robust in their effect on profit efficiency with most showing significance at either 1%, 5%, or 10% levels. Their effect seems to be fairly in terms of magnitude as compared to those found in the forage crops that were promoted in the lowland region. This is reflected by a relatively high-profit efficiency score that ranges from 0.7277 to 0.9875 except for the Cayman variety which was very low

(0.5368). From the results in Table 1, it is also clear that Bush rye is a lowland grass but it can also produce better biomass in the high regions. This can be attributed to the forage crop varieties promoted and the amount of rainfall received in the regions translating to the DM biomass harvested vis-à-vis the quantity of inputs. During the period of study, the highlands of Kenya experienced relatively more rain and this translated to higher biomass.

Table 2: Parameter estimation of the maximum-likelihood stochastic profit function for the Highlands Grasses

Grass species	Sugar graze	Camelo	Bush rye	Cayman	Boma Rhodes	Cobra	PaMa
logLP	-0.9322***	-0.8774***	0.2015*	-0.1066***	0.1466***	0.3009*	0.3998*
	(0.0009)	(0.00003)	(0.6506)	(0.0001)	(0.0118)	(0.2891)	(0.2481)
logLH	-0.7567***	-0.0379*	0.0284	0.1256***	-0.1812***	-0.0224	0.0653
	(0.0006)	(0.00001)	(0.2085)	(0.0002)	(0.0011)	(0.2001)	(0.0910)
logLF	0.0795	0.8042***	0.0798	-0.2161***	0.6468***	-0.3330**	0.6137**
	(0.0002)	(0.00008)	(0.8613)	(0.0003)	0.0079)	(0.4711)	(0.3607)
logPla	-0.61428**	0.0390	-1.0061**	0.0361	0.0215	1.4097***	-0.1828
	(0.0003)	(0.00005)	(0.5536)	(0.0001)	(0.0059)	(0.4839)	(0.2233)
logPGs	0.2703*	1.7162***	1.3455***	0.4458***	0.4627***	0.8682***	1.2415***
	(0.0004)	(0.0007)	(1.1016)	(0.0005)	(0.0122)	(0.2693)	(0.6419)
LogWM	1.5015***	0.0996*	-0.2436*	0.1725***	0.2384	-0.4112**	0.0498*
	(0.0008)	(0.00003)	(0.1722)	(0.00003)	(0.0012)	(0.2802)	(0.0670)
_cons	16.51355**	-5.341***	6.6506	7.7743***	1.1356*	-4.1125***	-6.7630
	(0.0034)	(0.0042)	13.4726	(0.0071)	(0.0001)	(0.0034)	(7.2215)
Average Inefficiency score (IS)	0.2723	0.1844	0.1959	0.4632	0.0125	0.0800	0.1369
Efficiency =1-IS	0.7277	0.8156	0.8044	0.5368	0.9875	0.9200	0.8631

Note: Note: ***, ** and * == > significance at the 1%, 5% and 10%
Sources: Authors own computation using experimental data

Determinants of (In) efficiency for Selected Legume Species

Leguminous fodder crops were also promoted to increaseprotein sources. Tables 3 and 4 present the legume crop performance with respect to protein levels. As reported by Kebede et al (2016), grass integration with legumes would result generally in a higher protein-rich and lower fiber content yield than grass only. The parameter estimation of the maximum-likelihood stochastic profit function for legume varieties promoted in the lowland and highland regions are presented in Tables 3 and 4, respectively. Generally, from the two Tables, elasticities seem to be robust in their effect on profit efficiency in the sense that most of them are significant at either 1%, 5%, or 10%. Comparably, elasticities for forage crops promoted in the two regions are generally not or only weakly significant, except for the response for Dolichos lablab biomass yield with respect to the cost of weed management (LogWM) and Lucerne biomass with respect to the cost of planting materials (LogPM). Irrespective of the signs, the profit efficiency of legume crops promoted in the two regions showed more responsiveness to the cost of land harrowing (LogLH) and cost of weed management (LogWM), except for forage crops that were promoted in the highland region that were more responsive to the cost of land preparation (logLP).

Regarding the profit efficiency scores, overall, the legumes that were promoted in the highland regions recorded high scores (ranging between 0.8473 to 0.9999) as compared to those that were promoted in the lowland areas (ranging between 0.7315 to 0.8478) which could perhaps be attributed to higher rainfall experienced in this region during the time of the study. This implies that the effect of high inefficiency in legume production in the lowland region requires reduction to the bare minimum if the farmers' target high profit margins.

Table 3: Parameter estimation of the maximum-likelihood stochastic profit function for the Lowland Legumes

Legume species	Dolichos lablab	Cowpea	Sunn hemp	Lucerne
logLP	0.2541***	-0.0076	-0.0089	0.0164*
	(0.0032)	(0.1539)	(0.1259)	(0.0004)
logLH	0.2250***	0.1046** (0.1956)	0.1073**	0.1369**
	(0.0023)		(0.0952)	(0.0012)
logLF	0.1321*	0.0487 (0.2063)	-0.0100	0.2909***
	(0.0011)		(0.1031)	(0.0015)
logPla	0.1906**	0.1016** (0.1886)	-0.0347	-0.0661**
	(0.0043)		(0.0382)	(0.0010)
logPM	0.1314*	0.0519	0.1274***	0.7186***
	(0.0029)	(0.1325)	(0.0875)	(0.0021)
LogWM	1.9246***	-0.1108**	-0.0556*	0.0795**
	(0.0000)	(0.1078)	(0.0798)	(0.0007)
_cons	24.0543*** (0.0802)	12.316***	14.042***	14.5513***
		(2.8458)	(1.9910)	(0.5843)
Average Inefficiency score (IS)	0.1588	0.2685	0.1522	0.2552
Efficiency =1-IS	0.8412	0.7315	0.8478	0.7448

Note: Note: ***, ** and * == > significance at the 1%, 5% and 10%
Sources: Authors own computation using experimental data

Table 4: Parameter estimation of the maximum-likelihood stochastic profit function for the Highland Legumes

Legume species	Sunn hemp[1]	Lucerne[2]	Purple vetch[3]	Velvet beans[4]	Sweet potato vines[5]	Desmodium[6]
logLP	0.2088*	-.2368**	-0.5979**	0.3769***	0.4039***	0.8369***
	(0.1295)	(0.0051)	(0.3089)	(0.0001)	(0.0051)	(0.00004)
logLH	-0.0859*	-0.0717*	0.1049**	0.1298*	-0.7751***	-0.4498**
	(0.0509)	(0.0048)	(0.0549)	(0.00001)	(0.0043)	(0.00003)
logLF	-0.4101**	-0.7543***	-0.2570*	-0.0439**	-0.1140*	-0.2903
	(0.1902)	(0.0263)	(0.1774)	(0.00002)	(0.0054)	(0.00004)
logPla	0.1224	-0.0583	0.2464***	0.8339***	4.2128***	-2.3085***
	(0.1319)	(0.0025)	(0.0890)	(0.0001)	(0.0086)	(0.00009)
logPGs	0.0079	-6.5436***	-0.0214	-2.2846***	3.9232***	0.4900**
	(0.3793)	(0.0273)	(0.0695)	(0.00008)	(0.0077)	(0.00002)
LogWM	1.5316*	-0.9865***	2.4437***	4.6820***	-20.741***	-7.229***
	(1.2716)	(0.0507)	(0.3674)	(0.0003)	(0.0002)	(0.0003)
_cons	1.4163	90.7418	-1.831181	-11.889***	107.3757	80.827***
	(10.3383)	(0.0056)	(0.0512)	(0.0019)	(0.0035)	(0.0026)
Average Inefficiency score (IS)	0.0225	0.0641	0.1572	0.0634	0.0001	0.0074
Efficiency =1-IS	0.9775	0.9359	0.8473	0.9366	0.9999	0.9926

Note: Note: ***, ** and * == > significance at the 1%, 5% and 10%
Sources: Authors own computation using experimental data

Conclusion and recommendation

The study employed a stochastic profit frontier model to estimate the efficiency of forage-producing farmers in the Counties of Kajiado, Narok, and Taita Taveta of Kenya. Using data obtained from the 60 forage-producing beneficiaries under the ICSIAPL project, the study showed that profit efficiency varied moderately among the sampled farmers. It ranged from 53.68 % to 98.75% and 73.15% to 99.99% with a mean of 76.22% and 86.57% for the study sample for grasses and leguminous crops, respectively. The mean level of efficiency indicates that there exists an opportunity to increase profit by improving the resource allocative efficiency. However, the coefficients reveal some variability, which confirms that the firms in the study area have different profit frontiers, hence heterogeneity investigation is recommended

as a future research endeavor. The policy implication in forage production of these findings is that profit inefficiency can be reduced significantly by reducing the cost of land preparation, land harrowing, and weed management, although other costs evaluated are also relevant.

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Status of Fodder Production and Marketing in Western Kenya: The Case of Busia, Kakamega and Siaya Counties

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Abstract

Feed is an important part of dairy cattle growth and health and has significant effect on milk yield. Currently, there is a large demand and market for fodder by both the progressive smallholders and medium scale dairy farmers. However, farmers are facing a challenge of feed and feed quality. The KSAP project came in to facilitate farmers' access to clean fodder planting materials in Busia, Siaya and Kakamega County. This was done through provision of various quality fodder planting materials to identified farmers. The farmers were trained on fodder planting materials production and marketing. This study aimed at assessing the state of fodder in the region after the intervention. A total of 223 farmers were interviewed. The farmers were purposively selected from the three study sites. Data was analysed using the SPSS software. Descriptive statistics such as percentage, frequencies, means and standard deviations were applied. Chi square test was also used to compare the difference in various variables tested across the counties. Results in indicate that napier grass and bracharia were the most known and planted fodder grass. There was a significant difference in the age of the farmers where majority of the farmers were 56 years and above. Nutritive value, biomass and early maturity were the key aspects that farmers considered when buying fodder planting materials. Majority of the farmers did not keep their fodder production record. Fodder production has the capacity to increase milk production and income through sale of fodder. The study recommends strengthening of the fodder marker market value chain.

Keywords: *Fodder, Market, Value chain, Status*

Introduction

The dairy industry in Kenya is an important sector that accounts for about fourteen per cent of the agricultural GDP and four per cent of the total GDP (Kenya National adaptation plan 2015 -2030) and 80% of all milk produced in Kenya is by smallholder farmers in rural settings (Techno serve 2016). Despite Kenya's long history of dairy farming, the dairy industry is stagnated in its formative stages, with some segments of its value chain being more advanced than others. Feed is one of the segments of the chain that still faces a number of challenges (Kwamboka et al 2022). This has led to low productivity due to inadequate feeding resources. Feed is an important part of dairy cattle growth and health and has significant effect on milk yield. Currently, there is a high demand and large market for fodder by both the progressive smallholders and medium scale dairy farmers (Mbijiwe 2015). Furthermore, the demand for forage is growing day by day due to the commercialization and growing dairy sector in Kenya. The demand is also associated with the increase in population, the growing urbanization and increased number of urban and peri-urban farmers involved in zero grazing. Therefore, fodder production has a potential to generate revenue generation for agricultural households due to the high demand. This will contribute to diversified income sources at the various value chain nodes of the dairy industry.

The Kenyan government has given priority to research and promotion of technologies that can encourage on-farm production of high yield fodder to reduce the cost of milk production. In western Kenya, smallholder dairy farmers depend on Napier as the main forage, which is currently under threat by napier stunt disease (NSD). Previous research has identified and developed high yielding Napier grass that is tolerant to NSD (Napier cv Ouma and Napier cv South Africa) and alternative forages such as Rhodes grass, Giant setaria, panicum species and Bracharia spp (Wamalwa et al. 2017; and Njarui et al. 2016). Despite the existence of applicable approaches for planting of forages, adoption rate among farmers has remained low over the years. One of the most limiting factors is inadequate supply of clean planting materials/seeds and reliance on farmer-to-farmer exchange of the planting materials leading to spread of pest and disease from one farm to another. There is therefore need to ensure the farmers sustainably get clean planting materials. The KCSAP project came in with the aim of availing superior seeds/planting materials of forage to small-scale dairy farmers for improved milk production. This was done through lead farmers who were expected to be champions and entrepreneurs in fodder by availing clean planting materials to the farmers. The farmers were trained on the fodder production and management with emphasis on the need to get quality seed from designated farmers. The objective of this study was therefore to assess the status of fodder seed production and marketing in the study sites.

Methodology

Study sites

The study was carried out in February 2023 in Siaya, Kakamega and Busia Counties in Western Kenya. These sites were purposively selected since they were involved in the KCSAP forage project study.

Busia County: Busia County is situated at the extreme Western region of Kenya and neighboring Uganda. Most parts of Busia County fall within the Lake Victoria Basin. The altitude is undulating and rises from 1,130 metres above sea level at the shores of Lake Victoria to a maximum of about 1,500 metres in the Samia and North Teso Hills. Temperatures range between 21º- 23ºC. Relative humidity is fairly high due to the site proximity to Lake Victoria and soils are predominantly nitisols and ferralsols. Crops grown within the county include maize, beans, sweet potatoes, finger millet, cassava, cotton, tobacco and sugar cane (Busia CIDP 2018-2022). The current project activities are located in Nambale sub-county, Bukhayo west ward of Busia County (Table 1). This site is the Lower Midland zone 2 (LM 2) (CIDP: Busia county 2018-2022).

Kakamega County: Kakamega County is located in western Kenya. The altitude ranges from 1000 m to 2000m above sea level. The county is divided into two main agro-ecological zones, i.e. Upper Midland (UM) and the Lower Midland zone (LM). Farmers in these region grow a range of crops including maize, tea, beans, local vegetables, groundnut, sweetpoatoes, sugarcane, finger millet, cassava and they also keep livestock such as cattle. (Kakamega CIDP 2018-2022). The project activities are located in Mumias East and Mumias West sub-counties (Table 1) which falls under the lower midland zone.

Siaya County: Siaya County is one of the six counties in Nyanza region. It has a land surface area of approximately 2,530 km² and water surface area of approximately 1,005 km2. The water surface area forms part of Lake Victoria (the third largest fresh water lake in the world). It approximately lies between latitude 0º 26´ South to 0º 18´ North and longitude 33º 58´ and 34º 33´ East. The County spreads across agro-ecological zones LM1 to LM 5. The County experiences a bi-modal rainfall, with long rains falling between March and June and short rains between September and December. Temperatures vary with altitude rising from 21° C in the North East to about 22.50° C along the shores of Lake Victoria. While in the South, it ranges from mean minimum temperature of 16.3° C and mean maximum temperature of 29.1° C.

Humidity is relatively high with mean evaporation being between 1,800mm to 2,200mm per annum within the County (CIDP: Siaya county 2018-2022).

Sample size and sampling

Purposive sampling was used to interview farmers who had received seed directly or indirectly from KSCAP fodder project primary producers. The snow balling method was used where those who were given seed mentioned the farmers they had shared seed with and the snow balling continued until all those who had received seed were interviewed. A total of 223 fodder seed consumers were interviewed.

Table 1: Number of farmers interviewed per County

County	Number of farmers interviewed
Siaya	44
Busia	113
Kakamega	66
Total	**223**

Data collection

The study utilized both primary and secondary data. Primary data was collected through household survey. A semi structured questionnaire was used to collect data from farmers. The questionnaire was uploaded on the mobile based Open Data Kit (ODK) for electronic data collection. Enumerators were selected and underwent training to conduct questionnaire administration.. The data detailed socio economic characteristics such as age, gender, land size and use, fodder awareness and use among other aspects.

Data analysis

The data was analysed using Statistical Package for Social Scientist (SPSS) computer software (Version 23). Descriptive statistics such as percentage, frequencies, means and standard deviations were applied. Chi square test was also used to compare the difference in various variables tested across the counties. A probability of 5% was considered significant for all statistical analyses. The results are presented in tables, graphs and charts.

Results and discussion

Socio economic characteristic of the respondents

The study checked key socio economic variables that could influence fodder production and utilization among the farmers and across the study counties. There was significance difference (P=0.000) in the ages of the respondents. Fodder farmers above 56 years were more (39.7%) compared to the other age brackets. However, in Kakamega County, majority of the farmers (43.8) were youth ranging between 26 – 35 years while Busia and Siaya Counties most of the farmers were above 56 years. Though there was no significant difference in education level, the level varied across the counties. For instance, Majority (36.4%) of the respondents in Busia County had attained primary level education while in Kakamega County majority (36.6%) had attained secondary education while in Siaya County majority (34.8%) had attained post-secondary education (Table 2).

Table 2: Socio economic characteristic of the respondents

Variable	Busia (n=113)	Kakamega (n=66)	Siaya (n=44)	Total (223)	Test statistics (χ^2)
Age					
18- 25 year	3.9	19.5	0	7.8	0.000
26=35 year	11.7	43.9	4.3	19.9	
36 -45 yeas	15.6	7.3	13	12.8	
46- 55 year	28.6	7.3	13	19.9	
56 and above	40.3	22	69.6	39.7	
Sex of respondents					
Female	58.4	43.9	34.8	50.4	0.085
Male	41.6	56.1	65.2	49.6	
Education level					
None	18.2	14.6	13	16.3	0.372
Primary	36.4	26.8	39.1	34	
Secondary	20.8	36.6	13	24.1	
Post-secondary	24.7	22	34.8	25.5	
Main occupation					
Casual employment	2.6	12.2	0	5	0.115
Farming	81.8	80.5	87	82.3	
Own business	10.4	7.3	4.3	8.5	
Salaried employment	5.2	0	8.7	4.3	

Land size and allocation

Siaya had the largest mean land size (6 acres) with a maximum of 22 acres while Kakamega had the least mean land size of 1.8 acres with a maximum of 8 acres. Conversely, land allocation was minimal with Siaya having the largest mean land size (2 acres) allocated for fodder production and Kakamega had the least mean land size (0.5 acres) allocated to fodder production. Land allocation could be associated with climatic conditions and farmer preference and trade-offs with other available farming enterprises.

Table 3: Land size and allocation (acres)

Variable	Busia (n=113)	Kakamega (n=66)	Siaya (n=44)
Land size			
Mean	3.2	1.8	6
Minimum	0.3	0.5	0.5
Maximum	10	8	22
Std deviation	2.2	1.7	5.5
Land under fodder			
Mean	0.7	0.5	2
Minimum	0	0.06	0.25
Maximum	5	3	9
Std deviation	0.9	0.6	2.2

Livestock ownership by fodder producers

The study sought to find out the number of cattle owned by the farmers. Siaya had the highest (8) mean number of livestock owned, while Kakamega had the least (2.9) mean number of livestock. The results were similar to the mean number of improved breads where Siaya had the highest number with a maximum of 28 improved cattle

Table 4: Number of cattle owned by tertiary producers

	Busia (n=113)	Kakamega (n=66)	Siaya (n=44)
Number of cattle owned			
Mean	4.4	2.9	8
Minimum	1	2.1	1
Maximum	17	10	31
Std deviation	3.3	2.1	6.4
Number of local breed owned			
Mean	2.4	0.9	3.2
Minimum	0	0	0
Maximum	14	4	15
Std deviation	3	1.2	3.9
Number of cross/improved cattle owned			
Mean	2.2	2	4.8
Minimum	0	0	0
Maximum	8	9	28

Farmers' awareness of fodder crops

Napier grass (97.5%) and Bracharia (60%) were the most known fodder across the study sites. The results show that there were significant difference in the awareness of the fodder for the different fodder crops. For instance, awareness of bracharia was significantly higher (P=0.038) in Kakamega while awareness of boma Rhodes was significantly higher in Siaya compared to the other study counties (**Error! Reference source not found.**).

Table 5: Percentage of farmers' reporting awareness of fodder crop

Fodder Aware	Busia (n=113)	Kakamega (n=66)	Siaya (n=44)	Total (223)	Test statistics ((χ^2))
Napier grass	97.4	100	94.7	97.5	0.545
Panicum	1.3	8.3	0	2.5	0.117
Brachiaria	61	75	36.8	60	0.038*
Boma rhodes	11.7	20.8	52.5	20	0.000*
Guatemala	3.9	0	0	2.5	0.424
Giant setaria	1.3	8.3	5.3	5.3	0.215
Other fodder type (desmodium, mulato, sudan grass, sweet potato vines)	33.8	29.2	47.4	30	0.43

Type of fodder grown

Majority of the respondents (95%) grew Napier grass across the study counties with Siaya County having the least farmers planting napier grass. Bracharia was the second most grown fodder (37.4%) in the region. There was a significantly higher (P= 0.000) percentage of farmers growing boma rhodes in Siaya compared to the other study counties. Despite the potential of

dairy farming, milk yields per cow were generally low and this was attributed to inadequate quality fodder and feeds. The other fodder crops like desmodium and mulato were not being promoted by the KCSAP project.

Table 7: Type of fodder grown (%)

Fodder grown	Busia (n=113)	Kakamega (n=66)	Siaya (n=44)	Total (223)	Test statistics ((χ^2))
Napier grass	98.7	95.1	82.6	95	0.009
Panicum	0	4.9	0	1.4	0.088
Brachiaria	33.3	46.3	34.8	37.4	0.368
Boma Rhodes	1.3	2.4	30.4	6.5	0.000
Giant setaria	0	0	4.3	0.7	0.079
Others (desmodium, mulato, sudan grass, sweet potato vines)	13.3	9.8	30.4	15.1	0.070

Percentage of farmers selling fodder

Apart from farmers feeding the fodder to their livestock, some farmers gain income from the sale of fodder. The study sought to find out if farmers in the study sites consider sale of fodder as a source of income. The results in figure 1 show that a larger number of farmers in Busia (47%) and Kakamega (40%) sale their fodder. In Siaya only 11% sale the fodder they plant (Figure 4).

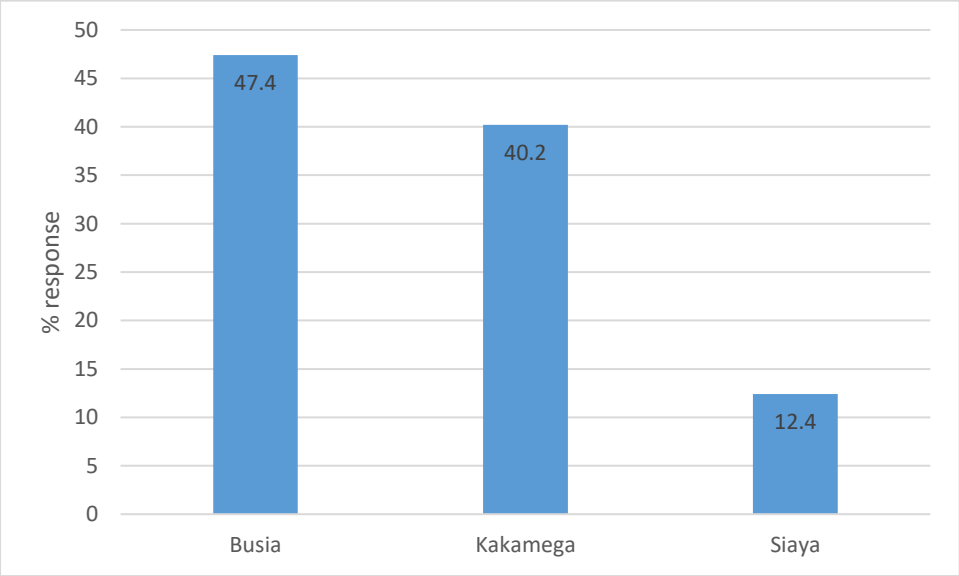

Figure 4: Percentage of farmers selling fodder

Form in which fodder is sold

Majority of the farmers who sale their fodder sold in the form of feed (51%) while only 24% sold as seed. Nonetheless, some sold both seed and fodder (26%). Looking at the unit of measure when selling the fodder, majority of the farmers (35%) sold as cuttings however, there was a significant difference (P=0.000) in the unit of measure across the study sites. For instance, in Kakamega majority of the farmers (52%) used bundles as a unit of measure, in Busia County majority used cuttings (41%) while Siaya County majority used splits (33%). To ensure quality seed reach the farmers there is need to have specialized seed producers who sell quality seed to the population. There is need to have standardized measure and pricing of the seed.

Table 7: Form in which fodder is sold

Variable	Busia (n=46)	Kakamega (n=39)	Siaya (n=12)	Total (n=97)	Test statistics (χ^2)
Seed	37	7.7	25	23.7	0.001
Feed	28.3	74.4	58.3	50.7	
Both feed and seed	34.8	17.8	16.7	25.8	
Unit of measure					
Bundles	52.2	15.4	0	30.9	0.000
Cuttings	32.6	41	25	35.1	
Sacks	2.2	0	16.7	3.1	
Splits	10.9	38.5	33.3	24.7	
Weight (Kg)	2.2	5.1	25	6.2	

Income from fodder sales

The study sought to find out the level of income received from the sale of fodder in the last three months prior to the study. Results in Table show that across the sites the farmers who sold fodder had a mean amount of 5,893 Kenya shillings with a maximum of 33,000/= Siaya Count had the highest mean sales of 12,291/=.

Table 8: Income from sale of fodder

County	Mean	n	Std. Deviation	Minimum	Maximum
Busia	5806.98	43	5594.615	0	22000
Kakamega	4019.23	39	8321.339	0	33000
Siaya	12291.67	12	11515.717	1500	27000
Total	5893.09	94	8054.370	0	33000

Mode of creating awareness on fodder availability

Overall, word of mouth was the most common method used to create awareness on fodder availability. Conversely, the methods significantly varied across the study sites. Busia County had a higher percentage (61.5%) of people using free sample, Kakamega County used field days more (51.7) compared to the other sites while Siaya County used social media more (57%). Use of social media to create awareness and market fodder is still very low in the region. There is need promote modern marketing strategies among the farmers.

Table 8: Marketing strategies used by fodder farmers

Marketing strategy	Busia (n=46)	Kakamega (n=39)	Siaya (n=12)	Total (n=97)	Test statistics (χ^2)
Social media	0	10.3	57.1	14.3	0.001
Word of mouth	84.6	96.6	57.1	87.8	0.016
Field days	7.7	51.7	0	32.7	0.003
Free samples	61.5	20.7	0	28.6	0.005

Characteristics that buyers look for when buying fodder seed and feed

Various attributes influences farmers preference for the different fodders. Nutritive value 35.6%), biomass 24.4%), early maturity (24.2%) and Texture (11.1) are the common characteristics the buyers look for when buying fodder seed. On the hand Nutritive value

(24.4%), biomass (17.8%), texture (11.1%) and short variety (11.2%) were the preferred characteristics that buyers looked for when buying fodder feed.

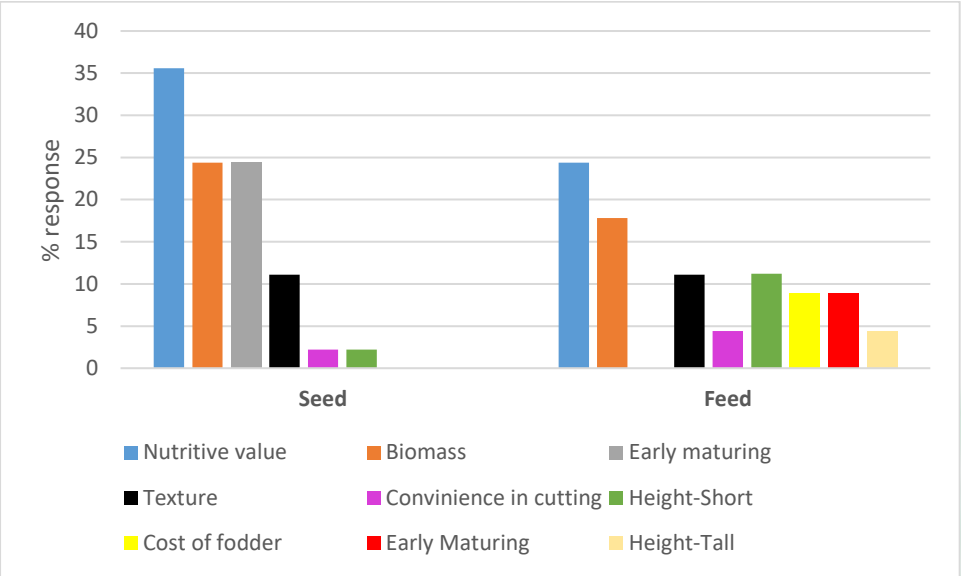

Figure 5: Characteristics that buyers look for when buying fodder seed and feed

Farmers Perception on Demand for Fodder

Farmers perception on demand for fodder was sought. Generally, the demand was found to be high. Though majority of the farmers felt the demand for fodder was high across the three counties, Siaya County had significantly higher (P=0.0021) number of respondents (75%) noting that the demand was high (Table 9)

Table 9: Percentage Fodder demand

Variable	Busia (n=62)	Kakamega (n=45)	Siaya (n-12)	Total (n=119)	Test statistics ((χ^2))
High	30.60	55.60	75	44.5	0.021
Low	21.00	13.30	0	16	
Moderate	24.20	20.00	0	20.2	
Very high	24.20	11.10	25	19.3	

Record Keeping

Record keeping is essential for the success of any enterprise. The study sought to find out farmers record keeping skills. Results in Table 10 show that majority of the farmers (77.8%) keep record. However when asked the type of record kept, the results show that farmers are selective on the type of record they keep. Majority of the farmers kept animal health record (77%), Milk production record (57%) and Milk sales record (57%). Though farmers who keep fodder production record were significantly higher (P=0.022) in Kakamega compared to Busia and Siaya, record keeping for fodder production and sales was very low. This may lead to farmers' misjudgement of dairy and fodder production enterprise since they lack clear records.

Table 10: Percentage of producers who keep record

Record Keeping	Busia (n=62)	Kakamega (n=45)	Siaya (n-12)	Total (n=119)	Test statistics ((χ^2))
NO	20.7	20	33.3	22.2	0.78

YES	79.3	80	66.7	77.8	
Type of Record Kept					
Fodder production record	8.7	50	5	22.9	0.022
Animal health record	73.9	87.5	75	77.1	0.729
Milk production record	47.8	62.5	100	57.1	0.142
Milk sales record	60.9	5	50	57.1	0.827
Fodder sales record	17.4	25	0	17.1	0.555
Other type of records	17.4	25	0	17.1	0.555

Constraint to fodder production

Farmers experience various challenges in fodder production that may hinder their optimum achievement. Results in Table 11 indicate that drought (51.3%), limited access to fodder information (21.8%) and limited access to clean planting material (13.5%) were the key challenges experienced by farmers in the three counties. However, there were significance difference (P=0.004) in the challenges experienced.

Table 11: Percentage of farmers reporting constraint to fodder production

Variable	Busia (n=62)	Kakamega (n=45)	Siaya (n-12)	Total (n=119)	Test statistics ((χ^2))
Drought	30.6	71.1	83.3	51.3	0.004
High price of fertilizer	4.8	0	0	2.5	
Limited access to fodder information	27.4	15.6	16.7	21.8	
Pest and Diseases	14.3	8.9	0	10.9	
Limited access to clean planting material	22.6	4.4	0	13.5	

Figure 6: Characteristics that farmers consider when buying fodder

Type of Fodder Fed on Livestock during Feed Shortage

During feed shortage, majority of the farmers fed their livestock on maize stalks (65.2%), natural grass (37.6%) and sugarcane tops (34.5%). On the other hand, there were significant difference across the counties on the type of feed used during feed shortage. A significantly higher percentage of farmers in Kakamega (65.9%) relied on sugarcane tops. The use of boma rhodes was significantly higher (P=0.000) in Siaya County compared to Kakamega and Busia counties while in use of napier grass was significantly higher (P=0.014) in Busia County.

Table 13: Type of fodder used during feed shortage

Type of feed	Busia (n=113)	Kakamega (n=66)	Siaya (n=44)	Total (223)	Test statistics ((χ^2))
Maize stalks	62.3	75.6	56.5	65.2	0.223
Natural grass	33.8	41.5	43.5	37.6	0.582
Sugarcane tops	28.6	65.9	0	34.5	0.000
Napier grass	37.7	14.6	17.4	27.7	0.014
Boma rhodes	0	2.4	26.1	5	0.000
Bracharia	5.2	0	8.7	4.3	0.212
Giant setaria	0	0	8.7	1.4	0.005

Other (hay, silage, lake weed, sweetpoato vines, banana stalks, cassava leaves)	24.7	29.3	39.1	28.4	0.398

Conclusion

Napier grass and bracharia are the most common fodder grasses known and planted in the study area despite a variety being of fodder promoted in the region. The awareness of the other types of fodder is still low. More than 30% of the farmers' sale fodder. The fodder is mainly sold as feed though there are some farmers who also sale seed. The farmers heavily rely on their fellow farmers, community based organizations/farmer groups and extension officers to access information of fodder respectively. Early maturing, nutritive value, biomass and texture were the most common attributes that farmers looked for when acquiring fodder seed for planting. Majority of the farmers keep records, however, fodder production record are kept by few farmers. Lack of records on fodder production and use may hinder farmers' proper assessment of their dairy enterprise performance.

Recommendation

i) Strengthen the fodder planting seed market system. This would facilitate farmers' access to clean planting materials.
ii) Sharpen farmers and farmer organization's skills on fodder production since they are the key sources of information. In addition promotion of other means of acquiring information
iii) Strengthen the fodder market value chain since there is potential for farmers to diversify their income through sale of green fodder and value added fodder products.
iv) Analysis of the low uptake of the other fodder crops despite their great potential.

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Evaluating Drivers of Feed and Fodder Technologies Uptake among Pastoral Beef Farmers in Kenya

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Abstract

For pastoral beef systems to become more productive and robust, technology and efficient management approaches must be embraced. In this study, pastoral beef producers in the counties of Isiolo and Kajiado were asked to identify variables impacting adoption of fodder Technology Innovations and Management Practices (TIMPs). The study examined the complex dynamics influencing farmers' choices in relation to three important TIMPs: planted fodder, feed supplementation, and fodder conservation. A cross-sectional method and the Seemingly Unrelated Regression (SURe) model were used. A total of 619 pastoral producers were sampled using a methodical sampling procedure. The objective of the study was to investigate the complex linkages between resource accessibility, socioeconomic factors, and the function of extension services in supporting technology adoption to better understand the underlying motives and barriers. The study found out that a variety of socioeconomic and environmental factors influenced adoption decisions of farmers. This included herd sizes, engagement in feed lot finishing, incomes, access to financing and water availability. The study findings point towards the significance of removing specific barriers, such as farmers' poor access to resources and socioeconomic limitations. In order to successfully catalyze adoption of TIMPs among pastoral beef farmers, this paper recommends tailored policies that prioritize market accessibility, technological knowledge, and information availability. Implementation of these recommended policies is likely to contribute towards making Kenyan agriculture more sustainable and the livestock industry more resilient.

Keywords: *Technology Innovations and Management Practices (TIMPs), fodder conservation, feed supplementation, planted fodder*

Introduction

The pastoral beef farming in Kenya holds immense potential, both in terms of its contribution to the national economy and the livelihoods of communities involved (Nyariki & Amwata, 2019). However, a lot of constraints limit the attainment of its full potential. Pastoral beef farmers have significant obstacles due to limited access to resources including water, pasture, and veterinary services (Dabasso *et al.*, 2021). In recent years, a number of TIMPs have shown potential in addressing some of the challenges that pastoral farming in arid and semi-arid lands face (Thongoh *et al.*, 2021). A variety of technologies have the potential to change the industry, from enhanced livestock breeds and feed formulae to precision farming methods and digital tools for monitoring and disease control. With the use of these technologies, it is possible to maximize resource use, increase production, lessen the effects of climate change, increase market access, and boost overall resilience. However, as stated in research conducted by KALRO (2020), a complex interaction of variables affect how pastoral beef farmers in Kenya

embrace modern technologies and management approaches. Farmers' decision-making processes rely heavily on socio-economic factors, particularly the cost-effectiveness and profitability of adopting new technologies. Access to knowledge, information, and support services were also found to be significant factors of the adoption of new agricultural technology (KALRO, 2020).

Within the Kenyan context, three key categories of TIMPs have gained attention: planted fodder, feed supplementation, and fodder conservation (Mbae *et al.*, 2020; Mohammed *et al.*, 2020). These TIMPs provide innovative ways to raise production, boost animal health, and lessen the consequences of climate change. Pastoral cattle farmers could offer their animals reliable and high-quality supply of feed by using planted fodder. Research done in Kenya has shown the benefits of utilizing better fodder species like Napier grass and Rhodes grass. These planted feeds have been shown to improve overall animal health, boost weight gain, and increase milk production (Korir, 2020). In addition to enhancing cattle performance, planted fodder minimizes the demand placed on natural grazing pastures, allowing them to regenerate and get restored.

Commercially available feed supplements, including concentrates, protein meals, and mineral mixes, can address nutritional deficiencies and enhance animal performance. Studies carried out in Kenya have shown that feed supplementation and weight increase are positively correlated, especially during times of low fodder availability (Makau, 2019; Muteng'e, 2021). To enable their widespread use among small-scale pastoral beef farmers, aspects related to pricing and accessibility of purchased feed supplements must be taken into account. Techniques for conserving fodder, such as creating silage and hay, provide an innovative way to deal with a lack of fodder during dry seasons or times when natural pastures for grazing are depleted.

The beef farming sector in Kenya is at a crucial point given the situation of pastoralism at the present time. Socio-cultural and economic factors interact with the possibilities of TIMPs to influence failure or success for pastoral regimes. Therefore, it's crucial to identify approaches to close technology adoption gaps and empower farmers so they can be more resilient. In an attempt to address this knowledge gap, this study provides insightful information about drivers of adoption of TIMPs and obstacles encountered, empowering stakeholders and policymakers to create targeted strategies and interventions that encourage widespread adoption of sustainable and efficient beef farming practices.

Methodology

The study was conducted in Kajiado and Isiolo counties of Kenya. These counties were purposively selected based on their significant contribution to the pastoral beef farming industry and their representation of different geographical locations and socio-economic characteristics within the sector. A sample size of 619 pastoral beef farmers was determined using Cochran's formula (Cochran, 1977), taking into account the desired level of precision, expected variability in the population, and desired confidence level. The sample size was considered sufficient to provide reliable and generalizable results while considering practical constraints such as limited resources and time. A mixed-methods approach was employed, combining quantitative and qualitative data collection techniques. Structured survey instruments were developed to collect quantitative data, covering aspects such as farmer demographics, farm characteristics, and adoption patterns of feed and fodder technology innovations and management practices. Qualitative interviews were conducted with a subset of participants to gain deeper insights into their decision-making processes and contextual factors. The collected data were analyzed using the Seemingly Unrelated Regression (SURe) model using STATA 17.0. This statistical technique allowed for the simultaneous estimation of multiple regression models while considering the interdependencies and correlations between

the different feed and fodder TIMPs (Jiang *et al.*, 2020). The SURe model provided a comprehensive assessment of the factors influencing the adoption of these practices among pastoral beef farmers.

Results and Discussions

Demographic characteristics

The findings of the study indicate that males headed majority (84%) of the sampled households in the study region. This conclusion illustrates the prevalent patriarchal structure that is common among most Kenyan households. The analysis also points to a major trend in decision-making processes for raising cattle, selling them, and using the money earned from beef cattle. In majority of the households (81.1%), men make these decisions. Furthermore, results show that 17% of male household heads have acquired a basic education, with 53% not having acquired formal education. This demonstrates how important it is to properly convey and share information about technology and innovations in ways that the target audience can understand well (Ofoegbu *et al.*, 2018. These methods could include exploiting local languages, using visual aids and demonstrations, and applying innovative techniques that improve comprehension.

The average age of household heads in the research region was 46 years old, which is also important to note. There may be a substantial experience and a wealth of wisdom within the community, based on the age distribution of household heads. To secure the transfer of knowledge and skills, it also implies the need to give priority to ways that support and target younger generations and other age groups. To address the prevailing gender disparity in household headship and decision-making, it is crucial to promote gender equality and empower women within these communities. Encouraging women's participation in decision-making processes, providing access to education and training, and creating opportunities for income generation can help challenge traditional gender roles and promote more equitable distribution of responsibilities (Grillos, 2018).

Determinants of technological choices among beef pastoral farmers

Determinants of technological choices among the sampled households are presented in Table 1.

Table 1: Determinants of technological choices among beef pastoral farmers

	Feed and Fodder Technology Innovations and Management Practices		
Variables	**Planted Fodder**	**Feed Supplementation**	**Conserved Fodder**
Herd size category	.022(0.022)**	-.003(0.872)	.024(0.105)
Feed lot finishing	.197(0.000)***	.121(0.263)	.213(0.011)**
Severe months	-.018(0.022)**	-.007(0.668)	.002(0.002)***
Income categories	.012(0.107)	.002(0.097)*	.040(0.000)***
Beef market distance	-.001(0.004)***	-.025(0.078)*	.001(0.493)
Age of household head	.001(0.959)	-.000(0.826)	-.013(0.007)***
Farm size	-.0001(0.426)	-.000(0.179)	-.004(0.054)*
Information access	.029(0.029)**	-.003(0.275)	.024(0.225)
Gender	-.015(0.515)	-.019(0.455)	-.022(0.543)
Own land	.011(0.662)	.052(0.255)	.044(0.299)
Access water	-.010(0.474)	.141(0.011)**	-.007(0.741)
Credit access	.103(0.001)***	.056(0.045)**	-.009(0.841)
Insurance access	.112(0.003)***	.052(0.390)	.007(0.908)
All weather road access	.074(0.001)***	-.014(0.848)	-.097(0.005)***
Group membership	.041(0.120)	.003(0.940)	.212(0.000)***
Power access	0.011(0.602)	-.054(0.317)	.103(0.001)***

*(*P <0.05, **P <0.01 and ***P <0.001, Standard error in parenthesis)*

The coefficient for herd size category in the Planted Fodder model is 0.0218, which is statistically significant at 5% level. The positive coefficient implies that the adoption of planted fodder is significantly influenced by larger herd sizes. Economies of scale may also be used to explain the beneficial impact of herd size on the uptake of planted forage. Because they frequently have more financial means, farmers with larger herds may find it more practical to invest in and maintain planted fodder systems.

In the Planted Fodder model, the coefficient for feed lot finishing is 0.1965, indicating a statistically significant positive relationship at a 1% level ($p<0.01$). This suggests that farmers were more likely to embrace planted fodder if they had adopted feed lot finishing technologies. This result implies that farmers with larger feed lots understand how critical it is to invest in their feed management practices by adopting technologies like planted fodder. Similarly, in the Conserved Fodder model, the coefficient for feed lot finishing is 0.2131, and it is also statistically significant at a 5% level ($p<0.05$). This suggests that farmers who used feedlot finishing techniques understood the benefits of proper nutrition for their livestock and were more inclined to use fodder preservation and planted fodder technologies.

In examining the variable for water access, under the Planted Fodder model, the coefficient is significant at the 0.004 level ($p<0.01$). This suggests that Kenyan pastoral beef farmers are less likely to utilize planted fodder as the duration of dry, harsh months increase. The outcome reveals that a major obstacle to the use of planted fodder technology is water constraint. Due to insufficient water available for irrigation, pastoral cattle producers may endure many dry months without water thus unable to establish and sustain planted fodder systems. This result is in line with an earlier study by Kurgat *et al.*, (2018), which investigated the adverse effects of water shortage on the adoption of agricultural technology in Kenya. Adequate water resources are essential for the establishment and growth of planted fodder crops, as they require regular irrigation for optimal production.

Under the Feed Supplementation model, the coefficient for income categories is 0.0015, which is positive. However, this coefficient is only marginally significant at the 10% level ($p = 0.097$). This suggests that income categories may have a limited influence on the adoption of supplementation among pastoral beef farmers. In addition, in the Conserved Fodder model, the coefficient for income categories is 0.0403, indicating a positive relationship. The coefficient is statistically significant at a high level of significance ($p< 0.001$), indicating that income

categories have a significant influence on the adoption of fodder conservation practices among pastoral beef farmers. These results demonstrate how different income levels have an influence on the adoption of various feed and fodder innovations and management strategies. Income groups do play a substantial effect in the adoption of fodder conservation strategies, even if they may not have a large impact on the adoption of planted fodder or the purchase of feed supplements. These results are in line with previous studies that have highlighted the importance of income in determining farmers' adoption decisions (Adanti *et al.*, 2022; Jerop *et al.*, 2018).

In the Planted Fodder model, the coefficient for beef market distance is -0.0013, indicating a negative relationship. The coefficient is statistically significant at the 1% level ($p < 0.01$), suggesting that distance to the beef market has a significant influence on the adoption of planted fodder technology among pastoral beef farmers. A negative coefficient suggests that as the distance to the beef market increases, the likelihood of adopting planted fodder technology decreases. Further analysis of the variable beef market distance shows a coefficient of -0.0251 under the supplementation model. Although the coefficient is negative, it is only marginally significant at the 10% level ($p = 0.078$). This indicates that distance to the beef market may have a limited influence on the adoption of feed supplementation among pastoral beef farmers. This finding is consistent with the research conducted by de Janvry and Sadoulet (2020), who noted that the impact of market distance on technology adoption decisions is context-specific.

The coefficient for the age of household head variable in the Planted Fodder model is 0.0012, indicating a positive relationship. However, the coefficient is not statistically significant ($p > 0.05$), suggesting that age may not have a significant influence on the adoption of planted fodder technology among pastoral beef farmers. This finding is consistent with the study conducted by Michels *et al.*, (2019), which found that age was not a significant predictor of technology adoption among livestock farmers. On the other hand, in the Conserved Fodder model, the coefficient for the age of household head variable is -0.0131, indicating a negative relationship. The coefficient is statistically significant at the 1% level ($p < 0.01$), suggesting that age plays a significant role in the adoption of fodder conservation practices among pastoral beef farmers. A negative coefficient implies that as the age of the household head increases, the likelihood of adopting fodder conservation practices decreases.

The results also reveal that the coefficient for Farm Size is -0.0001 under the Planted Fodder model, indicating a negative relationship. However, the coefficient is not statistically significant ($p > 0.05$), suggesting that farm size may not significantly influence the adoption of planted fodder technology among pastoral beef farmers. This finding could also be explained by the cultural practices of communal and nomadic grazing among pastoral farmers. On the other hand, in the Conserved Fodder model, the coefficient for Farm Size is -0.0037, indicating a negative relationship. The coefficient is statistically significant at the 5% level ($p < 0.05$), suggesting that farm size plays a significant role in the adoption of fodder conservation practices among pastoral beef farmers. This concurs with the findings by Belachew *et al.*, (2020) who noted that as farm size increases, the likelihood of adopting fodder conservation practices decreased in Ethiopia

In the Planted Fodder model, the coefficient for information access is 0.0286, indicating a positive relationship. The coefficient is statistically significant at the 5% level ($p < 0.05$), suggesting that information access plays a significant role in the adoption of planted fodder technology among pastoral beef farmers. A positive coefficient implies that as information access improves, the likelihood of adopting planted fodder technology increases. On the contrary, under Supplementation model, the coefficient for information access is -0.0029. However, the coefficient is not statistically significant ($p > 0.05$), suggesting that information

access may not have a significant influence on the adoption of feed supplementation among pastoral beef farmers.

In the Planted Fodder model, the coefficient for Credit Access is significant ($p < 0.001$). This indicates that access to credit has a significant positive effect on the adoption of planted fodder practices among pastoral beef farmers. In the Supplementation feed model, the coefficient for Credit Access is also significant ($p < 0.05$). This suggests that credit access influences the adoption of supplemented feeds among pastoral beef farmers. The positive coefficient indicates that farmers who can access credit are more likely to afford and purchase feed supplements to supplement their livestock's nutritional needs. However, in the Conserved Fodder model, the coefficient for Credit Access is not significant ($p > 0.05$). This implies that credit access does not play a significant role in the adoption of conserved fodder practices among pastoral beef farmers.

In the Conserved Fodder model, the coefficient for Group Membership is significant ($p < 0.01$). This suggests that belonging to a group or association has a significant positive influence on the adoption of conserved fodder practices among pastoral beef farmers. The positive coefficient indicates that farmers who are part of a group are more likely to engage in collective efforts and benefit from shared resources and knowledge related to fodder conservation. This finding aligns with previous research that has emphasized the role of social networks and group dynamics in promoting the adoption of sustainable agricultural practices (Dapilah *et al.*, 2020). In the Planted Fodder model, the coefficient for All Weather Road Access is significant ($p < 0.01$). This indicates that having access to all weather roads has a significant positive effect on the adoption of planted fodder practices among pastoral beef farmers.

Conclusion and Recommendations

This study explored the factors affecting Kenyan pastoral cattle farmers' adoption of various feed and fodder TIMPs. Within the three distinct categories of Planted Fodder, Feed Supplemented, and Conserved Fodder, the study uncovered a number of relevant factors that affect adoption decisions. The results emphasize the complexity of adoption choices and the need of taking into account a variety of variables when developing interventions to support sustainable cattle production. The findings make it clear that a variety of socioeconomic and environmental factors are quite important in influencing adoption decisions. The adoption of certain TIMPs was shown to be significantly influenced by variables like herd size category, feed lot finishing, income categories, access to financing, and the number of months with a severe water deficit. These findings highlight need for a tailored approach that promotes the adoption of feed and fodder technology while taking into account the different needs and characteristics of pastoral cattle farmers.

In light of these results, several recommendations can be made. First, government and partners should empower pastoral farmers while strengthening farmer support institutions such as farmer groups. This is crucial to enhance access to inputs and output markets for effective technology adoption. Furthermore, fostering collaboration and establishing platforms for knowledge exchange among farmers, such as farmer groups and associations, can enhance the adoption of sustainable practices. By acknowledging the significance of context-specific variables and adopting a holistic approach, policymakers, researchers, and extension services can develop targeted strategies and interventions that promote the widespread adoption of sustainable and efficient practices in pastoral beef farming.

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The Domestic Cat, Felis catus domesticus: Survival Challenges and Sustainability

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Abstract

The domestic cat, *Felis catus domesticus*, Erxleben,1777, is the only domesticated Species in the Cat family, Felidae. She is either "a house cat or a farm cat," which ranges freely and avoids human contact. About sixty cat breeds are recognized by various cat registries. The cat is a solitary hunter (carnivore) but social, living in packs. She can hear sounds too faint or high in frequency, for human ears. The cat is a well-known pet, besides the dog, which appears as a co-rival. She is, however, at the verge of extinction due to numerous challenges, spanning from nutrition, housing, health, mating, rearing of the young and cruelty from enemies like dogs and animal dis-likers, mostly humans. The cat displays a genetic mix of colour, beside the predominant monochrome in shades of brown, grey and black, which serve as camouflage to the specific living environment. The domestic cat is subjected to a handful of myths which impact negatively on their survival and sustainability. In times of economic crunch, the cat is the first to be eliminated from the household budget. Neglected cats hop from house to house and finally to the wild, in desperation, with limited guarantee for survival. Currently, there is an animal protection Act which is yet to be fully reinforced. The unveiling of the Kenya Society for the Protection and Care of Animals was a positive move but heavily dependent on expected donations from well-wishers, hence not sustainable. A study contacted at Ngong forest, Lenana (Coordinates: UTM 37M 0257490, 9858862 in Nairobi) on the local mixed breeds of cats, weighted on the challenges and suggested the following recommendations: De-centralization of the animal welfare body to all counties, protection of the domestic cat, for ownership and diversity; reinforcement of the pet adoption and survival rules; re-evaluation of myths that curtail cat survival; the veterinarians offering health services to the cats should re-think on the cat welfare and sustainability without hindering their reproductive Priviledge; need for collaborative effort to avail resources for cat basic needs; continued awareness on the policy and pet welfare to target groups and individuals, to enhance domestic cat survival while discouraging cruelty per se, in addition to the current annual "Animal lover's day."

Keywords: *Domestic cat, solitary hunter, living environment, myth, survival, sustainability*

Subsidies and Domestic Biogas Plant Installations in Kenya: Spatial Analysis and Policy Implications

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Abstract

Biogas installations on smallholder farms are widely perceived as a promising candidate technology for climate change mitigation, improving indoor air quality and therefore human health while at the same time reducing pressure on forest ecosystems. Through the Africa Biogas Partnership Programme, over 9,000 domestic biogas plants were installed between 2009 and 2014, with tapering subsidy support to partly offset private installation costs. This paper estimates the influence of subsidies on the deployment of biogas digesters. Using a panel dataset from 42 counties covering 48 months, a spatially explicit Tobit model is used to derive an estimate of the effect of subsidies on the capacity of domestic biogas plants added every month. Results suggest that subsidies played a significant ($p<0.1$) role in encouraging uptake. A 10% increase in subsidies is associated with a 5% increase in installed volumes. This implies that the cost of biodigester technology is still a barrier for a majority of the rural households targeted, and implies that subsidies can play a critical role to achieve scaled and accelerated uptake of the technology for households.

Keywords: *Subsidies; spatial panel data; anaerobic digesters; Tobit*

Background

The Kenya Climate Smart Agriculture Strategy (2017-2026) defines the context under which Climate Smart Agriculture (CSA) is to be applied thereby contributing to three defined components, viz; (i) increase productivity; (ii) adaptation and resilience, and (iii) reducing and/or removing GHG emissions without compromising productivity. One of the strategic objectives of the climate strategy is to mainstream efficient agricultural production systems to enhance productivity and minimize emissions as a co-benefit (Republic of Kenya, 2017a). This would be achieved through the climate change implementation framework 2018-2027. More specifically this would be driven through the implementation of agricultural sector Nationally Appropriate Mitigation Actions (NAMAs), with the dairy NAMA being among the first of such plans.

In line with the Bali Action Plan concluded at COP 18 in Doha, Kenya has prepared a NAMA for the dairy sector. This NAMA is expected to include the provision of assistance and incentives to the private-sector to invest in low emission, gender-inclusive dairy advisory services aimed at facilitating on-farm adoption of improved technologies, innovations and management practices; enabling investments in energy efficiency and renewable energy technologies in milk collection, chilling and processing; and supporting adoption of household biogas technology (FAO, 2017). Biogas production from animal manure, residues and on-farm produced or imported energy crops is a very promising option for generating renewable energy. Simultaneously, it reduces GHG (including CH_4) emissions both directly, through manure management, or by offsetting CO_2 emissions from fossil fuels and wood fuel. Through the dairy NAMA, it is projected that a reduction of 0.98M tCO2eq could be achieved in 10 years

with direct benefits from each of an estimated 20,000 digesters valued at $204 every year. Proposals are to provide a 40 percent subsidy and a concessional loan to dairy farmers would see them pay 10-20 percent of the upfront installation costs under this arrangement (Republic of Kenya, 2017b).

The Climate Change Act (2016) outlines the need to promote low carbon technologies by facilitating adoption of technologies that support a low carbon trajectory and climate resilience (Republic of Kenya, 2016). Through the Finance Act (2015), import duty exemptions have been granted for plastic biogas digesters, biogas and the leasing of biogas producing equipment in an attempt to encourage the use of biogas by households (Republic of Kenya, 2015). However, the exemptions apply to entire shipments and thus, small establishments might hardly obtain this benefit while at the same time, the process of obtaining such exemption is unclear to entrepreneurs (Clemens *et al.*, 2018). Moreover, most of the biogas plants in the country are mainly constructed out of locally available materials (e.g. cement, bricks).

Among dairy farms in the US, construction cost subsidies are shown to be a cost-efficient policy for simultaneously achieving a desired digester-adoption rate while also promoting renewable energy generation (Key and Sneeringer, 2012). In China which has almost a century long history with biogas, estimates show that with 43 million family sized units (producing 16 Giga cubic meters in 2013), government support through subsidies has been a major driving force behind rural household biogas development with a clear spatial diffusion process (Gu, *et al.*, 2016). To subsidize this technology, the Chinese government pays two-thirds of the cost of the digester and when reduced to a third of the cost, installations decreased (Rajendran *et al.*, 2012). A 10% increase in the subsidy-cost ratio was estimated to increase biogas plant installations by 3% although this was accompanied by a 4.3% drop in the working time of the digesters (Sun *et al.*, 2014). This appears to render the effect of the subsidy policy almost negligible when considered against actual use of the technology. In Nepal where over 200,000 households have installed biogas digesters, the subsidy policy in place since 1975 has not been effective in targeting the poor compared to that of solar home systems (Bhattarai *et al.*, 2018). Similar observations have been made in China where upper and middle-income farmers are more inclined to build the digesters, though their rates of abandonment are also high (Wang *et al.*, 2016).

Subsidies that lower the initial private investment cost can help align social and private optimal adoption decisions (Manning and Hadrich, 2015) and also increase the attractiveness of the system in situations with low shadow prices of competing energy sources (Gwavuya *et al.*, 2012). Some researchers have attempted to provide some guidance on how the Chinese policy can be reconfigured to comprise an initial construction subsidy and an annual subsidy in order to help maintain continuous use of the constructed plants (Wang *et al.*, 2016).

Description of the programme

The African Biogas Partnership Programme (ABPP) running in Kenya and five other African countries had as its primary objective, establishing a sustainable and commercially viable bio-digester market. Specific objectives included those of institutional strengthening, targeted functional biogas installations, promoting the use of bio-slurry and additional health benefits including reduced deforestation and GHG emissions while also providing rural employment opportunities. Through phase I (2009-2013) of the ABPP in Kenya, over 9,800 biogas plants were installed with an additional 3,400 plants installed between 2014 and 2017 during phase II. Abandonment rates were estimated at 23% in 2016, more than the targeted 10%, possibly due to changes in programme implementation—from a “program push” to a “market pull” model (Clemens *et al.*, 2018). Rebates offered to farmers upon construction of the units were pegged at KES 25,000 per installed plant until June 2013 when this was reduced to 18,500 for a further 6 months until December 2013 when this facility was withdrawn.

This change in program implementation is the main subject of this paper as subsidies that were on offer during phase I were phased out when the program transitioned to phase II. We use a panel dataset to answer the question: In addition to other determinants of adoption, how much does a subsidy provision affect the uptake of biogas plants. This is a positive question that can be answered by estimating the effects of subsidies, with no additional structure or assumptions.

Methodology

The standard econometric model

The analytical model shows the variables that are suspected to drive household's decision to adopt biogas and we expect that the same variables (averaged at the county level) will also determine the amount of installation capacity at the county level. We begin by using a hypothesized linear model of biogas capacity additions where the dependent variable shows additions in county *i* during time *t* (Crago and Chernyakhovskiy, 2014). Consider the following standard panel data one-way error components model:

$$y_{it} = x_{it}b + u_i + \epsilon_{it}; i = 1 \rightarrow N; t = 1 \rightarrow T \ldots (1)$$

where y is the dependent variable (biogas digesters installed), b is a p-vector of parameters, and u_i, ε_{it}, and x_{it} are random variables u, ε and x respectively, where u are time constant unobserved factors that affect y, such as cohesiveness, trust in others and degree of risk aversion whereas ε are time-varying shocks that affect y, and could include intra-county dynamics and other time varying shocks. The subscript i refers to individual units of observation, and t to time (Crago and Chernyakhovskiy, 2014). In this study, therefore x includes the following variables: subsidy amount, number of masons, fuel wood prices, herd size, water availability, household income, and education.

Spillovers

Unlike standard econometric models which assume no spillovers, a valuable aspect of spatial econometric models is that the magnitude and significance of spatial spillovers can be empirically assessed (Elhorst and Vega, 2013). In the standard econometric model (Equation 1), the indirect effect which is the impact of changing a particular element of an exogenous variable on the dependent variable of all other units is zero by construction (Elhorst, 2014). However, since neighbourhood effects have been shown to exist in the adoption literature at the individual level (Case, 1992; Foster and Rosenzweig, 1995; Staal *et al.*, 2002), we also expect this to reflect at the county level. This peer effect has been documented in several papers featuring adoption of PV (Bollinger and Gillingham, 2012; Graziano and Gillingham, 2014) and organic agriculture (Wollni and Andersson, 2014). In the Kenyan biogas scene, awareness and motivation to adopt the technology is also shown to have a peer effect (Nzila, 2017). An uneven spatial distribution of biogas plants installed in Ethiopia also seems to suggest the role of peer effects in stimulating adoption (Berhe *et al.*, 2017). The probability of adopting biogas in Uganda is also shown to be decreasing on account of remoteness of household location (Walekhwa *et al.*, 2009).

Due to travel costs, a particular mason may choose to work within a cluster of counties that are close together, and since geographic boundaries are only just that, s/he can install bio-digesters in one or more counties during a particular month. This presents the main motivation to extend the basic model to include spatial interaction/neighbourhood effects. Estimating Equation 1 using OLS does not allow for spillovers since it makes the implicit assumption that outcomes for different units are independent of each other, which is restrictive especially when dealing with spatial data (Elhorst ad Vega, 2013).

We are however not oblivious of the suggestion that potential adopters must become convinced of a technology's advantages and have access to the technology and complementary services

that facilitate its profitable use (Fuglie and Marde, 2015; Berhe *et al.*, 2017; Nzila, 2017). Therefore, a dynamic model is not difficult to envision. Experts have suggested that the ideal beginning point is to estimate a spatial Durbin model (LeSage and Pace, 2009). This is because it produces unbiased coefficient estimates even if the true data-generation process is a spatial lag or a spatial error model and it does not impose prior restrictions on the magnitude of potential spatial spillover effects (Elhorst, 2010). It also generalizes both the spatial lag and the spatial error model (Elhorst, 2014)

Endogenous interaction effects are typically considered as the formal specification for the equilibrium outcome of a spatial or social interaction process, in which the value of the dependent variable for one unit is jointly determined with that of neighbouring units[1]. Conversely, exogenous interaction effects arise where the dependent variable of a particular unit depends on independent explanatory variables of other units[2] (Elhorst, 2014). The basic expression of the dynamic spatial panel model with both endogenous ($y_{it} \leftrightarrow y_{jt}$) and exogenous ($x_{it} \rightarrow y_{jt}$) interaction effects for units *i* and *j* can be written as;

$$y_{it} = \tau y_{it-1} + \phi W y_{it-1} + \rho W y_{it} + x_{it} b + W x_{it} c + u_i + \epsilon_{it} \ldots\ldots (2)$$

Here, for each cross-section, W is a pre-specified binary contiguity weight matrix which describes the spatial arrangement of the n units and each entry in the matrix is either a 0 or 1 where $w_{ij} = 1$ if units (counties in our case) *i* and *j* can be considered neighbours whose borders are contiguous (Belotti *et al.*, 2017). Creation of these weights is implemented in GeoDa (Anselin, *et al.*, 2006) and uses Queen contiguity which unlike Rook contiguity also includes common vertices to prepare the spatial weighting matrix used in the analysis. The standard assumptions that $\varepsilon_{it} \sim N(0, \delta_\varepsilon^2)$ and $E(\varepsilon_{it}, \varepsilon_{js}) = 0$ for $i \neq j$ and or $t \neq s$ apply (Belotti, *et al.*, 2017).

Dependent variable

In the data, many instances occur during which in some months, some counties reported no biogas plants installed, $y_{it} = 0$; a corner solution. To deal with this problem, Crago and Chernyakhovskiy, (2017) used a Tobit estimator, noting that the dependent variable was bound to have many zeros; where "many" (as a rule of thumb) might be a third of observations. Our data on the dependent variable shows that ~40% of the observations are zero valued (Figure). Therefore, in order to estimate the model in the presence of zero inflation, dynamism and cross-sectional dependence/contemporaneous correlation, we opt to use a Tobit spatial panel estimator with volumes—rather than the number of installations—as the dependent variable. We opt to use the installed volumes since the number of plants would be a count variable by definition and a Tobit would not be appropriate for a count variable which would be better analysed through a Poisson regression (Wooldridge, 2002). A spatial Tobit works well when censoring is not more than 70% of the data in which case it could indicate a zero inflated Poisson process (LeSage and Pace, 2009).

[1] Given learning, biogas plant installations in county *i* will depend on those of neighboring county *j* since we would expect that neighbors learn from each other and if the number of installations in *i* are up, neighbors in *j* will get to learn about this and demand more installations.

[2] This could be from masons in *j* who will travel to *i* to perform the installations. This could arise out of sheer brilliance of some masons who have made a name in performing installations or even due to boundary effects; some masons may be situated close to the border of two units *i* and *j* and their services are thus going to be delivered in these two units.

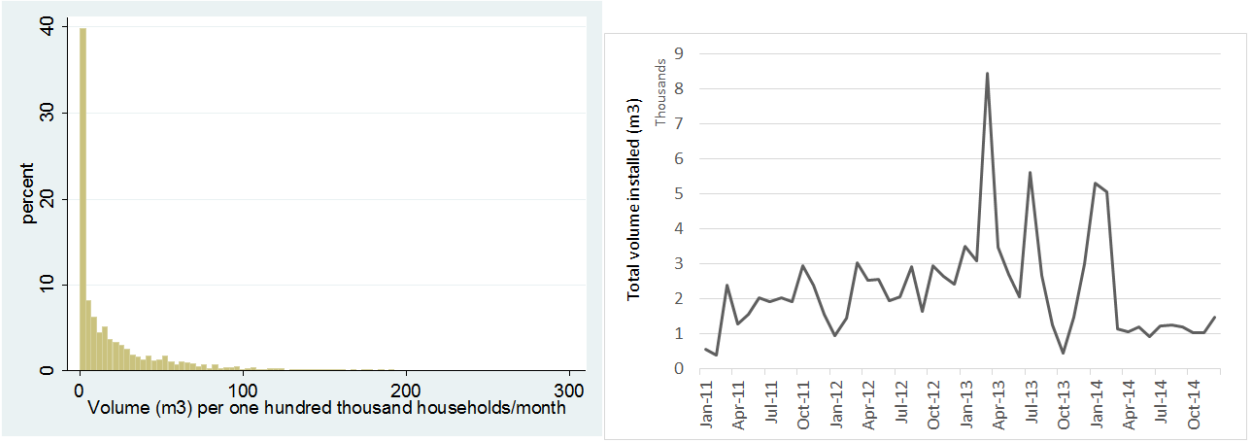

Figure 1: Volume of biogas plant installations (m^3) for 2011-2014

Success with promoting these biogas plants appears to vary significantly across county lines (Figure 1). As of December 2014, Kiambu had over 22,000 m3 of new installed capacity while Garissa and Isiolo each ended the year with less than 10m3 of new capacity installed. The spatial distribution of the plants is shown in Figure below and it is clear that some counties have larger numbers than others which we opine represents major dairy producing regions in Kenya. A Morans I computed as 0.28 indicates that there is some spatial autocorrelation between neighbouring counties and this is easily discernible by "eye-balling" the left panel of Figure 2. The correlation roughly coincides with the mixed farms and or agro-pastoral livestock production systems in Kenya reported in (Cecchi *et al.*, 2010). We therefore posit that since biogas digesters are more likely to be adopted on farms utilizing the zero-grazing or semi zero-grazing systems of dairy production, this needs to be taken into account. In the Kenyan highlands where most commercial dairy takes place, only 23% of farmers practice the extensive system (Bebe *et al.*, 2003). Given the relative difficulty of dung collection under this system, such farmers are not likely to invest in biogas plants unless they are able to commit to the huge labour input required for its collection (Mwirigi *et al.*, 2014).

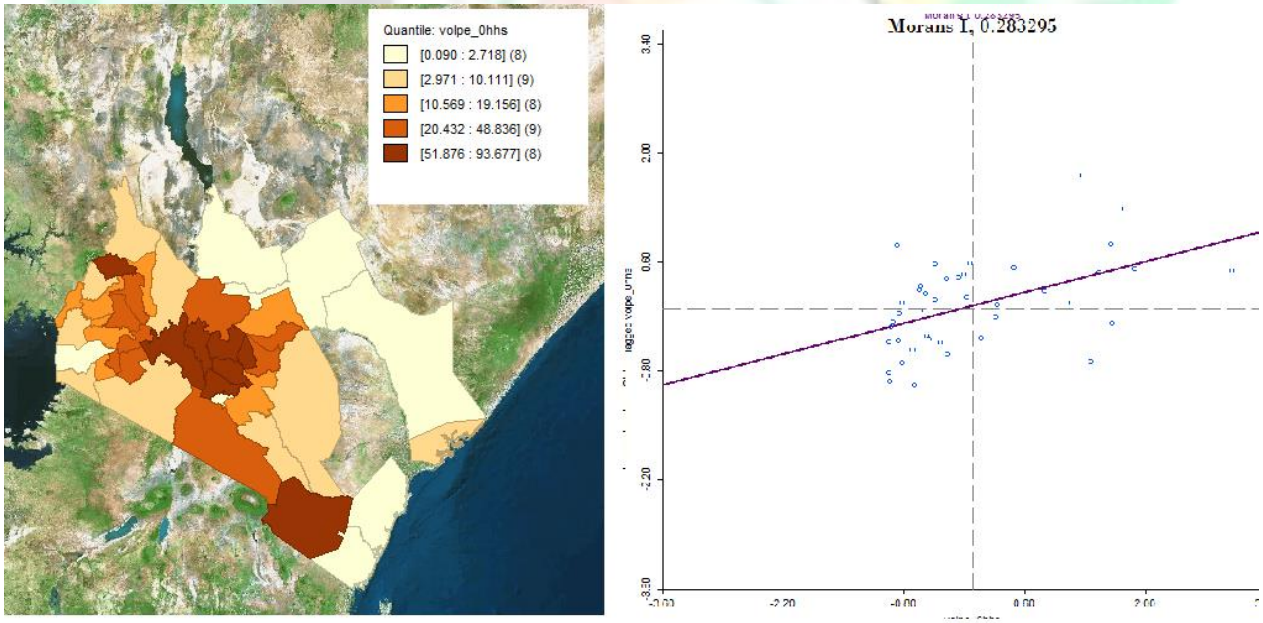

Figure 2: Distribution of biogas plants installed 2010-2014 across 42 counties

Independent variables

Explanatory variables used in the estimation are drawn from a number of sources (Kituyi *et al.*, 2001; Muriuki, 2014; Wiesmann *et al.*, 2016) and they include Tropical Livestock Units, fuelwood prices, water availability, household incomes, and education. The second panel of **Error! Reference source not found.** also shows a clear temporal signal with numbers growing over time albeit with a dip following withdrawal of subsidies. Subsidies were maintained at Ksh 25,000 per plant until July 2013 when they were lowered to Ksh 18,500 per plant until December 2013 when this facility was withdrawn. However, these were offered irrespective of the size of the digester to be installed. We use digester costs estimated for different sizes using information data from Muriuki, (2014) and the different subsidy levels to construct the variable (subsidy-cost ratio).

Results and discussion

Descriptive statistics

A total potential biogas production volume of 107,437 m^3 was installed during the 2011-2014 period. This was an average of 23.04 m^3 installed each month, with a standard deviation (37.74 m^3) in volume installed per month per 100,000 households. This ranged from a minimum of 0 m^3 to 304 m^3 in a month with these plants averaging 8m^3 each in size. An average of 10 masons were reportedly present in each county although in some months (particularly in the earlier months), there are counties in which there were no trained masons. A description of the variables in this analysis is summarized in in Table 1 below. The subsidy-cost ratio was 0.11 implying that on average, the subsidy catered for approximately 11 percent of installation costs. This ratio ranged from zero to 43 percent.

Table 1: Descriptive statistics of variables in the study: 2011–2014

	Unit	Varies by	Mean	Std dev	Min	Max	Expected sign
Dependent variable							
Volume of plants installed per 100,000 households[1]	m^3	C, M	23.04	37.74	0	304.39	
Independent variables							
Firewood price[2]	Ksh/kg	C, Y	2.78	0.68	2.03	4.87	+
Income[3]	Ksh/month	C	6,221	1,957	3,667	13,954	+
Education[3]	Index	C	0.96	0.28	0.17	1.68	+
Dairy TLU[4‡]	TLU	C	0.90	0.75	0.02	2.94	+
Water availability (%)[3]	Percent	C	51.62	16.30	21.4	82.7	+
Subsidy-cost ratio[1]		C,M	0.11	0.14	0	0.43	+
Number of masons	Number	C, M	10.63	23.35	0	196	+
Volume installed (t-1)	m^3	C, M	22.84	37.71	0	304.39	+

Notes: Data sources: 1) ABPP database, 2) Kituyi, *et al.*, 2001, 3) Wiesmann, *et al.*, 2016 4) ASDSP 2013 national household survey. Panel characteristics: C means that the variable varies by county, M by month and Y, by year. ‡TLU: Tropical Livestock Units (0.7 for an adult cow/bull, 0.2 for young immature female/male and 0.1 calves).

Econometric tests and analysis

Various econometric tests including the Levin-Lin-Chu unit-root test, the Harris–Tzavalis test and the modified Wald test for groupwise heteroskedasticity are conducted. A test for cross sectional independence, (the Pesaran CD test) is also conducted to check whether the residuals are correlated across entities since contemporaneous correlation can lead to bias in tests results. A Wooldridge test for serial correlation on the other hand returns F(1, 41) = 103.543, Prob > F = 0.0000 which leads us to reject the null hypothesis and conclude that the data manifests first-order autocorrelation. We ran a random effects model since as shown in Table 1, there are

variables that do not change with time, and a fixed effects specification cannot handle data of that nature.

We implement the analysis by estimating a Spatial Durbin model. In the regressions implemented, we take into account what Greene, (2006) notes about specification of the Tobit model; that "*it hangs crucially on the assumption of normality*" and that "*how fragile the model is because of this is unknown*". We therefore perform the estimations specifying both a Normal and a Weibull distribution to remedy any potential non-normality problems on the error term. Since we specified a log-log model, the coefficients shown in Table 2 are in effect, elasticities.

Table 12: Coefficients, direct and indirect effects estimated from the Spatial Durbin Panel Tobit (Weibiull specification)

Dependent variable : installed volume Sample period: 2011 – 2014 (42 counties)						
	Coefficient	**Standard error**	**Z**	**Direct effect**	**Indirect effect**	**Total effect**
Lagged volume	0.237***	0.029	8.05	0.1636	0.0686	0.2322
Subsidy-cost ratio	0.538*	0.324	1.66	0.3717	0.1560	0.5277
Dairy TLU	0.144***	0.061	2.37	0.1000	0.0420	0.1420
Water availability	0.001	0.003	0.37	0.0009	0.0004	0.0012
Fuelwood price	1.559***	0.324	4.80	1.0755	0.4513	1.5268
No. of Masons	0.222***	0.046	4.81	0.1536	0.0644	0.2180
Constant	0.567	0.386	1.47			
W*Lagged volume	-0.021***	0.007	-2.75	-0.0151	-0.0063	-0.0214
W*Fuelwood price	-0.112***	0.050	-2.23	-0.0775	-0.0325	-0.1100
W*No. of Masons	-0.013	0.016	-0.78	-0.0088	-0.0037	-0.0125
rho (ρ)	0.058***	0.010	5.81			
Sigma	0.771***	0.024	31.75			
-2LL	-1650.07					
Global Moran's I	0.2872***					
R2 Adj	0.58					

Notes: Robust standard errors (clustered by county-year) in parentheses; significance *** p<0.01, ** p<0.05, * p<0.1.

The tradition that biogas and cattle manure are spoken in the same sentence is clear from the results presented in Table 2. The coefficient on dairy herd TLUs is significant (p<0.05) and this is not surprising because biogas plants utilizing other forms of substrate other than cattle manure are the exception rather than the norm.

Being an important subject of this paper, subsidies are shown to be important in driving installations. An increase in subsidy by 10 percent is associated with a 5.3 percent increase in installed volumes (p<0.1). This figure is much higher than that estimated in China (3 percent). The results show as expected that a subsidy policy would be associated with increases in volumes installed. However, whether this is true for actual use of the plants is not clear, given results in China which reflect that actual use and subsidy levels are negatively related.

The data also shows some bumps at the time close to the subsidy change. The behaviour could be said to describe either of two different processes. Procrastination or *"present biased preferences"* could be one such explanation where present-biased preferences give stronger relative weight to an earlier moment as it gets close (O'Donoghue and Rabin, 1999). Here, most would be installations are done close to the last date to the termination of the subsidy, since the expenditure to be borne on the cost installation is constant irrespective of when this is done. Alternatively, it could be a manifestation of what some researchers call the "*Announcement Effect*". The latter occurs when investors respond to information about imminent termination of a form of subsidization by realizing their investment earlier than planned in order to obtain

the subsidy (Gürtler and Sieg, 2010). How this behaviour affects the estimates derived in the analysis is unknown, although an announcement effect is likely to inflate the impact of the subsidy on installations. The mechanism through which this happens is not difficult to imagine. Installations that would otherwise have been recorded (planned) after the subsidy change are lumped (observed) before the subsidy change, leveraging observations before this change.

In addition, the average size of digesters was 9.2 M^3, 8.8M^3, 8.5M^3 and 8.4M^3 during the 4 years (2011-2014) respectively. A trend test reveals this downward trend to be significant. This appears to suggest that households may have also scaled down on the size of plants installed as time went. In a way, this can be seen as an attempt to maximize on the subsidy.

Conclusion and recommendations

A demonstration in this paper is the use of spatially weighted estimations that account for Tobler's first law (TFL) of geography: that "everything is related to everything else, but near things are more related than distant things". These results shed some light to what many researchers underestimate—the importance of spatial correlation—which allows the study of phenomena in its actual spatial context.

Going forward, investigating the key motivations besides direct subsidies that drive biogas installations would also be an appropriate follow-up. All these would help in the turning the nationally determined contributions to concrete climate policy in line with the Paris Agreement which took effect in November 2016. In the formulation used in this paper, pro-environmental behaviour which in some studies has been used to explain the adoption of renewable energy technologies is assumed away. Therefore, these results on a policy variable—subsidies—need to be regarded as one among other policies that integrate and balance ethical suasion with financial incentives. The unavailability of data to estimate this influence is one major drawback in this study.

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