Animal Production Society of Kenya

Sustainable Livestock Innovation and Technology: Roadmap to Improved Food and Nutrition Security

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Sustainable Livestock Innovation and Technology: Roadmap to Improved Food and Nutrition Security

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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. These may be new technologies or approaches, emerging challenges, controversial issues with implications for livestock production that require rational conversation, national or regional trends which may have consequences for animal agriculture. The APSK 2017 symposium focused on examining macro trends that underpin livestock production in Kenya.

The livestock sub-sector contributes over 30% of the farm gate value of agricultural commodities, about 10% of the national GDP, and at least 50% of the agricultural GDP. Domestic livestock also supply the local requirements of meat, milk, dairy products and other livestock products while accounting for about 30% of the total marketed agricultural products. However, the supply and demand for livestock products is affected by increasing population, urbanization, policy environment and, the import/export markets among other factors. Particularly, urbanization will offer opportunities for business throughout the country and will require the development of innovative products to meet the specific needs of an emerging consumer class. At the same time, it is clear that rural incomes will not be substantially increased by exclusive emphasis on subsistence livestock production; rather, more market-oriented production systems will be needed. This, therefore, implies that revitalization of livestock industry is likely to yield a wide range of positive impacts/effects throughout the country.

The APSK 2017 symposium provided opportunity for rational discussions on these livestock trends and sought ways of addressing the associated challenges while harnessing existing opportunities. Under the overarching theme “Sustainable Livestock Innovation and Technology: Roadmap to Improved Food and Nutrition Security”.

We would like to express our gratitude to the sponsors of the conference. Special thanks are due to presenters and authors of papers and posters, our colleagues on the symposium organizing committee, institutions and individuals who assisted in one way or the other, and the esteemed conference participants. The venue, setting and the overall conference atmosphere provided opportunity for networking by participants from across the country. After the symposium, presenters were asked to submit or revise their papers, taking into account the issues raised during the symposium discussions. The papers were then subjected to light technical reviews and language editing, therefore, ensuring that intellectual content remains that of the authors. APSK does not necessarily share the views expressed in this proceeding; responsibility for its content rests entirely with the authors.

It is our hope that the APSK 2017 symposium proceedings will provide useful reference material for those interested in understanding the major trends and associated issues covered during this conference.

Samuel M. Mbuku, PhD
Chairman, Animal Production Society of Kenya
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Sustainable Livestock Innovation and Technology: Roadmap to Improved Food and Nutrition Security

Eldoret, Kenya 5–7 April 2017
Invited Paper: Jointly Innovating with Farmers: Context and Future with Agricultural Research

Prof. Linnet Gohole
University of Eldoret

The presentation focuses on how researchers and development agents are supposed to work jointly with farmers. To achieve this, various factors are supposed to be brought into play which include, research moving from on-station to on-farm, enhancing adoption of technologies/skills/knowledge to the farmers, conducting participatory research with farmers, planning research with farmers and listening to the voice of farmers.

The situation on the ground is that adoption rates of research products and innovations by farmers is low since they are not involved when the technologies are being implemented. The mode of participation is biased and applied instead of bottom-up approach. Farmers and stakeholders are not involved while some technologies are being packaged and recommended such as cereal banks, tea picking machines among others. The focus of researchers and policy makers is on enhancing the yield and not putting into consideration the different contexts the farmers are found in. There is too much academic and technical aspects and there is no emphasis on social aspects as a result the farmers do not understand the technology hence low adoption.

The researchers and the policy makers need to ask these questions to guide them as they initiated projects: Who are the beneficiaries of the project? Is research addressing farmers’ needs adequately? Are farmers genuinely involved in the whole project cycle? Are farmers’ opinions sought and incorporated in project activities? Are farmers’ various contexts considered – social, gender, economic (one size does not fit all)

Innovation – definitions

The term innovation has been defined by various scholars as given below:

- Anything that is new, useful, and surprising – Drew Boyd
- Something new or different that delivers value to the world – Jorge Barba
- Turning an idea into a solution that adds value from a customer’s perspective – Nick Skillicorn
- The application of ideas that are novel and useful – David Burkus
- Development and execution of knowledge and technologies that make farming more sustainable, resilient, and productive

Why innovation?

The reason why new innovations are called for is because old ways of doing things is no longer of value or profitable, there is also need to get new ideas/skills/knowledge/technologies/methods e.g. Hermetic storage – PICS bag

Some ideas are a surprise, some come by chance, others are sought and they range from simple to complex. There is also need to consider the ideas and technologies of farmers since they can be improved.

How to use innovations with farmers, the first step is by inclusion where by many researchers and development agents are supposed to convene multiple and diverse stakeholder’s forums, there should be genuine collaboration - authentic collaborative engagement where by every stakeholder is supposed to add value. Reciprocity where by stakeholders need to build trust based on shared interests and honest interactions, mutuality should be embraced where by stakeholders should negotiate and have win – win agreements and engagements should be realistic.
How to go about it?

Farmer-researcher co-creation – This should be done by engaging the farmers as partners to ensure relevance, use of research processes and results, to integrate local and global research, to link social & technical inquiry, to enhance quality through capacity building, to integrate farmer knowledge into the research. Incentivize, support and reinforce farmer participation to ensure responsiveness to farmers’ needs, knowledge, problems, concerns and constraints. Lastly, make the research process empowering: Build social, technical, and methodological capital through the farmer-researcher co-creation process.

Participation at each stage

Expectations

When researchers use innovations jointly with farmers the performance improves drastically due to the following factors;

- Genuine farmer involvement in research-> understanding-> ownership-> adoption
- Farmers determine what options are good for them in their own context (OxC)
- Farmers’ ideas and innovations considered and trialed -> farmers become researchers -> better understanding -> empowered to innovate on their own
Invited Paper: MIAVIT Working with stakeholders to increase livestock productivity in Kenya

Faustine Wanjala

MIAVIT is a German animal nutrition company, which is a family-guided company at the heart of animal nutrition in Europe and worldwide. The company began by producing premixes for the feed industry. The name MIAVIT has been synonymous with minerals, amino acids and vitamins since the company was founded in 1964. The Company provides feedstuffs, supplements, minerals and vitamins.

Today, MIAVIT is an internationally successful company supplying customers in more than 80 countries worldwide. Through its wide range of products, it provides innovative, environmentally friendly and economically viable solutions for animal and human nutrition. To suit customers’ specific needs, the company offers products in powder, tablet, paste and liquid form. In Europe, it is one of the leading manufacturers and suppliers in the fields of premixes, feed additives and supplementary feeds.

MIAVIT GmbH has now opened a new office and warehouse in Kenya to serve customers’ needs for quality nutritional products. Located in Nairobi, the new MIAVIT office and warehouse will ensure that the company’s products are available at all times for its Kenyan customers. A dedicated team of animal nutritionists and veterinarians are working in the East African market to give the customers technical advice and to share knowledge on animal nutrition and management.

Products offered

MIAVIT’s expertise is reflected in the company’s wide range of high-quality products, which have proven successful for decades. The products meet the needs of modern, environmentally friendly, economically viable animal nutrition. The products are offered in both powder and liquid form such as:

- Customized pre mixtures
- Specialty feedstuffs
- Liquids
- Feed supplements (vitamin E powder, choline chloride powder)
- Pet food products
- Trace element mixtures for biogas plants
- Toll manufacturing (e.g. mineral feeds)

In view of the large number of different formulations produced, their modern manufacturing facilities work with the requisite absolute precision throughout, starting from the precise metering of raw materials. The Company’s products are continuously monitored by certified laboratories, and careful selection of raw materials and suppliers as well as a high degree of automation ensure consistently high quality.
Invited Paper: Diamond V XPC™: Managing Intestinal Health for Balanced Immunity, Improved Production and Safe Food

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Diamond V is a global, technology-driven company that develops and manufactures all-natural products that improve nutrition, health and performance in food animal and companion animal species. Diamond V XPC, originally developed in 1943 is a unique, fermentation based feed additive composed of numerous functional metabolites proven via peer-reviewed research to support production, animal health and food safety in all classes of animals.

The unique metabolites in XPC support robust digestive health by balancing gut microbiota, boosting the immune system (innate and acquired) and optimizing gut morphology for increased nutrient retention. These uplifts help chicken reach their genetic potential by improving feed efficiency, production, product quality (cleaner and stronger egg shells), and reduced mortality. Poor air quality in poultry houses and wet litter lead to discomfort in chicken, increased feet, breast pad lesions and secondary infections that are of great welfare concerns among the stakeholders in the poultry industry. XPC enhances growth of the good microbial populations while suppressing populations of disease causing microbes in the gut therefore improving digestion, feed utilization and ensures reduced diarrhea in chicken. This will reduce ammonia accumulation and dampness of the barn therefore improving animal welfare.

Currently, food safety is a matter of global concern and consumers are not only worried about food security, but also safety of the food they consume. Poultry products (meat and eggs) contaminated with bacteria mainly: Salmonella, Campylobacter and E-coli are the main causes of food borne illnesses in the world. Furthermore, widespread antibiotic resistance in humans has also been closely linked to residues in animal products such as meat and eggs. The ban of sub-therapeutic antibiotic use in animal feeds for growth promotion has also exacerbated the situation of food safety. There is need therefore to come up with non-antibiotic solutions that can help reduce the amount of harmful bacteria in poultry meat and eggs. Inclusion of XPC in poultry diet directly reduces contamination of poultry products through reduced bacterial loads in the gut and bacterial shedding, therefore ensuring less contamination in the barn and the environment. XPC also reduces the prevalence (number of positive birds in the barn), implying reduced cross contamination of the clean birds. It also reduces the virulence (ability to cause disease) and antibiotic resistance of salmonella recovered from the birds. In conclusion, persons consuming XPC fed birds or eggs will experience safer food with reduced infection rates from food borne illnesses and reduced antibiotic resistance. XPC inclusion rate is 1.25Kg per tone in all classes of poultry feeds.
POLICY, VALUE CHAINS, MARKETS AND OTHER CROSS – CUTTING ISSUES AFFECTING LIVESTOCK PRODUCTION

Dairy marketing through co-operatives, opportunities and challenges: The experience of Smallholder Dairy Commercialization Programme, Kenya

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Abstract

Dairy Co-operatives help create more equitable growth by making markets work better for members, by generating economies of scale, increasing access to information, and improving bargaining power. Co-operatives can increase access to credit and inputs and make value addition a reality so that members of co-operatives can earn more from their products. However, the current performance of dairy Co-operatives in Western Kenya is not clear. There is a need to identify the challenges and options for improvement of the cooperatives so as to enable smallholder dairy farmers to improve their livelihoods. The objectives of this paper were to establish the challenges faced by the Co-operatives working with the Smallholder Dairy commercialization Programme and identify new opportunities. Six farmer’s co-operative societies were purposively selected as case studies. They are located in the Counties covered by the Smallholder Dairy Commercialization Programme. Information relating to quantities and prices of milk handled by these cooperatives was collected and analyzed using Excel software. Further interviews were held with chairpersons of these co-operatives to identify constraints and possible solutions. Sugoi Farmers Co-operative society marketed over 40,000 liters of milk per month in some occasions, showing a good performance. Marinyin and Cheptil co-operatives seem to have constraints to collective milk marketing. The milk prices ranged from Ksh 23 per liter to Ksh 34 per Litre. Market information can inform decision making by the cooperatives. The major buyers of milk from the co-operatives are Brookside Dairies Ltd and New KCC Ltd. Further work needs to be done on the cost of milk production and possibilities of these co-operatives forming an apex body to enhance the market power of milk marketing cooperatives. In addition, cooperatives that provide other services to farmers on credit – feeds, artificial insemination and loans – have recorded a good success. Training of cooperative management staff on market research is also recommended to enhance their performance.

Keywords: Dairy, Cooperatives, Marketing, Performance

Introduction

International Co-operative Alliance (1995) defines a Co-operative as an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspirations through a jointly-owned and democratically-controlled enterprise. The co-operative model is a unique model as the members are the owners, the managers and also the patrons or clients.

Cooperative development in many countries has shown that farmers who are effectively organized can benefit from aggregated links to markets and services, from accessing centralized services that can help them achieve higher yields and higher incomes, and from speaking with a collective voice to advocate for their needs (Siavashan & Khari 2012). At a global level, countries with the highest share of cooperatives in marketed outputs (e.g., Taiwan, Korea, Netherlands, France, etc.) also have high average yields for staple
crops like rice and wheat, as well as substantial cash crop exports. Farmers achieve economies of scale because of collectiveness and are able to cope with market changes (Clegg, 2006). In Ethiopia, farmers who are members of cooperatives tend to achieve higher yields, and staple crops that are marketed through cooperatives attain a price premium of around 7-8%. The 2008 World Development Report reviewed the evidence and concluded that “Producer organizations are essential to achieve competitiveness for small-scale producers.” (Wanyama, 2008)

Co-operative movement in Kenya is over 100 years old. The first co-operative project in Kenya was a dairy co-operative in Kipkelion, registered in 1908, followed by Kenya Co-operative Creameries which was registered in 1931 which was the sole marketing agent for milk. This changed with the liberalization of milk marketing in 1992 (Ngigi, 2005). When state control was removed from the co-operative movement in 1997, many dairy co-operatives collapsed. This was a result of mismanagement of the co-operatives and their inability to work in a liberalized milk market. Since then liberalization of the milk market players entered the dairy sector. Many small scale traders moved in to sell raw milk from farmers to consumers and private processors as a result of disorganized marketing systems. Farmers have continued to be exploited by the small scale traders or middlemen in the milk marketing process. Despite dairy being an important economic activity in Kenya, most small scale dairy farmers have not benefited from the hard work and investment they continue to put in the business. Efforts have been made and continue to be made to encourage farmers to join together to form co-operatives to do collective marketing of their milk.

Dairy co-operatives can be used as an important instrument for economic development for small scale farmers in Kenya. The smallholder Dairy Commercialization Programme (SDCP) which is supported by the Government of Kenya and International Fund for Agricultural Development (IFAD) has for the last 10 years worked with small scale farmers in nine Counties with the main aim of having a commercially oriented dairy sector in the programme area. The SDCP has supported organization of farmers into co-operatives and given grants for coolers and other accessories in eight co-operatives in the programme area. Dairy Co-operatives help create more equitable growth by making markets work better for members, by generating economies of scale, increasing access to information, and improving bargaining power. Co-operatives can increase access to credit and inputs and make value addition a reality so that members of co-operatives can earn more from their products.

**Objective**

The objective of the study was to establish the challenges faced by the Co-operatives working with the Smallholder Dairy commercialization Programme and identify the new opportunities.

**Methodology**

**The Study Area**

The Smallholder Dairy Commercialization Programme covers 9 counties namely Nakuru, Uasin Gishu, Trans Nzoia, Kakamega, Bungoma, Kisii, Nyamira, Bomet and Nandi (see Figure 1) and this formed the sampling frame of the study.

**Sampling Procedure**

Cluster sampling was used to select Uasin Gishu, Nandi and Bomet Counties as the study area. The clusters were based on the dairy cooperatives supported by SDCP in the county, population of dairy cows in the county and the predominant milk production system. Uasin Gishu County has the highest population of dairy cows in the Country while Bomet and Nandi Counties are low cost milk producing counties due to the use of open grazing system of milk production. The three counties have dairy cooperatives supported by SDCP. Therefore purposive sampling was used to select the cooperatives in the identified clusters based on their partnership with SDCP. These cooperatives are: Chepkatet Farmers Cooperative Society Ltd (FCS),
Springfield FCS, Moi’s bridge FCS and Sugoi FCS in Uasin Gishu County; Marinyin FCS in Bomet county and Cheptil FCS in Nandi County. Purposive sampling makes the study more focused, is less costly and less time consuming. The selected cooperatives had received support from SDCP in terms of provision of bulk milk coolers. These cooperatives have varied membership Cheptil FCS, Marinyin FCS, and Sugoi FCS has a membership of 1,400, 300 and 577 members respectively. Springfield FCS, Chepkatet FCS and Moi’s bridge FCS had a membership of 421, 270 and 628 members respectively.

**Figure 1:** Map of the Kenya showing the study area

**Instruments of data collection**

A questionnaire was developed as an instrument to collect both primary and secondary data. It consisted of both closed and open ended questions and administered to the management committee members being the unit of analysis. The respondents were asked to respond to the same set of questions. A questionnaire was preferred because of its ability to collect data from a large population. At the end both quantitative and qualitative data was collected from the dairy cooperative societies and dairy training institute. Data-collection technique involved oral questioning of respondents, either individually or as a group. The data for analysis was generated from performance of the dairy cooperative societies. These cooperatives also provided constraints faced in their organizations.

**Procedure for administration of the instruments**

The survey was conducted in the 6 dairy cooperative societies identified above. The Management committee members were the unit of analysis while resource persons and county government officers were involved as key informants.
Data Analysis procedure

Descriptive statistics was used to analyze the data. The descriptive statistical techniques used were mean, variance and standard deviation.

Results and Discussion

Milk Marketing

The findings of this study reveal that the cooperatives were handling varying quantities of milk per month. Moi’s bridge cooperative society had the highest amount of milk followed by Springfield Cooperative society (Figure 2). Chepkatet had not started collective milk marketing. Chepkatet faces stiff competition from mobile milk traders since mobile traders sell milk at low prices hence the consumers prefer buying milk from them that Chepkatet cooperative whose prices are slightly higher compared to those of hawkers.

Figure 2: Quantity of milk (L/month) marketed through Chepkatet, Springfield and Moi’s bridge cooperatives

Figure 3: Quantity of milk (L/month) marketed through Sugo, Marinyin and Cheptil cooperatives
Sugoi Co-operative marketed over 40,000L of milk per month in some occasions, showing good performance (Figure 3). Marinyin and Cheptil cooperatives on the other hand seems to be performing poorly in collective milk marketing. This is attributed to poor management by the committee members leading to low levels of trust by milk suppliers who in turn opt to sell their milk directly to milk hawkers. The prices received for milk sales are shown in Figures 4 and 5. The prices range from Kshs. 23 to Ksh 34 per litre. They do not offer any other service other than bulking of milk.

**Figure 4:** Price of milk/L (Ksh) received by Moi’s bridge, Springfield and Chepkatet Cooperatives

**Figure 5:** Price of milk/L (Ksh) received by Cheptil, Marinyin and Sugoi Cooperatives

**Constraints and possible solutions**

It was realized that the Management Committee Members of these cooperatives (Chepkatet, Cheptil, Marinyin, Moi’s bridge FCS, Sugoi FCS and Springfield FCS) had several constraints. They had not been
trained in milk hygiene and handling, marketing management, governance, and value addition and had not been exposed to all vital business components such as entrepreneurship, business planning and accounts and Management. The supervisory too had not been trained on entrepreneurship, business planning accounts and Management, marketing Management, milk hygiene and handling and value addition. This implies that both the Management Committee Members and the supervisory face a major challenge in executing their managerial and supervisory responsibilities. Despite of the shortcomings the Management Committee Members was found to be cohesive enough since they work as a team, attend meetings, make decisions and are able to achieve most of the objectives. They also faced stiff competition from milk hawkers. The possible solutions include increased efficiency and cost reduction to ensure that they benefit from economies of scale. In addition, training based on a training needs assessment is recommended. Market information provision for cooperatives is crucial as milk is a perishable product.

**Conclusion and Recommendations**

The major buyers of milk for the cooperatives are Brookside dairies Ltd and New KCC Ltd. In a duopoly market, the competition is not stiff and price fixing or collusion can easily take place to the detriment of the smallholder dairy farmer. Further work needs to be done on the cost of milk production and possibilities of these cooperatives forming an apex body to enhance the bargaining power of the cooperatives in the marketing of milk. In addition, cooperatives that provide other services to farmers on credit such as supply of animal feeds, artificial insemination and advances tend to record good success. Training of cooperative management staff on market research is recommended.

**References**


Gender Participation and Commercialization of Smallholder Dairy Farming in Uasin Gishu County, Kenya

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Abstract

Women play crucial roles in dairy farming though they usually have limited access to land, financial resources and other resources for production. In developing countries, over 75% of the poor are rural smallholder producers who derive their livelihoods primarily from agriculture. Kenyan smallholder dairy producers constitute 80% of the dairy producers out of which 61% are women. Small holder dairy farmers produce about 80% of total milk produced and 70% of the total milk marketed in the Country. Therefore, smallholder dairy producers derive their livelihoods from dairy farming. Thus, commercializing smallholder dairy farming will be an important pathway out of rural poverty and will be a powerful tool for the improvement and sustainability of livelihoods of smallholder dairy producers. In Uasin Gishu County, the proportion of smallholder dairy producers in the commercialization scale is 70% subsistence, 20% semi-commercialized and 10% commercialized. This therefore, indicates that commercialization level is still low and variable. The objective of this paper therefore was to establish the influence of Gender participation on commercialization of smallholder dairy farming. Descriptive research design was used to obtain primary data through a sample size of 384 smallholder dairy producers who were selected using stratified random sampling technique. Data analysis procedures used includes: mean, standard deviation, Pearson correlation coefficient, Spearman's rank correlation coefficient and multiple regressions. Results obtained indicate that gender participation has significant role on commercialization of smallholder dairy farming. It is therefore recommended that the Government of Uasin Gishu County together with policy makers; planners; smallholder dairy producers and other relevant stakeholders in the dairy value chain in the County should formulate policies, strategies and design programs and projects that will address the influence of gender participation in order to achieve sustainable rural development in the County and Kenya.

Keywords: Smallholder, Dairy Farming, Producers, Commercialization, Gender, Participation

Introduction

Majority (over 75%) of the poor in developing countries are rural smallholder producers who primarily depend on agriculture for their livelihoods (Gollin et al, Otieno et al, Gebreselassie et al, and Vancompernolle et al). Kenyan smallholder dairy producers constitute 80% of the dairy producers and they produce about 80% of total milk production and 70% of the total milk marketed (Kenya National Dairy Master Plan 2010 & International Fund for Agriculture Development [IFAD] 2015). Dairy farming in Kenya is the source of livelihoods for the smallholder dairy producers. It contributes 4% of the total gross domestic product (GDP) and 14% of agricultural GDP (Sessional Paper No 5 of 2013 on National Dairy Development Policy). Globally, international development agencies are giving due attention to intensification and commercialization of smallholder farming as a means of achieving food and nutrition security, and poverty reduction. Kenya in particular is providing support to the transformation of the prevalent subsistence smallholder dairy farming to competitive, commercial and sustainable dairy industry intended to lead to economic growth, poverty alleviation, wealth and employment creation (Agricultural sector development strategy. 2010, Uasin Gishu County Annual Report 2013 and Simonyan et al).

The women who engage in dairy farming operators usually have limited access to land and financial resources Kenya Smallholder Dairy Commercialization Programme: Main Report, IFAD 2006 and 2015.
Land in Kenya is obtained either through purchase or inheritance and this makes it difficult for women to obtain land because traditionally family land is inherited by men only. Since land is the most used collateral to access credit, women then have a problem of raising finance to expand their dairy operations (Cefe et al 2014 and Nguyen et al 2003). Women play significant roles in dairy production and trading in Kenya and they are involved in dairy activities more than men in most parts of the Country Nmadu, et al 2012. A survey carried out in 1999 in a representative sample of households in Kenya, shows that 67% of dairy farm households are male-headed and 33% are female-headed Salami et al., 2010. Furthermore, even in male-headed households, 61% of the dairy operators were women. There is clear gender-based division of labour in dairying production, where by women contribute more labour in collecting feeds, processing, milking, marketing of milk, cleaning of sheds and fetching of water for animals while men are involved in establishment of the units, purchase of the animals and parasite control. New strategies have been put into place operation in the Rift Valley and Western Provinces, where by hired labour is replacing family labor.

The adoption of a commercial orientation to smallholder dairy production entails additional investment costs, notably with respect to transport of feed, equipment for milking and hiring of labour for harvesting hay, forage crops, feeding, watering and herding of the dairy animals.

In commercial system, profit maximization is the main motive of the entrepreneur and inputs are predominantly obtained from markets Ele et al 2013, Kenya National Dairy Master Plan 2010, Hall et al., 2005 and Ogbe et al., 2009. Omiti et al., (2009) defines agricultural commercialization as an agricultural transformation process in which farmers shift from mainly consumption-oriented subsistence production towards market- and profit-oriented production systems. The smallholder dairy producers in Uasin Gishu County are mainly subsistence oriented (70%) whereas semi-commercialized and commercialized one are (20%) and (10%) respectively Uasin Gishu County Annual Report. 2010. This indicates that the commercialization of smallholder dairy farming is low and variable. This may be influenced by Gender participation.

Methodology

The study Area

This study took place in Uasin Gishu County which has a total area of 3,327.8 Km². It extends between longitude 34° 50′ and 35° 37′ east and 0°03′ and 0°55′ north. It is made up of six Sub-Counties namely: Soy; Turbo; Kapsaret; Kesses; Ainabkoi and Moiben Uasin Gishu County Annual Report. 2013a. The county is the leading milk producing county in Kenya with three (3) categories of smallholder dairy producers namely: subsistence (70%), semi-commercialized (20%) and commercialized (10%) UasinGishu County Annual Report 2013a and County Intergrated Development Plan; UasinGishu County, 2013c. The County is therefore characterized by subsistence smallholder dairy farming.

Research Design and Method of Data Analysis

This paper used descriptive research methodologies. Stratified random sampling was used to select 384 respondents with Sub-Counties constituting the strata. Data analysis used included descriptive and inferential statistics. Descriptive statistics used were mean and standard deviation while inferential statistics consisted of correlations (Pearson and spearman’s rho), regression (multiple regressions) and Household Commercialization Index (HCI) as indicated by the formulas below:

Mean \( \bar{x} = \frac{\sum x_1}{n} \) (1)

Standard deviation \( \sigma = \sqrt{\frac{\sum (x_1 - \mu)^2}{n}} \) (2)

Pearson Correlation \( r = \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sqrt{\left(\sum x^2 - \frac{\left(\sum x\right)^2}{n}\right)\left(\sum y^2 - \frac{\left(\sum y\right)^2}{n}\right)}} \) (3)
Spearman's \( r_S = 1 - \frac{6 \sum d^2}{n(n^2 - 1)} \) (4)

\[ Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon \] \quad (5)

Where \( Y \) = Average HCI (Dependent variable).

\( X_i-n \) = Gender participation (Independent variables)

\( \beta_0 \) = Constant or Point of intercept on Y axis

\( \beta_1-n \) = Regression coefficients.

\( \varepsilon \) = Residual term or the error

\[
HCI = \left[ \frac{\text{Gross value of milk sales per household per month}}{\text{Gross value of total milk production per household per month}} \right] \times 100
\] \quad (6)

The Household Commercialization Index (HCI) ranges from zero to 100%. A value of zero indicates a totally subsistence oriented producer. The closer the index is to 100%, the higher the level of commercialization Muhammad-lawal et al., 2014 and Nmadu et al., 2012. In the determination of HCI, the study used dairy milk production and dairy milk sales. The Gebresellassie et al., 2008, Jaleta et al., 2009, Muhammad-lawal et al., 2014, Omiti, et al., 2009, and Vancompernolle et al, 2014 provide scale of commercialization (HCI) as: 0%-30%: subsistence oriented producers; 31%-65%: Semi-commercialized producers; 66%-100%: Commercialized producers.

**Results and Discussions**

**Results of Gender Participation**

Gender Participation in smallholder dairy production was analyzed using descriptive statistics (Tables 1-7; Figures 1-7 below):

The results show that majority of respondents (59) had men alone accessing knowledge and technology in dairy development (Table 1; Figure 1 below).

![Access to knowledge and technology](image)

**Figure 1:** Access to knowledge and technology

This means that most of the producers had man alone accessing knowledge and technology. Majority of the respondents (74%) indicated that productive asset ownership was accessed by both men and women (Table 2; Figure 2 below).
This indicates that both men and women have access to productive assets.

In the case of educational level, most of the respondents (81.6%) had attained secondary level of education and above while 95.4% of the respondents had attained primary level of education and above (Figure 3 below).

Among the respondents, majority (65%) had men alone controlling income (Figure 4 below).

This results imply that most of the respondents had men alone controlling income. In the control of assets by gender, most of the respondents (74.9%) had men alone controlling assets (Figure 5 below).
This shows that majority (74.9%) of the respondents had men alone controlling assets.

The results show that most of the respondents (67.2%) had men alone making decisions on dairy aspects (Figure 6 below).

The proportion of respondents in relationship to land ownership was as follows: 44.5% of the respondents had family land/inheritance, 52.5% had purchased land, and 3.0% had leased land (Figure 7 below).

This means that most of the respondents had purchased their land.
**Inferential Results of Gender Participation**

The inferential statistics used were correlations and multiple regression analysis.

**Correlation Results**

The correlations used were Pearson correlation coefficients and Spearman’s rho and the results are shown in table 8 below:

Correlation results of a Pearson (0.940) and Spearman’s rho (0.813) show that there is significant positive relationship between respondents’ access to knowledge and technology, and the average Household Commercialization Index. The correlation results of a Pearson (0.875) and Spearman’s rho (0.890) indicate that there is a high significant relationship between respondents’ access to assets, and the average Household Commercialization Index (HCI). The correlation results of a Pearson (0.820) and Spearman’s rho (0.826) indicate that there is a positive significant relationship between respondents’ level of education and the average Household Commercialization Index (HCI).

According to results of a Pearson (-0.733) and Spearman’s rho (-0.691), there is a highly significant negative relationship between respondents’ control of income, and the average Household Commercialization Index. The results of a Pearson (-0.695) and Spearman’s rho (-0.721) show that there is highly significant negative relationship between respondents’ control of assets, and the average Household Commercialization Index (HCI). The correlation results of a Pearson (0.680) and Spearman’s rho (0.600) show that there is highly significant positive relationship between respondents’ decision making on dairy aspects, and the average Household Commercialization Index (HCI). The results of Pearson (0.501) and Spearman’s rho (0.616) indicate that there is a significant positive relationship between respondents’ ownership of land, and the average Household Commercialization Index (HCI).

**Table 1: Correlation Results of Gender Participation**

<table>
<thead>
<tr>
<th>No.</th>
<th>Independent variables</th>
<th>Correlation Model</th>
<th>Pearson Correlation</th>
<th>Spearman’s rho</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Access to knowledge and technology</td>
<td></td>
<td>.940**</td>
<td>.813**</td>
</tr>
<tr>
<td>2</td>
<td>Access to assets</td>
<td></td>
<td>.875**</td>
<td>.890**</td>
</tr>
<tr>
<td>3</td>
<td>Level of education</td>
<td></td>
<td>.820**</td>
<td>.826**</td>
</tr>
<tr>
<td>4</td>
<td>Control of income</td>
<td></td>
<td>-.733**</td>
<td>-.691**</td>
</tr>
<tr>
<td>5</td>
<td>Control of Assets</td>
<td></td>
<td>-.695**</td>
<td>-.721**</td>
</tr>
<tr>
<td>6</td>
<td>Decision making</td>
<td></td>
<td>.680**</td>
<td>.600**</td>
</tr>
<tr>
<td>8</td>
<td>Land ownership</td>
<td></td>
<td>.501 *</td>
<td>.616*</td>
</tr>
</tbody>
</table>

Key to Table 1: **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed). Sample size, N = 384. Correlation between each variable and itself = 1.00.

The correlation coefficients in table 1 above indicate that the Household Commercialization Index of the respondents and the Gender participation of smallholder dairy producers (independent variables) are significantly correlated. However, some correlations were more powerful statistically at 1% level of significance than the others at 5% level. Access to knowledge and technology: access to assets; level of education; control of income and decision making have correlation coefficients greater than 0.5 (+ or -) and they are significant at 99% confidence level. On the other hand, land ownership has low Pearson coefficients of 0.501 at α = 0.05.

**Regression Results**

The regression results presented by the formula below show that Gender participation influence the average Household Commercialization Index (HCI) at various levels:

\[
\ln(Y_i) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \beta_6 X_{6i} + \epsilon
\]

\[
(\beta_0 \pm 0.15) (\beta_1 \pm 0.179) (\beta_2 \pm 0.125) (\beta_3 \pm 0.110) (\beta_4 \pm 0.092) (\beta_5 \pm 0.078) (\beta_6 \pm 0.026)
\]
The multiple regression (0.208) results confirm that access to knowledge and technology has highly significant positive association with average Household Commercialization Index. A unit (one percent) increases of level of access to knowledge and technology causes an increase of HCI by 0.208 (20.8%). According to the results, access to assets has a standardized coefficient of 0.190 meaning that access to assets is positively associated with average HCI and, coefficient is highly significant at 1%. A unit (one percent) increases of level of access to assets causes an increase of HCI by 0.190 (19%). The results show that level of education has a standardized coefficient of 0.148 meaning that level of education is positively associated with average HCI and, coefficient is highly significant at 1%. A unit (one percent) increases of level of education causes an increase of HCI by 0.148 (14.8%).

The findings show that control of income has a standardized coefficient of -0.108 implying that control of income by one gender is negatively associated with average HCI and, coefficient is highly significant at 1%. A unit (one percent) increases of level of control of income by one gender causes a decrease of HCI by 0.108 (10.8%). According to results, control of assets has a standardized coefficient of -0.105 meaning that control of assets by one gender is negatively associated with average HCI and, coefficient is highly significant at 1%. A unit (one percent) increases of level of control of assets by one gender causes a decrease of HCI by 0.105 (10.5%). The findings show that decision making on dairy aspects has a standardized coefficient of 0.095 implying that there was a significant positive relationship between respondent’s decision making on dairy aspects, and the average HCI and, coefficient is highly significant at 1%. A unit (one percent) increases of level of decision making on dairy aspects by one gender causes a decrease of HCI by 0.095 (9.5%). The results indicate that ownership of land has a standardized coefficient of 0.026 implying that owning land is positively associated with average Household Commercialization Index and, coefficient is significant at 5%. A unit (one percent) increases of owning land causes increase of HCI by 0.026 (2.6%).

The results of regression analysis show that the independent variables (Gender participation) influence the average HCI at various levels. The R Square statistics (0.774) means that the ten independent variables (Gender Participation variables) in the regression model account for 77.4 percent of the total variation in the given HCI. The model fits data with a high significance.

**Gender Participation and Average Household Commercialization Index (HCI) Results**

The determined HCI results are indicated in figures 9-15 below:

(i) **Access to Knowledge and Technology**

The majority of the respondents (59.4%) were men alone accessing knowledge and technology and had an average HCI of 29%. 11.5% of the respondents who were women alone accessing knowledge and technology had average HCI of 26%. However, 29.1% of the respondents who were both men and women having access to knowledge and technology had the highest average HCI of 58% (Figure 9 below). The results therefore show that for higher HCI to be achieved in dairy farming, both gender should access knowledge and technology in increasing dairy production and access to markets for higher income. Until recently, women were usually excluded from variety of services such as access to inputs and they were neglected by agricultural extension services. In addition, some institutional arrangements such as market contractual agreements were exclusively for male-headed households.
This study finding is confirmed by results obtained by [Farinde et al., 2003] that one of the biggest challenges to the stakeholders involved in the process of agricultural transformation in Sub-Saharan Africa is the high percentage (70-80%) of women responsible for household food production. According to [5; 26], demand for modern technologies promotes the input side of production and facilitates the development and advancement of technological innovations. The use of modern technologies can result in higher productivity and production entering markets (Farinde et al., 2012). Farinde et al; 2009 found that specialized production leads to higher productivity through greater learning by doing, scale economies, exposure to new ideas through trade (better knowledge diffusion through exchange), and also better incentives in the form of higher income. The household-level technological changes can help to secure food self-sufficiency under a risky food-market environment. Limited knowledge and skills are the major issues affecting access to employment and income generating opportunities for both genders (Ele et al 2013, Kebebe et al., 2015, Omiti et al., 2006 and Tangka et al 1999).

The importance of resource-saving and high-enhancing technological innovations and their adoption by the ultimate users are unquestionable in smallholder commercialization process (Ezezika et al 2012), Taking Stock on IFAD Experience in Market Access Innovation and Opportunities to Favour Market Access for the Rural Poor. IFAD, 2013 and Jaleta, et al 2013]. Adopting a temporal perspective, (Tefera, et al ., 2010) argued that, in the short-run, increased commercialization could occur without change in agricultural technologies, but the inverse would be less likely due to the indispensable demand-side pull for technological innovations. The findings also conform to that of Smallholder Dairy Commercialization Programme Additional Financing: Updated Programme Design Report IFAD 2015 and Ochola et al 2003 that remoteness restricts access to information about technologies and changing prices, leaving the rural smallholders unable to respond to changes in market incentives. Limited knowledge and skills are the major issues affecting access to employment and income generating opportunities.

(ii) Access to Assets

The results show that 74% of respondents who were both men and women accessing assets had average HCI of 28%, whereas 4.9% of the respondents who were women alone accessing assets had average HCI of 23%. Furthermore, 21.1% of the respondents were men alone having average HCI of 24% (Table 10 & Figure 10 below). The involvement of both genders is crucial because the respondents are able to invest in dairy production jointly for higher dairy productivity and income. Men and women should all become agents of positive change and sustainable development in the society. Assets empower the rural poor and therefore highly vulnerable households are expected to have lower commercialization index. Relatively well endowed with agricultural capital have high potential of commercializing. The acquisition and ownership of productive assets can pave the way for household to participate in economic activities. Households with relatively higher production levels have higher probability of market participation and commercialization.
The results also conform to that of Heierli et al 2001 who argue that assets empower the rural poor by increasing their incomes and make them less vulnerable to shocks and the extent of vulnerability determines HCI. According to Jayne et al 2012 improving access to land among the land-constrained smallholder households would be a seemingly effective way to reduce poverty, as a very small incremental addition to land access is associated with a large relative rise in commercialization and consequently in income. Gebreselassie et al 2008 found out in their study that coefficient for land is statistically significant at 1% while the coefficient for oxen ownership is relatively high but significant only at the 5%. The result also conforms to those of (Berem et al 2011, Gebreselassie et al 2008, 29; 38).

(iii) Level of Education

According to HCI results, respondents (16.7%) with graduate level of training had the highest level of commercialization (69%), whereas 4.6% of the respondents with adult literacy education had the lowest commercialization level of 26% (Table 11 and Figure 11 below). The results show that HCI level increases with the increase of education levels. This is because the respondents with higher level of education are able to increase their dairy productivity through access to knowledge and technology, and access market through access to market information among others issues of marketing. Intellectual capital as captured by education is hypothesized to play a positive role in influencing market participation and HCI. Level of education gives an indication of the household ability to process information and causes some producers to have better access to understanding and interpretation of information than others. High education level is important, as it is likely to lead to the reduction of search, screening and information costs. Education also makes the producers to access market information and be able to engage in trade effectively. Education would significantly enhance producers’ ability to make accurate and meaningful decisions and level of education raises human capital and increases their level of managerial abilities which is an incentive for commercialization. Traditionally low education levels have posed a major barrier to entrepreneurship and access to technology.
Education is an important tool to escape poverty, but only if the education system reaches the right people with the right content Heierli et al., 2001. However, the expectation may be reversed when there are competing and more remunerative employment opportunities available in the area that require skills that are enhanced by more education Heierli et al., 20030. Gebresellassie, et al., 2008 found out in his study that coefficient for literacy of the household head is positive and significant, which implies a high probability of better production among farm households with an educated head. According to Rande et al., education would significantly enhance producers’ ability to make accurate and meaningful decisions. Randela et al 2006; Nyamanga et al 2008 also opined that level of education raises human capital and increases their level of managerial abilities which is an incentive for commercialization. Nmadu et al 2012 found out that educational status increased technical efficiency of birds’ production and HCI of commercial poultry farmers. Ele et al 2013, found out that on average a household head is married and has between 19 and 22 years of farming experience, and has had at least a primary school education, which indicates that they can at least read and write, an important factor in the commercialization of farming. There are some individuals who inherently have better skills and capabilities to do the implicit cost-benefit analyses required and apply their talents to quickly adapt to and exploit new opportunities Jaleta et al 2009. The result is also in line with those of Agwu et al 2012, Agwu et al 2013, Taking Stock on IFAD Experience in Market Access Innovation and Opportunities to Favour Market Access for the Rural Poor, IFAD 2013, Muhammad-lawal et al 2014, and Poulton et al 2008.

(iv) Control of Income

According to the HCI results, 26.7% of the respondents were both men and women controlling income and had the highest commercialization level of 68%, whereas 8.3% of the respondents were women alone controlling income and had the lowest average HCI of 25% (Table 12 & Figure 12 below). This is because the money generated and controlled by both men and women is reinvested in the dairy for increased productivity hence higher HCI. Whatever proportion of female labour is involved in dairy production, income from sales of milk is usually controlled by men.

![Figure 12: Control of income by gender](image)

[23], reported that the impact of smallholder commercialization on the gender dimension depends on the commodity’s gender specific labour demand and on who controls the income generated. The shift from staple maize to sugarcane production in Kenya and the Philippines was associated with a significant reduction in the percentage of women’s labour use in agricultural activities, from 50.5% to 1.2% in Kenya and from 9.1% to 2.5% in the Philippines Tefera et al 2010. However, in Guatemala, the shift from maize to vegetable production increased the proportion of women’s labour use from 6.1% to 21.5% Tefera et al... The finding conforms to that of Agwu et al 2012.

(v) Control of Assets

The results indicate that 16.8% of the respondents were both men and women controlling assets and had commercialization index of 52%. 8.3% of the respondents were women only controlling assets and had commercialization index of 23%. However, 74.9% of the respondents were Men alone controlling assets
and having average HCI of 25% (Table 13 and Figure 13 below). This is due to the fact that joint control of productive assets by both gender empowers them to increase the dairy productivity and access to markets hence increased HCI. The results are confirmed by those of Berem et al., 2011, Gebreselassie et al., Muhammad-lawal et al., 2014, Nguyen et al 2003, and Poulton et al., 2011.

![Figure 13: Control of Assets by Gender](image)

(vi) **Decision making on Dairy Aspects**

According to the results below, 16.4% of the respondents were both men and women making decision on dairy aspects and had commercialization index of 61%. 16.4% of the respondents were women alone making decision and had commercialization index of 21%. The 67.2% of respondents were Men alone making decision on dairy aspects and had average HCI of 24% (Figure 14 below). This is because women are also important agents in decision making on commercialization of smallholder dairy farming process. The findings are in line with those of Manfre et al., 2013 on reducing the gender gap in Agricultural extension and advisory services.

![Figure 14: Decision making on dairy aspects by gender.](image)

(vii) **Land Ownership**

According to the results, 52.5% of the respondents who own purchased land had higher commercialization index of 67%, whereas 44.5% of the respondents with family/inherited land had lower commercialization index of 20%. The 3% of the respondents with leased land had average HCI of 23% (Figure 15 below). This is because respondents who purchase land have high potential and capacity to maximally utilize the available land thereby obtaining higher productivity and HCI. The larger the size of arable land a household uses, the higher the production levels are likely to be, and the higher the probability of market participation and HCI.
Figure 15: Land ownership

Poulton et al., reported that access to arable land is a necessary condition for market participation. Gebreselassie, et al., found out that land and oxen, which could also be used as proxies for capital stock, are found to be important in explaining the variation in the level of production his sampled households. The coefficient for land is statistically significant at 1% whereas the coefficient for oxen ownership is relatively high but significant only at the 5% level. The findings are in line with those of Gebreselassie, et al., 2011, Hichaambwa et al., 2012, Nguyen et al., 2003 and Nyamanga 2008.

The HCI results for the Gender Participation range from 25% (subsistence) to 40% (semi-commercialized). This means most of the respondents are not commercialized due to the influence of their Gender participation. Hence there is need to address the influence of Gender Participation of smallholder dairy producers on commercialization of smallholder dairy farming in order to achieve sustainable development.

Conclusions and Recommendations

The study results show that Gender Participation of smallholder dairy producers has significant influence on commercialization of smallholder dairy farming. It is therefore recommended that the County Government of Uasin Gishu in consultation with policy makers; planners; smallholder dairy producers and other players in the dairy farming should address Gender Participation issues particularly through formulating policies, strategies, projects and programmes that may promote access to knowledge and technology, assets by both men and women for increased level of commercialization; enforce access to education to all citizens and ensure that all sexes have control of income and assets for increased commercialization; develop special programmes for women empowerment to access credit, land and appropriate technology.

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Rapid food security assessment among pastoral communities of northern Kenya

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Abstract

Food security assessments in Kenya have traditionally used the vulnerability approach. Although this approach has been able to identify households for food relief, the ability of the communities to withstand future shocks has not improved. This study uses the FAO food insecurity assessment model to identify key indicators of food security and these indicators are used for development of a rapid food security assessment tool. Under the FAO resilience model, food resilience indicators are broadly grouped as income and food access, access to basic services, social safety nets, assets, adaptive capacity and stability. A multi stage approach was used to sample 300 and 360 households in Mandera and Turkana Counties respectively. A questionnaire captured household socioeconomic characteristics and data on the broad food security indicators. Principal Components Analysis was used to identify key indicators that could be useful in identifying resilient households, and subsequently for computation of household resilience index. Analysis of these indicators using Principal Component Analysis established that diet diversity score, durable index and education level of household head were the most important indicators determining household food resilience. Efforts to build household resilience to food insecurity should therefore focus on increasing family incomes and literacy levels. These three indicators could also be useful in targeting non-resilient households that need support and evaluating resilience building interventions among pastoral households.

Key words: Pastoral households, Food security, Resilience, livestock

Background

Food security assessment studies have traditionally focused on vulnerability of a household to food insecurity. Although humanitarian support has helped save lives, especially in the Arid and Semi Arid Lands (ASALs), the ability of the communities to withstand future shocks have not been improved (USAID, 2011). It is for this reason that food security interests are now shifting to resilience approach. Resilience has been defined as ‘the ability of countries, communities and households to manage change, by maintaining or transforming living standards in the face of shocks or stresses- such as droughts, earthquakes or violent conflicts – without compromising their long term prospects (DFID, 2011). Building resilience of communities will help such communities cope positively with changes and hence avoid the negative impacts of future shocks.

Several models have been and are being developed in an effort to measure food security resilience (Ciani and Romano 2013; Collins, 2012; Vaitla et al (2012; Tulane and UEH 2012). In the Alinovi resilience model (Alinovi et al., 2008, 2010a and 2010b), resilience is a multidimensional latent variable which is estimated using cross-sectional household data from the Kenya Integrated Household Budget survey and from the Palestinian public perception survey respectively. Components used to compute household resilience index were social safety nets, assets, access to public services, income and food access, stability and adaptive capacity.
**Materials and Methods**

The study was carried out in Turkana and Mandera Counties, Kenya. Mandera is situated on the north-eastern part of Kenya and it borders Somalia and Ethiopia. It has three main livelihood zones: a pastoral economy zone on the eastern side of the county, an agro-pastoral economy zone on the western side and an irrigation zone on the northern end along the Daua River. Pastoralism is the main economic activity and is practised by 60% of the population. The County has an irrigation potential of 10,500 ha but only 6,500 ha are being utilized. Over 95% of households access their food through the market. Horticultural crops, especially water melons and bananas, are produced under irrigation. Some maize is grown but is usually sold as fodder. The recurring droughts have made most households food insecure as they lack the means to purchase food once they lose most of their livestock.

Turkana County is the largest County in Kenya, with a land area of 68,680 km$^2$. It borders Uganda to the West, Sudan and Ethiopia to the North, Samburu and Marsabit Counties to the East and to the South it borders Baringo and West Pokot Counties. The main socio-economic activity in the County is nomadic pastoralism. This is an activity that supports slightly over 60% of the County population.

Turkana County has been in constant need of food relief for the last two decades due to protracted drought episodes. In mid-2013, 111,500 people were under food relief programme. At the same time, the Ministry of health of the government of Kenya, World Food Programme (WFP) and World Vision (WV) were running Supplementary Feeding Programmes (SFP) targeting 9,985 children, under-five years of age and 7,015 pregnant and lactating mothers (Turkana LRA, 2013).

**Sampling procedure and data collection**

A multi stage approach was used to sample 300 and 360 households in Mandera and Turkana Counties respectively. Sub counties in the two counties were purposively identified based on predominant livelihood strategies pursued; whether pastoral, agro-pastoral or off-farm. For each livelihood zone, at least 3 villages per County were identified through a balloting process. The overall number of villages identified for the study was therefore 11 and 13 for Mandera and Turkana respectively. In each village, 30 households were systematically sampled from lists obtained from the local chiefs. Questionnaires were administered to the 660 households. The questionnaire captured household socio-economic characteristics and data on food security indicators broadly grouped as income and food access, access to basic services, social safety nets, assets, adaptive capacity and stability.

**Operationalization of food security indicators**

Indices for each of the six components of food security resilience were computed as follows:

**Income and food access**

This component was computed from five indicators:

- **Per person daily income, per person daily expenditure, Household Food Insecurity and Access Score (HFIAS),** as developed by Coates *et al* (2007), was computed from an aggregate of nine scores based on questions that attempt to assess three dimensions of food access: anxiety about being unable to access sufficient food, the inability to secure sufficient amounts of food and the experience of not having sufficient food intake. The HFIAS index was developed by summing up the scores of each response, per person daily calorific intake was obtained from computation of energy equivalents of foods consumed in the household per month and Diet Diversity Score (DDS) was obtained from summation of scores for the various food types consumed within a household using a 24-hour recall.
Access to basic services

Access to basic services component was derived from scores of perception on security, mobility and transport constraints and phone networks. For all the indicators, ordinal scores of 1, 2 and 3 were given for poor, fair and good respectively.

Social safety nets

This component was computed from three indicators:

- **Amount of cash and in kind assistance** in monetary terms,
- **Frequency of assistance** (a score of 1-6) and
- **Overall opinion of targeting** (score of 1 or 2) as either unfair or fair respectively.

Assets

The index for household assets was computed from:

- **Housing type index** (whether the house was modern or traditional),
- **Durable index** obtained by summing up all the various physical assets (plough, bicycle, radio, TV, pack animals) and
- **Tropical livestock units** (TLUs) owned by the household. The conversion factors used were 0.7, 0.1, 0.1 and 1.0 for cattle, goat, sheep and camel respectively (Tache and Sjaastad, 2010).

The conventional indicator for housing, which is number of rooms, was not used since a majority of pastoralists in both study sites are housed in traditional dwellings. The indicator for land size was also disregarded as pastoral land is generally communal.

Adaptive Capacity

Adaptive capacity index was computed from a combination of the following indices:

- **Diversity of income sources** that was computed as the sum of all the different sources of income to the household,
- **the number years spent in formal schooling by household head**,
- **the employment ratio** that was computed as the number of household members actively involved in some economic activities divided by the total number of household members and
- **Food consumption ratio** that was computed as amount of money spent on food divided by total household expenditure).

Stability

The index for stability was computed by considering the following:

- **The number of household members who had lost jobs within the previous six months**, 
- **Whether there had been change in income or expenditure** (1 for yes and 0 for no) and
- **The safety net dependency ratio** that was computed as the amount of money received under safety net programme divided by total household income.

The relevant indicators were identified by isolating those indicators that showed significant differences between Poor and non-Poor households.

**Computation of household food security resilience index**

Principal Component Analysis (PCA) was used to compute resilience indices of households, based on the nine relevant indicators that had been identified. PCA is a data reduction procedure that replaces a set of
correlated variables with a separate set of uncorrelated ‘principal components’ that represent unobserved characteristics of a population.

PCA of the nine indicators revealed that diet diversity score, durable index score and years of formal schooling by household head were the major determinants of household resilience level (Table 1). Based on the contribution of each indicator towards the overall household resilience level (% of variance in Table 1), the household resilience was computed as:

\[ R = 0.27353DDS + 0.14158DI + 0.12106 SYs \]

where DDS was the diet diversity score, DI was the durable index score and SYs was the number of years spent by a household head in formal learning institution.

**Discussion**

**Income and access indicators**

Dietary diversity score (p=0.001), per person daily expenditure (p=0.003) and per person daily income (0.030) showed significant differences between poor and non-poor households. Studies have established a strong association between household socio-economic status and dietary diversity score (Hatloy et al., 2000; Allan et al., 1991). More better off households had higher scores for dietary diversity. Dietary diversity score is also an indicator of nutrient adequacy of feed, especially among children and adults (Mirmiran et al., 2006) and has direct bearing on the nutritional quality of a diet (Hatloy et al., 1998; Ogle et al., 2001). Diverse diets are associated with improved health status (Hodgon et al., 1994). The per person daily expenditure also showed a significant difference between poor and non-poor households. Per person daily expenditure is also an indicator of household socioeconomic status. These two indicators are both strongly associated with household socioeconomic status, implying that an improvement of the latter would enhance household food security status. Improving household income would therefore have a great impact on enhancing household food security position. Per person daily expenditure also showed significant difference between Poor and non-Poor households. This is expected as Poor households, being better off, are able to incur higher expenditure compared to non-Poor households.

The score for food insecurity and access score did not vary significantly between poor and non-poor households. Pastoral areas access their food through the market and food relief. In pastoral areas, relief food is distributed to almost all households, irrespective of the actual need.

**Assets**

Durable index is a measure of the ability of a household to accumulate assets. Poor households were therefore expected to have more assets, hence a higher durable index score. The durable index thus came out as an important indicator of identifying poor households. Assets are an important determinant of household resilience as they help to buffer households against unexpected shocks, since they can be liquidated for cash to procure food during difficult times. Since durable index is directly related to household income, it implies that improved household asset accumulation is an indicator of household welfare. When a household is able to accumulate assets, it is assumed to be poor as asset accumulation can only happen once a household has met its basic food requirements.

**Adaptive capacity**

The level of education of the household head influenced the ability of a household to adapt and take up alternative livelihoods in the face of a shock. Weir and Knight (2000) have discussed the link between education and adoption of agricultural innovations. It is observed that the more literate individuals are able to innovate more or learn from innovators faster than the less literate individuals. They are also able to take up more remunerative off-farm activities as compared to the less literate individuals.
**Household Resilience index**

Among the identified nine resilience indicators for pastoral households, three were key in ensuring household food resilience. These were diet diversity score, durable index and years of formal schooling of household head. These three indicators could explain 54% of change in resilience index score of a household.

Both the diet diversity score and durable index score are proxy indicators of household income, as households with more income will likely have superior diet diversity and durable score index scores. Interventions that increase household income will therefore have a greater impact in improving household resilience to food insecurity.

**Conclusion**

Principal Component Analysis established that diet diversity score, durable index and education level of household head were the most important indicators determining household food resilience. These indicators could be useful and targeting non-poor households and evaluating performance of resilience building interventions among pastoral households.

**Recommendations**

The significant indicators were all proxy indicators of household socioeconomic status, accessibility to basic services and literacy levels. Resilience of pastoral communities in general could be improved through increased household incomes, improved accessibility to basic services and education. A food resilience index obtained using dietary diversity score, durable index and education level of household head would be more appropriate for use in Kenya’s pastoral areas for monitoring progress of projects or programmes on pastoral food security resilience. Targeting of needy pastoral households for food relief interventions has been a challenge as the individuals tasked with the responsibility of identifying such households are blamed for favouring less deserving households while ignoring cases that may be more deserving. In the absence of an objective test to establish the truth behind such allegations, an outsider will be powerless to intervene without being blamed for undermining the community relief committees. The derived resilience index formular will therefore form a basis of validating the authenticity of lists of households identified for food relief support through community relief committees.

**References**


Tulane University and State University of Haiti (2012). Haiti Humanitarian assistance Evaluation. From a resilience perspective. Tulane University Disaster Resilience Leadership Academy.


### Table 1: PCA output of relevant resilience indicators

**Total Variance Explained**

<table>
<thead>
<tr>
<th>Component</th>
<th>Initial Eigenvalues</th>
<th>Extraction Sums of Squared Loadings</th>
<th>Rotation Sums of Squared Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>% of Variance</td>
<td>Cumulative %</td>
</tr>
<tr>
<td>Diet diversity score</td>
<td>2.462</td>
<td>27.353</td>
<td>27.353</td>
</tr>
<tr>
<td>Durable index</td>
<td>1.274</td>
<td>14.156</td>
<td>41.508</td>
</tr>
<tr>
<td>Per capita income</td>
<td>.947</td>
<td>10.527</td>
<td>64.140</td>
</tr>
<tr>
<td>Per capita expenditure</td>
<td>.824</td>
<td>9.156</td>
<td>73.296</td>
</tr>
<tr>
<td>Safety net dependency</td>
<td>.703</td>
<td>7.815</td>
<td>81.112</td>
</tr>
<tr>
<td>How do you rate the road network in the area?</td>
<td>.659</td>
<td>7.323</td>
<td>88.434</td>
</tr>
<tr>
<td>Number of members of household that had lost jobs in the previous six months</td>
<td>.550</td>
<td>6.106</td>
<td>94.540</td>
</tr>
<tr>
<td>Change of income over previous last six months</td>
<td>.491</td>
<td>5.460</td>
<td>100.000</td>
</tr>
</tbody>
</table>

Extraction Method: Principal Component Analysis
Analyzing the role of development agents in cushioning the pastoral communities of Isiolo County against the effect of climate variability

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Abstract

Climate variability is a natural phenomenon and of late it is becoming more frequent and more intensive especially in the Arid and Semi-arid Lands (ASALs). This has affected the livelihoods and the coping strategies of the pastoral communities of the ASALs. As a result of this there was need to conduct a study and assess the type of development agents existing in the region and the type of assistance they provided. To achieve this objective, this study applied household interviews, focus group discussions and key informant interviews to collect data. Quantitative data was analysed using the SPSS software and descriptive statistics to give frequencies and percentages. The study findings revealed that there are various development agents which assists the pastoralists of Isiolo, namely, Government Departments, NGOs and Faith based organizations. Type of assistance given included, resettlements, medicine, restocking, destocking, subsistence funds for the old people, relief foods and livestock feeds. The study findings also indicate that the assistance given was inadequate and this was attributed to poor leadership, selfishness and marginalization. In most cases inappropriate interventions were put in place such as providing maize to the community when what they really needed was livestock for restocking. For the pastoralists of Isiolo County to benefit from development agents there is need for proper coordination of development agents assisting livestock communities. There is also need for government departments, NGOs and faith-based organizations to ensure full engagement and effective participation of the local communities in the conception, design and implementation of sustainable solutions to reverse the effects of climate variability.

Introduction

Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. IPCC (2007) gives indicators of climate variability as extended droughts, floods, and conditions that result from periodic El Niño and La Niña events. According to Apata and Adeola (2009), the African continent is the most affected by the adverse climate change which is manifested by increased droughts, floods, windstorms and other extreme climate phenomena. In Kenya there are various indicators of climate variability which include erratic rainfall patterns, persistent droughts and vanishing glaciers on Mt Kenya (Kanywithia, 2010:5). The most affected areas in Kenya by climate variability are the arid and semi-arid lands. Omosa (2005:7) stated that these areas constitute 80% of Kenya’s land mass and support 70% and 25% of the nation’s livestock and human populations, respectively. As climate change looms globally, extreme weather events have already impacted on the pastoralist’s livelihoods in significant and uncertain ways as is the case in Isiolo County. According to Sergine and Verchot (2006:9) pastoral communities living in the predominant arid and semi-arid districts of Kenya are bearing the brunt of adverse consequences particularly food insecurity due to droughts, floods and livestock diseases.

Natural disasters such as drought, floods, earth quakes and storms are not new to the arid and semi-arid areas. Traditionally, pastoralists have used indigenous coping strategies to address these disasters. Their coping mechanisms appear to have worked well since time in memorial but recent studies have shown that
climate variability has weakened their coping strategies. This led to the emergence of this study which aimed at assessing whether livestock communities are accessing external assistance and the type of assistance offered.

In order to achieve this, the study sought to answer the following questions:

i) Which are the development organizations involved in assisting the Borana community in the study site?

ii) What type of assistance is provided by the development agents?

iii) What is the Borana attitude to the assistance provided by the communities?

Materials and methods

Study site and unit of analysis
This study took place in Isiolo Central which is a Sub-County of Isiolo County situated in northern Kenya. The study focused only on the Borana community because it is the largest community in the County, although there are other small communities. This being the case the study was concentrated in the areas occupied by the Borana Community. The unit of analysis was the individual man and woman household.

Sample size and sampling procedure
This study applied both random and non-random sampling strategies. In selecting the study site simple random sampling technique was applied whereby the names of the three Isiolo sub-Counties were written on pieces of paper which were folded several times. The pieces of paper were then put in a container which was shaken before the researcher picked one of them. This happened to be Isiolo Central. Three villages were selected purposively with the help of the local provincial administration who assisted the researcher to identify the three villages which were occupied by the Borana community.

To get a representative sample size this study used a formula used by Mugenda and Mugenda, 1999. The accessible population in this study was 4000 households to be used to calculate sample size. Mugenda and Mugenda recommend the formula:

\[ nf = \frac{n}{1 + \frac{n}{N}} \]

Using the above formula sample size is:

\[ nf = \frac{384}{1 + \frac{384}{4000}} = 350 \]

To cater for those households that would decline to participate or drop out during the process of investigation, the study proposed a sample size of 400. Systematic sampling was applied to select households for the interview. The sampling interval was determined by the equation given below.

Where:
- \( n \) = required sample size
- \( N \) = Population size
- \( n = 400 \)
- \( N = 4000 \)
- (i.e., 1 in 10)
Data collection methods

Household interviews

Household interviews were conducted with household heads, male or female, through the administration of a questionnaire to the respondents. The interviews were conducted in Borana local language by enumerators who were from the community. The enumerators were recruited and trained before the actual collection of the data took place. Where a household identified for the interview and the head was not present at the time of the visit, effort was made to revisit the household until one of them was found and interviewed. The questions answered by household heads were on the external agencies assisting the pastoralists to cope with various disasters, type of assistance given, whether the assistance given is satisfactory or not.

Focus group discussions

The researcher had initially anticipated to conduct three focus group discussions but it was not possible due to insecurity. Therefore, only two focus group discussions were conducted and each group had 10 participants who were selected purposively. Each group had men and women who were above 45 years of age. The issues discussed included development agents existing in the region, type of assistance given and pastoralists’ attitude towards the assistance offered.

Key informant interviews

Key informants were selected purposively and the focus was on those informants with rich information on the topic and who were willing to share the information which they had, in order to increase the scope or range of the data. A total of 12 key informants were interviewed, which included chief’s representative of various villages, Senior chief Isiolo Central, a biometrician EDA, project coordinator food for the hungry, Livestock officer, Agricultural officer, project coordinator Arid-lands, Kenya forest service officer, water and irrigation officer and NALEP officer.

Data processing and analysis

Data obtained from focus group discussions and Key informants were sorted out and interpreted in relation to the research general objective. On the other hand, quantitative data derived from the household interviews were edited, coded and analysed using the Statistical Package for Social Sciences (SPSS) software version 20 spreadsheet. Descriptive statistics were run to give frequencies and percentages.

Research Findings

Organizations that give assistance to the Borana pastoralists

The findings of this study indicated that there are organizations that assisted the community during times of calamities. They include government departments, NGOs and faith-based organizations. The organizations were ranked according to their level of involvement and contributions. A majority (70%) of the respondents said that government departments were highly involved in offering assistance to the respondents whenever they were faced with the negative effects of climate variability. They were followed by 26% who ranked NGOs as the second. Faith-based organizations had 3%, while 1% of the respondents said that there were no agents which assisted them. Figure 1 gives the external agents which assist the respondents when faced with natural calamities.
Figure 1: Institutions and organizations and assistance offered during calamities

The type of assistance given by government institutions and other organizations

Figure 2 below shows the type of assistance respondents got from the external agents. Half (50%) of the respondents suggested that they were given relief food and feeds for livestock. This was mainly done by the government whenever there were droughts and floods. On the other hand, 22% indicated that they were given medicine, while 17% respondents stated that they were relocated whenever there were floods and ethnic conflicts. Other (7.5%) respondents said that destocking and restocking as other forms of assistance given. Destocking programmes were initiated by the government during the time of droughts to avoid massive losses of livestock. Key informants reported that after severe droughts pastoralists were given a few livestock to build a herd. Government departments including Arid-lands, Ewaso Nyiro Development Authority (EDA) and NGOs were reported as being involved in restocking initiatives. Another 2.5% of respondents stated that subsistence funds are given to the elderly, while 1% indicated that no assistance was given.
Respondents’ attitudes towards assistance given

The study findings suggest that the government, NGOs and faith-based organisations had made efforts to assist the Borana pastoralists whenever they were faced with negative effects of climate variability. Figure 3 below shows that a majority (60%) of the respondents stated that the type of assistance they got was not enough. According to the respondents, the food given was very little, was never available on time and sometimes it was given after three months. The other problem was that the assistance given sometimes never reached the intended beneficiaries. Relief food was usually intended for the very poor but in many cases the largest share ended up in the hands of the rich. Thirty per cent of the respondents said that the type of assistance given was good, 8% indicated that the NGOs were not doing much while 1% said that no assistance was ever given.

![Respondents’ attitudes towards assistance given](image)

Figure 3: Respondents’ attitudes towards assistance given

Adaptive strategies not implemented on a large scale

Study findings indicates that there were some important adaptive strategies which were not implemented on a large scale. Figure 4 below shows that 39% of the respondents gave water harvesting technologies, 36% talked of restocking programmes, and 18% listed irrigation and agricultural inputs. On the other hand, 3% of respondents said security is not given attention it deserves, and 2% said planting of trees. Lastly, 2% of the respondents talked of unemployment. One of the key informants suggested that if a slaughter house was constructed in Isiolo County, it would save livestock losses which are encountered by pastoral communities while waiting for the Kenya Meat Commission (KMC) to buy their livestock when they are on the verge of death.
Respondents’ perceptions of why some adaptive strategies were implemented on a limited scale

Various reasons were given by respondents regarding why some suitable adaptive strategies were not implemented on a large scale included lack of representative when important decisions were being made. This was stated by 40% of the respondents. On the other hand, 22.3% of the respondents said that this was due to poor leadership and management of government institutions and organizations. They also stated that most of the development agents were corrupt and concentrated on buying vehicles and initiating projects which were not beneficial to the local communities. Another 17.8% of the respondents stated that they were not consulted when development agents were initiating projects. This means development agent used the top-bottom approach when trying to solve climate variability-related problems which is a wrong approach in project implementation. Twelve per cent of the respondents stated that pastoralists were marginalized and that their views were not taken into consideration. Another 6.8% of the respondents stated that leaders were not from Isiolo County, and so they were not well versed with the local communities’ priorities. Finally, 1.1% of the respondents said that people were not united hence they were not in a position to present their grievances with one voice.

The most suitable organization to initiate adaptive strategies

Figure 5 below shows that the government was ranked highly (75%) as the most suitable agent to initiate suitable adaptive strategies against the negative effects of climate variability in the study area. Twenty-per cent of the respondents indicated that NGOs were the best suited, while 5% said that the community was the best suited.
Conclusion and Recommendations

The findings of this study indicated that there are development agents which assist livestock keepers whenever they are faced with climate related disasters. However, most people felt that they were not getting enough of this assistance since the development agents promote short term initiatives instead of promoting long-term structural development that would reduce the vulnerability of the local communities. They tend to focus on food relief and this offers short-term solutions to crises and also keeps the local community in a chronic state of dependency. The findings of this study also suggest that development agents have not implemented some important adaptive strategies in the study area on a large scale. These strategies include water harvesting technologies, restocking and destocking, irrigation, handling security issues, planting of trees and offering employment. This is attributed to poor leadership, selfishness and marginalization. This means that development agents working in the study area lack coordination and they also emphasize their own views concerning adaptive strategies relating to climate variability. In most cases inappropriate interventions were put in place such as providing maize to the community when what they really needed was livestock for restocking.

There is need for proper coordination of development agents assisting livestock communities in Isiolo County. There is also need for government departments, NGOs and faith-based organizations to ensure full engagement and effective participation of the local communities in the conception, design and implementation of sustainable solutions to reverse the effects of climate variability.

Reference


Does mineral supplementation affect quality of camel (Camelus dromedarius) milk? The case of north eastern region of Kenya

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Abstract

A study was carried out in Bangali - Tana River County and Bute - Wajir County Kenya, to assess effect of mineral supplementation on the level of iron, zinc, selenium and vitamin A in camel milk. Design of the experiment was Balanced Randomized Complete Block (BRCBD) with factorial arrangement of the treatments. The two sites represented blocks. Treatments were at three levels i.e. { (Chumvi Kuria – CK, a mineral formulation for camels containing calcium, phosphorus, potassium, magnesium, iron, copper, zinc, cobalt), (Chumvi Kuria+selenium - CK+Se, a variant of CK containing selenium) and, the control }. Each camel was individually fed 200g/day of either CK or CK+Se every morning over a period of 90 days with a 7-days acclimatization period at the beginning. Milk samples for mineral analysis were taken at beginning of the experiment and thereafter once at end of every month and delivered to laboratory where iron, zinc and selenium were analyzed using Atomic Absorption Spectrophotometer (AAS) while vitamin A was analyzed using High Performance Liquid Chromatography (HPLC). Two way analysis of variance was used to analyze effect of treatments on iron, zinc, selenium and vitamin A while mean separation was done using least significant difference (LSD). The treatments did not significantly influence the level of iron in the milk from one month to the other although the CK+Se exhibited higher influence than CK. There was a general downward trend for zinc thought to be a result of negative interaction with selenium observed to increase over time with supplementation. The mean monthly difference for zinc was not significant at 0.05 level. Selenium concentration in the milk was positively influenced by supplementation although the treatment differences were not significant at 0.05 level. A downward trend for vitamin A was observed. However, the mean monthly difference was not significant at the .05 level. The study concluded that supplementation with both CK and CK+Se positively or negatively influenced concentration of the mineral elements and also vitamin A with the overall concentration remaining within the acceptable level for quality camel milk.

Keywords: Mineral analysis, Iron, Zinc, Selenium, Vitamin A, Human health

Introduction

Camels play a key role in the livelihood, investment and food security in northern Kenya by providing milk, meat and trade opportunities based on these main products. Most of the pastoral communities in northern Kenya depend on camel milk for survival due to the ability of camels to thrive and continue supplying milk in very dry periods when other livestock species are unable. Camels usually consume thorn and hard plants containing minerals. Studies by El-Agamy (2006, 2009), Hashim et al. (2009), Konuspayeva et al., (2011), Ahmed et al., (2014) have reported that the amount of calcium, magnesium, phosphorus, sodium and potassium of camel milk is higher than in the bovine. Iron is reportedly about 10 times more than bovine milk. Copper levels are also higher in camel than bovine milk. Other studies revealed that camel milk has anti-diabetic property due to the presence of special protein like insulin (Zagorski et al., 1998; Agrawal et al., 2007) as well as antioxidant and antimicrobial capacities (Salami et al 2010). The minimum adult human daily requirement for calcium or phosphorus is easily provided by 2.5 and 4 cups of camel milk, respectively (El-Agamy, 2009). According to Akbar (2014), one kg of camel milk meets 100% of daily human
requirements for calcium and phosphorus, 57.6% for potassium, 40% for iron, copper, zinc and magnesium, and 24% for sodium. Camel milk is thus very important in the diet of humans. However, milk production in camels is low due to the fact that camels depend on the generally low quality natural vegetation with no or minimal supplementation with proteins, energy and minerals. Furthermore, mineral deficiencies in northern Kenya camels which not only affect quantity but also quality of milk produced has been reported (Kaufman, 1998; Kuria et al., 2004; Onjoro et al., 2004).

The study objective was to assess effect of mineral supplementation on the level of iron, zinc, selenium and vitamin A in camel milk.

Methodology

The study was carried out in Bangali in Tana River County and Bute in Wajir County. A previous study (Kuria et al., 2012) had shown that Bangali and Bute differed in terms of mineral concentration in the key forage species for camels. Further, the areas differed in terms of soils with Bangali having a mixture of sand and the red soils while Bute was predominated by sandy soils. The two sites were therefore considered as blocks in designing the field experiments.

The experimental camels were females between 1st and 7th month of lactation, within the 1st to 4th parity and not pregnant. The experimental design was Balanced Randomized Complete Block Design (BRCBD) with factorial arrangement of the treatments. The design was balanced in the sense that for all the treatments, the observations were equal. The factors were two i.e. site at two levels (Bute and Bangali) and treatment at three levels {(CK, a mineral formulation for camels containing calcium, phosphorus, potassium, magnesium, iron, copper, zinc, cobalt), (CK+Se, a variant of CK containing selenium) and, the control which did not receive anything}. Each treatment was replicated five times where individual camels (5 No.) assigned to each treatment were the replicates. Each site represented a block. Individual camels under a treatment represented the sampling units. In allocating camels to the treatments, similar camels in terms of parity were grouped together to control confounding factors. The parity and lactation stage of each camel were recorded at commencement of the experiment as part of baseline data.

Each camel was individually fed 200g/day of either CK or CK+Se every morning over a period of 90 days with a 7-days acclimatization period at the beginning. Milk samples for mineral analysis were taken at beginning of the experiment and thereafter once at end of every month. The milk samples were delivered to Good Manufacturing Practice Services Ltd (GMP), an accredited private laboratory in Nairobi Kenya, for analysis. The milk samples were analyzed for Fe, Zn, Se and Vitamins A, considered critical for human health. The minerals were analyzed using Atomic Absorption Spectrophotometer (AAS) while vitamin A was analyzed using High Performance Liquid Chromatography (HPLC) (Meyer, 2013).

Statistical Analysis

The effect of treatments on iron, zinc, selenium and vitamin A (month by month analysis) was done using two way (factors: months and treatments) analysis of variance while LSD was used to separate the means. Note that in running the statistical analysis as well as drawing of charts, data for week one was ignored as this was collected during the acclimatization period.

Results and Discussion

Iron

For the element iron, Figure 1 illustrates the treatments trend during the 3 month period. The month and treatment were not significant i.e. the treatments did not significantly influence the level of iron in the milk although the CK+Se exhibited higher influence than CK. There was no clear pattern of the response as the level of iron in milk appeared to drop initially and rising towards end of the experiment for all treatments.
This finding contradicted Alwan et al., (2014) in Libya who reported that animal feed is an effective factor on the amount of iron in camel milk. The level of iron in the milk was however within the range reported by Nnadozie et al., (2014) and Ibrahim and Khalifa (2015) i.e. 0.1 to 0.28 ppm. However, the amount of iron in this study was lower than 0.7 to 3.7 ppm reported by Kappeler (1998), Konuspayeva et al., (2008) in Kazakhstan, Shamsia (2009) in Egypt and El-Agamy (2009).

![Iron concentration in milk](image)

**Figure 1:** Monthly iron concentration in camel milk for both sites during the experimental period.

**Zinc**

There was a general downward trend for zinc but it was difficult to attribute the downward trend for control camels to the treatments. Zinc interacts with selenium and both positive and negative interactions between these two elements have been reported (Brätter et al., 1997; Faye et al., 2014). While Brätter et al., (1997) reported a negative correlation, Faye et al., (2014) reported that Zinc concentration in milk was positively correlated to selenium content. In this study, selenium was observed to increase over time with supplementation while zinc declined. The results were therefore in agreement with Brätter et al., (1997) but in conflict with Faye et al., (2014). The level of zinc in the milk was within the range reported by Ibrahim and Khalifa (2015). The mean monthly difference was not significant (p>0.05). However, the level of zinc in this study was much lower than the 1.48 to 5.0 ppm reported by Kappeler (1998), Al-Wabel (2008) in Saudi Arabia, Shamsia (2009) in Egypt, El-Agamy (2009), Al Haj & Al Kanhal (2010), Alwan et al., (2014) in Libya and Nnadozie et al., (2014) in Nigeria.
Figure 2: Monthly Zinc concentration in camel milk for both sites during the experimental period

Selenium

Selenium concentration in the milk was within level reported by Faye et al., (2011). The selenium concentration in the milk was positively influenced by supplementation (Figure 3) as exemplified by the positive coefficients in the equations for CK+Se and CK in agreement with earlier reports by Al-Awadi and Srikunar (2001), Seboussi et al., (2009) and Faye et al., (2011). Faye et al., (2014) also reported significantly higher Se concentration in the milk of supplemented than in control group of camels. Although no selenium was directly incorporated in the CK, it exhibited the strongest positive effect on the concentration of Se in milk. The negative coefficient for control camels suggest that selenium was getting depleted in the body system with advancing lactation. The treatment differences were however not significant (p>0.05).

Figure 3: Monthly selenium concentration in camel milk for both sites during the experimental period
Vitamin A

A downward trend for vitamin A was observed affecting all the groups making it difficult to attribute the trend to the treatments. However, the mean monthly difference was not significant at the 0.05 level. The level of Vitamin A in the milk was lower than 0.38 ppm reported by Ibrahim and Khalifa (2015).

![Graph showing monthly vitamin A concentration in camel milk.](image)

**Figure 4:** Monthly vitamin A concentration in camel milk Treatment for both sites during the experimental period

Conclusion

Supplementation with both CK and CK+Se did not affect concentration of the mineral elements of interest in camel milk. With exception of vitamin A, the trends were similar to what had been reported earlier. Most importantly, the overall concentration remained within the acceptable level for quality camel milk.

Recommendation

Based on the findings of this study, it is not possible to say that quality of camel milk can be out lighty improved through direct supplementation of the camel diet with minerals seemingly due to other factors that come into play. However where supplementation has to be done, feed manufacturers should avoid incorporating mineral elements known to negatively interact with each other as the potential benefits may not be realized.

Acknowledgement

The team highly appreciate the EU/GoK for funding the study through the Arid and Semi-Arid Lands (ASAL) – Agricultural Productivity Research Project (APRP). The team treasure the facilitation of field activities by the National Project Coordinator and Institute Director, Sheep and Goat Research. Further, the team sincerely regard the support by office of Chief, Bute-Wajir and Bangali-Tana River counties who unreservedly assisted in identifying owners of the camel herds and the field research assistants to work with. Finally, the team cannot afford to ignore the cooperation by the camel owners which made the trials and field data collection possible.
References


Browse Forage Mixtures for Goat Feeding in Kenya: Effects on Performance

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Abstract

The study was conducted to determine the effect of supplementing browse forage mixtures on the performance of growing small east African goats. Two browse forage mixtures comprising of Acacia brevispica, A. nilotica, A. mellifera, Zzyphus mucronata and Berchemia discolor were formulated and offered at two levels (20% and 40% intake) to twenty goats. T1. Basal diet (Rhodes grass hay) ad libitum (control), T2. Control plus 20% of B. discolor, Z. mucronata, A. mellifera and A. nilotica mixture, T3. Control plus 40% of B. discolor, Z. mucronata, A. mellifera and A. nilotica mixture, T4. Control plus 20% of Z. mucronata, A. brevispica, A. mellifera and A. niloticamixture, T5. Control plus 40% of Z. mucronata, A. brevispica, A. mellifera and A. niloticamixture. The feed intake and weight change of the goats were monitored. The intake of the basal diet increased with supplementation with the browse forage mixture which also translated into increased total dry matter intake. The goats consuming the control diet had the lowest total dry matter intake (357.8 g/day). The live weight change varied among all the treatments. The goats consuming the control diet lost weight (-16.7 g/day) during the experimental period. The goats consuming the diet with 40% supplementation with browse forage mixture 2 gained the most (P<0.05) weight (42.3 g/day) while those supplemented with 20% of browse forage mixture 2 and 40% of browse forage mixture 1 had similar (P>0.05) weight gain but which was lower than those consuming 40% of browse forage mixture 2. The results of this study shows that supplementation of growing goats fed on poor quality basal diet with browse forage mixtures improves the performance of the goats.

Keywords: Browse, goats, growth, supplementation

Introduction

The browse foliages found in the Kenya’s arid and semi arid lands together with other tropical areas has been found to contain high levels of protein, vitamins and mineral elements (Bamikole et al., 2003) which is higher than levels in most grasses. Locally available and low-cost browse foliages can be harvested and utilized as protein supplement to improve small ruminants’ productivity during these critical periods of the year (Osuga et al., 2012). When goats are allowed to browse freely in the rangelands, they selectively feed on mixture of browse foliage trees and shrubs. The intake of the browse foliages as a mixtures leads to a diverse supply of nutrients as compared to when the animals are restrained to one type of foliage. This reduces dependence on a single species of the foliage and alters type and number of rumen microorganisms (Wambui et al., 2012). It has also been observed that when ruminants consume a variety of browse foliages, this does not only extend the choice of available feeds but also dilutes levels of antinutritional factors in the foliages thereby increasing the palatability of the feeds. However, most past efforts have concentrated on assessing individual browse forages for use in supplementary feeding of ruminants especially small ruminants. Therefore, the aim of this study was to investigate the effect supplementing browse forage mixtures to growing goats fed on low quality basal diet on their growth performance.

Materials and Methods

Study site: This study was conducted at the School of Agriculture farm, Kenyatta University, located at an altitude of 910m above sea level. The area receives an average annual rainfall of about 1100 mm
**Feeds and Treatment diets:** Two browse forage mixtures were formulated based on availability of the browse forages and palatability. The mixtures comprised of the following 1) *B. discolor, Z. mucronata, A. mellifera, A. nilotica* mixture, 2) *Z. mucronata, A. brevispica, A. mellifera* and *A. nilotica* mixture. Rhodes grass hay was used as a basal diet. The treatment diets were:

1. T1. Basal diet (Rhodes grass hay) *ad libitum* (control)
2. T2. Control plus 20% of *B. discolor, Z. mucronata, A. mellifera* and *A. nilotica* mixture
3. T3. Control plus 40% of *B. discolor, Z. mucronata, A. mellifera* and *A. nilotica* mixture
4. T4. Control plus 20% of *Z. mucronata, A. brevispica, A. mellifera* and *A. nilotica* mixture
5. T5. Control plus 40% of *Z. mucronata, A. brevispica, A. mellifera* and *A. nilotica* mixture

**Animal and Experimental design and protocol:**

Twenty male Small East African goats about 1 year old; mean body weight 17.3 kg were randomly assigned to experimental treatments and pens in a completely randomized design (four animals per treatment). The goats were allowed to acclimatize to the premises, treatment diets and the prevailing weather conditions for two weeks. The animals had access to clean water and commercial mineral block *ad libitum* throughout the experimental period. Weekly weight change was determined by weighing the goats for two consecutive days on a weekly interval at 08:00h before the animals accessed feed or water. The data was collected for 10 weeks. All the data were analyzed to determine the significance between treatment means and significant means were separated using Tukey procedure at *P*<0.05 level.

**Results and Discussion**

The results on the DM intake and live weight gain (LWG) of the growing goats are summarized in Table 1.

**Table 1.** Mean DM intake (g/day) and live weight gain (LWG)(g/day) of growing goats

<table>
<thead>
<tr>
<th>Treatments</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>T5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage mixture</td>
<td>-</td>
<td>78.9</td>
<td>158.4</td>
<td>80</td>
<td>154.5</td>
</tr>
<tr>
<td>Hay</td>
<td>317.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>286.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>250.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>281.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>263.4&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Maize Bran</td>
<td>40.1</td>
<td>40.1</td>
<td>40.1</td>
<td>40.1</td>
<td>40.1</td>
</tr>
<tr>
<td>Total</td>
<td>357.8</td>
<td>405.8</td>
<td>448.6</td>
<td>401.9</td>
<td>458</td>
</tr>
<tr>
<td>LWG</td>
<td>-16.7&lt;sup&gt;d&lt;/sup&gt;</td>
<td>7.15&lt;sup&gt;c&lt;/sup&gt;</td>
<td>17.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>19.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>42.3&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Means with different superscript in a row differ significantly (*P*<0.05)

The goats consuming the browse mixture supplements consumed significantly (*P*<0.05) more roughage than the control goats. However, the lower level of supplementation had more intake of the basal diet than the higher level of supplementation, which implies some substitution effect by the browse mixtures. Overall, the total dry matter intake improved with supplementation with higher levels of supplementation (40%) having more dry matter intake.

The low DM intake in the control group could have been as a result of high fiber content of the diet (638.4g/kg DM) this concurs with studies by Abdulrazak *et al.*, (1997) that supplementation of low quality diets improve intake of the basal diet. Browse are also higher in protein which may improve microbial growth in the rumen thus increase rate of fibre digestion. The findings are in support of work by Wambui *et al.* (2010) that feed intake and growth performance differ significantly between browse foliage mixtures when fed to ruminant livestock as a basal feed.

The weight gain by the goats differed significantly (*P*<0.05). Goats supplemented on mixture 2 (T4 and T5) at 20% and 40% had significantly (*P*<0.05) higher live-weight gain (LWG) of 19.1 and 42.3 g/day respectively, followed by the goats consuming mixture 1 (T3) at 40% (17.1g/day). The goats feeding on T2
had the lowest weight gain, while those without browse supplement lost weight (-16.7g/day) during the experimental period. However there was no significant (P<0.05) difference in LWG between T3 and T4, though animals on T3 consumed higher levels (158.4gDM) of the mixture (1). Though T3 had higher CP than T4, (173.3 and 165.6 g/kg DM respectively), LWG in T4 was higher. This could have been due to low tannins levels of 20.2 and 34.8g/kg DM in B. discolor and Z. mucronata foliages respectively (Osuga et al., 2012), which constituted 50% of T4.

Conclusion

Supplementation of low quality basal diet with browse forage mixtures has beneficial effects on the growth performance of growing goats. Harvesting and mixing of the browse forages might be a sustainable way of utilizing the browse forages found in marginal areas of Kenya with improved performance of animals when they are offered as supplements to low quality lignified feeds which is common during the dry periods.

Acknowledgement

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References


Evaluation of spineless Cactus (Opuntia ficus indica) and Prosopis juliflora-based rations as alternative feed resources for small ruminants in Kenya

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Abstract

Marginal areas are characterized by fluctuations in the quantity and quality of feed resources due to rapid lignifications of forage materials as a result of extreme temperatures and water stress exacerbated by climate change. Cactus and Prosopis spp are drought tolerant, and thus can be a potential feed resource in dry lands to sustain livestock productivity. Cactus (Opuntia ficus indica) is rich in energy, while prosopis spp is a good protein source for livestock. This study was aimed at determining the optimum level of their inclusion in a ration as indicated by animal performance. In-vitro nutrient digestibility was determined using a rumen fermenter in a closed system, with four test diets incubated separately. The diets were; (A) 100% Cenchrus ciliaris grass hay as basal diet (as control ). (B) 80% C. ciliaris hay + 20% wilted spineless cactus forage, (C ) 50% C. ciliaris hay + 20% spineless cactus + 30% Prosopis leaf meal, (D) 50% C. ciliaris hay + 20% spineless cactus + 30% Prosopis pods meal. In in vivo rumen fermentation, sixteen red maasai weaner lambs, 4 months old, with an average initial live weight of 13 kg (± 2.6) were used in the study comprising feed intake and nutrient balance trials. The sheep were blocked by weight in a randomized complete block design (RCBD). Within each block, the animals were randomly allocated to the 4 treatments, with 4 animals each as replicates. The results of this study indicated that the lambs receiving Prosopis pods-based rations (T4) consumed higher amounts of feed as compared to those fed other rations (T3, T2 and the control diet, T1). There were no significant differences in feed intake between lambs fed Prosopis leaf meals and spineless cactus based rations (T2 and T3).

The highest fecal output was recorded for lambs fed prosopis pods-based rations. Fecal output was positively related to DM intake, in vivo and in vitro feed degradability. However, fecal Nitrogen was negatively correlated to these values. Prosopis pods-based diets (T4) had significantly (P<0.001) lower fecal nitrogen excretion as compared to other test diets (T1, T2 and T3). Highest fecal nitrogen excretion was recorded in the Prosopis leaf meal based diets (T4) and the control (T1). Results indicated that the in vivo digestibility of neural detergent fibre (NDF) increased significantly (P<0.0001) in Prosopis pods-based diets as compared to other test diets. However prosopis leaf meal based rations (T3) had acceptable degradability levels of above 50%, as compared to the cactus (T2) and the control diet (T1) which had degradability coefficients of below 50%. The results of in vitro dry matter (DM) degradability characteristics of feeds used in the study indicated that dietary treatments had a significant (P<0.0001) effect on dry matter degradability. The immediately degradable feed fractions varied (P<0.05) among the treatments diets from 42% (C.ciliaris hay (control diet, T1) to 63% for Prosopis pods-based rations (T4) which were degraded faster than the rest of the test diets. The study revealed that spineless cactus species-based diets (Ficus indica var innermis) (T3) degraded faster than Prosopis leaf meal (T3). The study concludes that a diet with Prosopis pods in combination with spineless cactus has commendable performance for red maasai sheep, as a representative of ruminant animals raised in rangelands. On the basis of the findings of this study, it is recommended that formulation of total mixed rations (TMRs) with the noxious invasive Prosopis and spineless cactus spp. (as protein and energy sources respectively) is an ideal intervention to combat feed scarcity and quality in rangelands to adapt livestock systems to climate change.

Key words: Prosopis, cactus, Livestock, Rangelands, digestibility
Introduction

Pastoralism being the main-stay of most rural communities in Baringo County, current aggressive invasion of *Prosopis species* on the main grazing areas and elimination of grasslands is becoming a big threat to their livelihoods. The invasive potential of *Prosopis spp.* and the emerging trends of massive colonization of wetlands are already showing the indications of great disaster of national and international importance (Ben Salem et al., 1996). The magnitude of the problem is easily understood in the contest that most infestations seen today are still relatively young stands and of moderate densities yet their negative impacts have already been felt by the pastoralists through elimination of treasured pasture lands. The full impact of their invasion is likely to be felt when the infestations will achieve high densities in the next 10-20 years if no intervention is introduced in good time. If un-checked, *Prosopis spp* has the potential to wipe out pastoralism in the near future. Watering points for both livestock and wild game is not accessible in some areas due to the impenetrable thickets of *prosopis spp*. Reports by Harding and Bate (1991) revealed that, with good rainfall, the colonization rate of *P. Juliflora* would not be a solution owing to high overhead costs. Therefore, small-scale prosopis-based feed industry would be an important avenue that can convert weedy invasions into productive and profitable model (Pasiecznik, et al., 2001). The seeds are passed un-digested in the animal gut and are able to germinate readily under favourable conditions. Efforts to address its control and management will therefore be a big relief to the affected communities, while improving livestock productivity.

On the other hand, Cactus is drought tolerant and makes use of little moisture in rainy season to produce large quantities of forage. It has high carrying capacity than any other drought tolerant fodder in arid and semi-arid areas. It remains green and succulent during drought thus supplying the much needed energy, water and vitamins in drought period. It withstands severe defoliation and has good regeneration ability. It is easy and cheap to establish while its maintenance cost is low. Due to their anatomic and physiological makeup, Cactus withstands a wide range of soils types as well as harsh climatic conditions. Therefore, development of good pastoral system should incorporate cactus establishment as it is also suitable in soil conservation and reduction of desertification (Nefzaoui and Ben salem 2001 and De kock 1980). The fact that cacti combine drought tolerance and water use efficiency, it produces large quantity forage that remain green and succulent in drought period, it is easy and cheap to establish, makes it the best fodder option in the changing climatic situations. The current study was aimed at investigating the feed value of spineless cactus (*Opuntia ficus indica*) and *Prosopis juliflora* as forage resource in a total mixed ration for improving livestock productivity in range lands.

Materials and Methods

**Location of the study**

The study was carried out between June and August, 2014. *In vitro* dry matter (DM) digestibility was carried out at the University of Nairobi, Animal production laboratory. *In vivo* nutrient digestibility was done at Kenya Agricultural and Livestock Research Organization (KALRO), Perkerra research station, a semi-arid region in AEZ V, with average annual mean minimum rainfall of 300 and mean maximum of 600mm per annum (FAO, 1996).

**In-vitro Dry matter digestibility**

*In-vitro* nutrient digestibility was determined using a rumen fermenter, in a closed system according to Jouany and Thivend (1986). Four test diets were incubated separately. The diets were; (A) 100% Cenchrus ciliaris grass hay as basal diet (as control (without supplementation), (B) 80% C. ciliaris hay + 20% wilted
spineless cactus forage, (C) 50% C. ciliaris hay + 20% spineless cactus + 30% Prosopis leaf meal, (D) 50% C. ciliaris hay + 20% spineless cactus + 30% Prosopis pods meal.

A sample of each substrate (13g DM) was incubated in duplicate in a one litre flask with 100 ml of strained rumen liquor, 100 ml of solid rumen content, 300 ml of artificial saliva and 187 mg of soluble nitrogen provided as ammonium sulphate solution, and shaken in a water bath at 39°C for 96 h. Rumen fluid was collected before the morning feeding from one rumined cannulated Boran steer, receiving chopped Rhodes grass hay ad libitum as basal diet and supplemented with Lucerne hay. Liquid samples of 9 ml were taken from the flasks at the beginning of incubation (t0) and then after 96 h. Duplicate blank i.e rumen fluid without sample was included in each flask to correct for possible effect of rumen fluid on fermentation process. Dry matter residue was determined after 96 h of digestion.

In vivo rumen fermentation

Experimental animals and feeding management

Sixteen red maasai weaner lambs, 4 months old, with an average initial live weight of 13 kg (± 2.6) were used in the study comprising feed intake and nutrient balance trials. The sheep were drenched against internal parasites before the beginning of the experiment. Experimental animals were housed in individual pens indoors during the 42 days long trial. At the end of the feed intake trial, the animals were transferred to metabolism cages and used in a digestibility and Nutrient-balance trial for a further 14 days.

Research design and treatments

The sheep (red maasai weaner lambs) were blocked by weight in a randomized complete block design (RCBD). Within each block, the animals were randomly allocated to 4 treatments, with 4 animals each as replicates. Feed, which was offered at 0800 and 1600h, was weighed and sampled daily during the data collection period and samples bulked over the six weeks period. A total of 288 samples were collected (3 samples bulked per week per animal*6 weeks trial*16 experimental animals). Each animal block received one of the following four test diets; (A) 100% Cenchrus ciliaris grass hay as basal diet (without supplementation as control, (B) 80% C. ciliaris hay + 20% wilted spineless cactus forage (C) 50% C. ciliaris hay + 20% spineless cactus + 30% Prosopis leaf meal (D) 50% C. ciliaris hay + 20% spineless cactus + 30% Prosopis pods meal. Ratio combinations of the test diets were (A) 1:0:0 (Grass forage (as control) (B) 4: 1 (Grass hay:spineless cactus) (C) 5:2:3 (Grass hay: Spineless cactus: Prosopis leaf meal (D) 5:2:3 (Grass hay: Spineless cactus: Prosopis pods meal). Feeds were offered in separate troughs. Mineral lick and water were provided ad libitum.

Feed intake trial

To calculate daily feed intake, amounts of the test diets and the control offered to and refusal by each individual animal were recorded daily. Samples of feed offered and refusal were collected three times per week for DM determination (at 105°C for 48 h). Sub-samples of feed offered were dried at 60°C, ground to pass through a 1-mm sieve and stored for laboratory analysis.

In vivo Neutral Detergent Fibre digestibility

The sheep were transferred to metabolism cages for the digestibility trial. Feeding, management and treatments remained the same as during the growth trial indicated above. The animals were allowed 14 days adaptation period, followed by total faecal collection for 7 days. The amount of feed offered and refusal were recorded daily and samples bulked separately for each animal for the entire collection period. Samples of feed offered, feed refused, and faeces were collected daily from each animal, and frozen pending laboratory analysis. DM content of all three samples (feed offered, feed refused, and faeces) were estimated after drying the samples at 105°C for 24 h. At the end of the entire collection period, feed refusals and pooled animal faecal samples and representative samples were taken for laboratory analysis. Feed offered and refused and faecal samples were dried in a forced-air oven (60°C for 48 h) and ground to pass through a 1-mm sieve and stored pending chemical analysis.
Laboratory analysis

The collected samples were dried in an oven at 60°C, ground in a hammer mill to pass a 1 mm sieve and stored for subsequent chemical analysis. The samples were analyzed for DM, N and Neutral Detergent fibre (NDF). The NDF was determined by the detergent procedures of Van Soest (1994). Nitrogen in collected feed samples was determined according to macro-Kjeldahl procedures (AOAC, 1999). Crude protein was calculated as N% x 6.25.

Statistical analysis

The recorded data were subjected to t-test and analysis of variance (ANOVA) followed by means separation according to the least significant difference (LSD) method (p<0.05) using the general linear modeling procedure (SAS, 2000).

Results

Ash content varied from 96 to 139 g kg⁻¹ DM in the test diets with and without protein supplementation. Highest ash content was recorded in the control diets (T₁). Prosopis-based feed rations had higher (P<0.05) levels of CP ranging from 125 to 188 g kg⁻¹ DM for Prosopis pods and Prosopis leaf meal based rations. Cenchrus ciliaris hay had the highest (P<0.05) NDF levels, as compared to cactus and Prosopis-based rations which had lower fibre values (Table 1).

Table 1: Chemical composition of experimental diets (g kg⁻¹ DM)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>DM</th>
<th>CP</th>
<th>NDF</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁ (C100) (control)</td>
<td>873</td>
<td>63</td>
<td>756</td>
<td>139</td>
</tr>
<tr>
<td>T₂ (C80, CT20)</td>
<td>800</td>
<td>82</td>
<td>738</td>
<td>133</td>
</tr>
<tr>
<td>T₃ (C50, CT20, PL 30)</td>
<td>720</td>
<td>125</td>
<td>704</td>
<td>130</td>
</tr>
<tr>
<td>T₄ (C50, CT20, 30 PP)</td>
<td>700</td>
<td>188</td>
<td>663</td>
<td>96</td>
</tr>
</tbody>
</table>

Abbreviations: C= C. ciliaris, CT= Cactus, PL= Prosopis leaf meal, PP= Prosopis pods meal

Effect of test diets on Dry Matter intake, Fecal output and Fecal Nitrogen

Ration type had a highly significant (P<0.0001) effect on voluntary feed intake of the red maasai weaner lambs (Table 2). The lambs receiving prosopis pods-based rations (T₄) consumed higher amounts of feed as compared to those fed other rations (T₃, T₂ and the control, T₁). There were no significant differences in feed intake between lambs fed prosopis leaf meals and spineless cactus based rations. The highest fecal output was recorded for lambs fed prosopis pods-based rations (Table 2). Fecal output was positively related to DM intake, in vivo and in vitro feed degradability.

Nitrogen was negatively correlated to these values. Prosopis pods-based diets had significantly (P<0.001) lower fecal nitrogen excretion as compared to other test diets. Highest fecal nitrogen excretion was recorded in the prosopis leaf meal based diets (T₃) and the control (T₁).
Table 2: Effect of *Prosopis-Cactus* spp. based diets on performance of red maasai weaner lambs

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Treatments</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>SEM</th>
<th>P-value (0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI (g/d)</td>
<td></td>
<td>402c</td>
<td>553b</td>
<td>684b</td>
<td>863a</td>
<td>4.3</td>
<td>0.000***</td>
</tr>
<tr>
<td><em>In vivo</em> NDFd (%)</td>
<td></td>
<td>20.0d</td>
<td>47.0c</td>
<td>63.0b</td>
<td>78.0a</td>
<td>2.5</td>
<td>0.000***</td>
</tr>
<tr>
<td>Fecal-N (g/d)</td>
<td></td>
<td>1.98a</td>
<td>1.22bc</td>
<td>1.58ab</td>
<td>0.88c</td>
<td>0.13</td>
<td>0.001***</td>
</tr>
<tr>
<td>Fecal output (g/d)</td>
<td></td>
<td>163c</td>
<td>266b</td>
<td>331b</td>
<td>498a</td>
<td>2.4</td>
<td>0.000***</td>
</tr>
<tr>
<td>IVDMD (%)</td>
<td></td>
<td>42d</td>
<td>51b</td>
<td>46c</td>
<td>63a</td>
<td>0.19</td>
<td>0.000***</td>
</tr>
</tbody>
</table>

Means with different superscript letters (a-d) along the same column differ significantly (P<0.05). Abbreviations: DMI= Dry matter intake, *In vivo* NDFd= *In vivo* Neutral detergent fibre digestibility, Fecal-N= Fecal Nitrogen, IVDMD= *In vitro* dry matter digestibility

**In vivo** Neutral Detergent Fibre degradability

Results indicated that the *in vivo* digestibility of neural detergent fibre (NDFd) increased significantly (P<0.0001) in prosopis pods-based diets as compared to other test diets (Table 2). However prosopis leaf meal based rations (T3) had acceptable degradability levels of above 50%, as compared to the cactus (T2) and the control diet (T1) which had degradability coefficients below 50%.

**In vitro** Dry matter degradability characteristics

The results of *in vitro* dry matter (DM) degradability characteristics of feeds used in the study are presented in Table 2. The dietary treatments had a significant (P<0.0001) effect on dry matter degradability *in vitro*. The different feed rations had variable DM degradability pattern as shown in figure 1 below.

![DM Degradability pattern](image)

**Figure 1:** *In vitro* DM degradability of experimental diets

The degradable feed fractions varied (P<0.05) among the treatments diets from 42% (C.ciliaris hay) to 63% for prosopis pods-based rations which were degraded faster than the rest of the test diets. The study revealed that spineless cactus species-based diets (T2) degraded faster than prosopis leaf meal (T3), (Fig 1). Prosopis leaf meal-based diet, being leguminous, was expected to degrade faster than the cactus based rations.
Discussion

**Chemical composition**

Ash content varied between treatment diets. Ash content is an indicator of mineral content in forages (Van Soest and Robertson, 1985). However, according to Ben Salem et al, (2010), high ash content of forages is also an indicator of relatively low energy in forages. The variation in ash content between treatments in this study could also be attributed to growth stages of the basal forages at harvesting (Karimi and Ungar, 1986). The C. ciliaris hay was advanced in maturity, while the cactus and prosopis were green. The CP of prosopis-based feed rations were within the range of 13 and 19%, comparable to the commercial feed concentrates in the market. This implied that these feeds can effectively be used as strategic supplementation to animals in the rangelands as an adaptation strategy to poor quality feeds, exacerbated by climate change. As was expected, C. ciliaris hay had the highest levels of NDF. Plants structural components increases as the plant matures (Preston, 1986).

**Dry Matter intake and Fecal output**

Prosopis pods-based rations had the highest dry matter intake. According to Kyuma (2013), the prosopis pods, together with seeds have high CP contents ranging from 25 to 35%. Therefore the observed higher DM intake in animals in T4 was mainly due to the high CP content in this ration, which could be associated with high digestibility of Prospis spp. pods in the ration. According to Leng (2005), rumen microorganisms require CP for their own cell synthesis. In this way they multiply in number and are capable of attacking the fibrous feeds in the rumen, thereby increasing the degradability potential of the basal feed. These studies indicate that feed intake is not optimum when animals are only fed on a basal diet such as pastures’ grass hay, and this may also limit animal production as shown in the current study.

Protein supplementation significantly increased fecal output. The higher fecal output of animals in T4 could be explained in part by the reported high CP content of these feeds (188 g kg⁻¹ DM, as compared to 63 g kg⁻¹ DM in the control diet) (Table 1), and in vitro digestibility of Prosopis pods-based test diet reported in the current study (Table 2). These findings are similar to previous studies (Bengaly, 1996, Tolera and Sundstol, 2000a) who also found improvements in feed intake due to protein supplementation to animals given maize stovers as basal diet. Efficient feed digestibility improves rate of feed passage in the GIT, thereby creating a room for more rumen filling via intake.

**Fecal Nitrogen utilization**

Results from this study show that prosopis pods-based rations resulted in a decrease in fecal nitrogen output. However, these were unexpected results where the diets with more proteins supplementation produced the least amount of fecal nitrogen. In contrast, Tolera and Sundstol (2000b) reported a negative nitrogen balance when maize stovers were fed without supplementation. In the current study, protein supplementation significantly reduced nitrogen excretion in the faeces. These findings can best be explained by the fact that T4 diet induced high DM intake concomitant with high nutrients digestibility as well as nitrogen retention, and therefore more nutrient were available for tissue deposition. This implies that diet T4 was providing well balanced nutrition and resulted in absorption of ingested nutrients efficiently.

**In vivo NDF digestibility**

The Neutral Detergent Fibre (NDF) is considered a close estimate of the total fiber constituents of feedstuffs since it measures cellulose, hemicellulose, lignin, silica, tannins and cutins. The fibre fraction contents have negative correlation on feed digestibility and intake. As NDF in the forage increases, animals will consume less forage. A recommended maximum NDF requirement is 50-60% (Ben Salem, 2010). The current study showed that supplementation to the basal diet of C. Ciliaris Prosopis pods significantly increased the NDF digestibility in vivo. This is in agreement with previous studies by Smith et al (1989) who found out that legumes have the highest nitrogen content, and gave the highest intake of maize stovers. This increase in NDF digestibility is best explained by the fact that nitrogen supply to the rumen which in turn improves the
microbial populations such as fibrolitics which degrade fibre fractions in the rumen (Leng, 2005). However, there was a significant difference in NDF degradability between Prosopis spp. pods and prosopis leaf meals supplementation. Findings on relatively low NDF digestibility in prosopis leaf meal concurred to the reported low in vitro DMD reported in the current study and that of A. nilotica reported by Rubanza et al (2003). This low in vivo and in vitro DM digestibility in prosopis leaf meals is probably due to either its high lignin content or its level and nature of tannin or their interaction effects on feed digestibility. The control diet (T_1) had the lowest NDF digestibility (20%) which is far below the recommended 50% and above (Leng, 2005). In addition to the low CP in the control diet, the noted low NDF digestibility is supported by the low nutritive potential of most low quality roughages such as hays, as in C. ciliaris reported in this study. The low digestibility of the control diet (T_1) could also be explained by its high proportions of fibre (Table 1). Fibre fraction defines extent and rate of feed digestibility (Fonseca et al, 1998).

**In vitro Dry matter digestibility**

Dry matter digestibility (DMD) is the portion of the dry matter in a feed that is digested by animals at a specified level of feed intake. The study showed a significant effect of protein supplementation on DM digestibility. Feed quality determines the relationship between digestibility and intake. Feed digestibility and intake are inversely related in high quality feeds (Hicks, 1990), and directly related in low quality roughages. Therefore the intake of the low quality roughage in the control diet (T_1) was mainly limited by its low digestibility. However, it was observed in the current study that the control diets contained significant levels of ash content. Ash contents in feeds is an indicator of minerals. According to Ben Salem, the high levels of soluble salts in the plants could result in low digestible organic matter in the dry matter (DOMD) so that animals still need to consume high levels of DM to meet their energy requirement (Masters et al, 2006, Norman et al, 2009b). As observed in this study, these levels of salt can limit voluntary feed intake (VFI) so animals may not be able to get enough energy to maintain weight. Further, high salt incurs a metabolic energy cost to process and can lower the efficiency of digestible energy to ME by up to 10% (Arieli et al., 1989., Masters et al., 2006a). The study also showed higher DM digestibility in the sole cactus species based diet (T_2) than in T_3 (Prosopis leaf meal-cactus based diet). This finding can be associated with condensed tannins in prosopis leaves (Kyuma, 2013). Tannins found in most browses form complexes with plant proteins which decrease their rate of degradation in the rumen. According to Kaitho (1998), tannins protect the proteins from digestion even in the small intestines.

**Conclusion**

Inclusion of cactus meal, prosopis leaf meal or propsopis pods improved the protein content of the rations, increased both in vitro dry matter digestibility and in vivo NDF digestibility. These supplements could be used to supplement grasses consumed by small ruminants in dry areas as an alternate to commercial concentrates.

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Evaluation of *Brachiaria* grass cultivars for seed production from suitable sites in Western Kenya

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Abstract

Several *Brachiaria* cultivars were introduced in Western Kenya and have been widely adopted by farmers because of their biomass yields and nutritional quality. Currently there is no commercial seed production of Brachiaria in Kenya to meet the high demand. The objectives of this study were to evaluate nine *Brachiaria* cultivars; *Brachiaria brizantha* cvs Xaraes, MG4, Marandu, Piata and Mulato 11; *B. humidicola* cvs Llanero and humidicola, *B. decumbens* cv. Basilisk and *B. ruziziensis* cv Congo Signal for seed production and to determine suitable sites of production. The 2 sites were Alupe and KALRO Kitale. All the cultivars did not produce any seed in Alupe. At KALRO Kitale, cvs. MG4, Piata, Basilisk and Congo Signal produced seeds; while cvs, Xaraes, Marandu, Mulato II, Llanero and Humidicola did not attain 50% flowering or produce seeds. MG4 had higher seed yields, 83kg/ha (p< 0.01) than Basilisk, Congo Signal and Piata. All the cultivars were susceptible to spider mites except Llanero and Humidicola. The cultivars that produced seed showed varying levels of susceptibility to Ergot disease with the highest incidence occurring in Piata-3.5 and the lowest in Basilisk-2.88. Evidence of flowering and seed formation was noted in four *Brachiaria* cultivars but caryopsis did not harden. Closeness to the equator and prevalence of spider mites and ergot disease render the region unfit for commercial seed production.

Keyword; - Brachiaria, Cultivar, Seed production, Spider mites, Ergot

Introduction

Agriculture is a major contributor to Kenya’s economy (KARI, 2009). Farmers in Western Kenya practise mixed farming in which maize and dairy are the main enterprises. A major constraint to livestock production in this region is the shortage of nutritious forages (Ndung’u-Magiro et al., 2016). The commonly used forage is Rhodes grass (*Chloris gayana*), which has low nutritional value and DM/ herbage production, especially in the dry season requiring large acreage to produce enough quantities. Since land sizes are continually becoming smalle, there is need to introduce other grass species with higher DM yield per unit area and of improved nutritional value (Nguku et al., 2016). Napier grass, the most commonly grown fodder, has succumbed to Napier stunt disease (Orodho, 2006), and also its production during dry season is very low.

*Brachiaria* grass, a native of east and central Africa was introduced to Latin America, Southeast Asia and northern Australia where it revolutionized grassland farming and animal production (Ndikumana and de Leeuw, 1996). The implementation of the Swedish funded research programme “Climate-smart” *Brachiaria* grasses for improved livestock production in East Africa has led to high publicity of the importance of *Brachiaria* grasses resulting in a big interest in these grasses among farmers, policy makers and researchers across Kenya (BecA, 2014). The programme aims to increase animal productivity through enhanced feed availability using climate smart *Brachiaria* grasses. *Brachiaria* can be established using either seed or vegetative material. Establishment by vegetative material is labour intensive, and is more expensive than establishment by seed, which can easily be mechanized (Kandemir and Saygili, 2015). Many *Brachiaria* cultivars reproduce through apomixis which is the production of seed without fusion of male and female gametes (Araujo et al., 2007). The demand for *Brachiaria* seed is high, and farmers in the Western Kenya aim to produce seed both for export and domestic market.
Seed production potential can be linked to environmental factors (Monteiro et al., 2016). In the humid lowland tropics, especially near the equator grass seed production can be a big challenge (Phaikaew et al., 1997). Many species which grow well in such areas often do not produce seed and those that do, the production is normally very low, including Brachiaria decumbens, cv Basilisk (Hare et al., 2015). It has been found that altitude and latitude influence flowering and seed set in Brachiaria hybrids.

Several Brachiaria cultivars were introduced in the Western Kenya and have been widely adopted by farmers because of high biomass yield and nutritional quality. Currently there is no commercial seed production in Kenya to meet the increasing high demand. There is therefore need to produce seed locally instead of relying on imported seed which is expensive. The objective of this study was to evaluate Brachiaria grass cultivars for seed production in Western Kenya and to determine suitable sites for optimum seed production.

Materials and Methods

Sites

The trial experiments were set at KALRO Kitale and Alupe in Western Kenya. The specific characteristics of the experimental sites are shown in Table 1.

Table 1: Location and climatic conditions of experimental sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Kitale</th>
<th>Alupe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>1°06.6’ N</td>
<td>0°28’ N</td>
</tr>
<tr>
<td>Longitude</td>
<td>43°59’ E</td>
<td>34°07’ E</td>
</tr>
<tr>
<td>Agro-ecological zone</td>
<td>UM&lt;sub&gt;3&lt;/sub&gt;</td>
<td>LM&lt;sub&gt;3&lt;/sub&gt;</td>
</tr>
<tr>
<td>Altitude (m asl)</td>
<td>1890</td>
<td>1187</td>
</tr>
<tr>
<td>Mean temperature (°C)</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>Annual rainfall (mm)</td>
<td>1000-1200</td>
<td>1100-1450</td>
</tr>
<tr>
<td>Soil type</td>
<td>Acrisols</td>
<td>Rhodi Ferralsols</td>
</tr>
</tbody>
</table>

UM-Upper Midlands; LM-Lower Midlands

Experimental design and treatments

Nine grasses, Brachiaria brizantha cvs Xaraes, MG4, Marandu and Piata, B. humidicola cvs Llanero and Humidicola, B. hybrid cv Mulato II, B. decumbens cvs Basilisk and B. ruziizensis cv Congo Signal were evaluated for seed production. The experiment was set up in a randomized complete block design with four replicates, in plots of 5m x 4m separated by 1 m. The grass cultivars were planted in May 2014 at KALRO Kitale and in June the same year at KALRO Alupe by hand drilling the seed in 2 cm deep furrows separated with an inter-row spacing of 0.5m at a seed rate of 5 kg/ha. Triple super phosphate (TSP 46% P<sub>2</sub>O<sub>5</sub>) was applied at the rate of 200 kg TSP/ha. The seeds were covered with a thin layer of soil. The plots were kept weed free by hand weeding. The grass was cut back in April both at Kitale and Alupe and top dressed with Calcium Ammonium Nitrate (CAN) at the rate of 40kgN/ha.

Data collection

Data collection was conducted from an area of 2m x 2m within the plot. Seed was harvested by shaking into well labelled khaki bags after every 2 days. Data collected included: the number of plants/m<sup>2</sup>, number of tillers per plant, number of inflorescence per plant and per m<sup>2</sup> and seed yield. Likert scale of 0-5 was used to score for spider mite and ergot disease incidence and 1-5 for extent of damage. Days to appearance of the first flower and to 50% flowering were noted. Seed was harvested and weighed. Germination tests were carried out 2 months after harvesting in petri-dishes as described by Koech et al. (2014) and in soil.
Data analysis

Data on number of plants/m², number of tillers/plant, days to first flowering and 50% flowering, number of inflorescence per plant and per m², spider mite and ergot disease incidence and extent scores and seed yield were subjected to ANOVA based on the model designed for randomized block design (RCBD) using SAS package. Means were compared using Least Significant Difference (LSD).

Results and Discussion

All the *Brachiaria* cultivars did not produce seed at KALRO Alupe, which could be attributed to environment influence. Seed production is linked to environmental factors (Monteiro *et al.* 2016). In Brazil successful *Brachiaria* seed production was in latitudes 15°-22° S at elevations of 700-1000m a.s.l. (Andrade, 2001), while in Thailand it was in latitudes 19°-22° N at elevations of 700-1200m a.s.l. (Hare *et al.* 2015). Our study sites KALRO Kitale and Alupe are too close to the equator making them unsuitable for *Brachiaria* seed production.

Out of the nine cultivars only Basilisk, Congo Signal, MG4 and Piata produced seeds. There was no significant difference in maturity period among varieties as expressed by days to 50% flowering (Table 2). Days to appearance of first flower followed a similar trend. Cultivars, Marandu, Mulato II, Xaraes, Llanero and Humidicola neither attained 50% flowering nor produced seeds. MG4 had significantly higher inflorescence per metre² (P<0.01) and seed yield (P<0.01) than Piata, Congo Signal and Basilisk (Table 2). Cultivars with a higher number of inflorescence also gave higher seed yield. However, this trend was not observed the following season after cutback. Piata which had the highest number of inflorescence per metre² (37) compared to Basilisk (32), MG4 (29) and Congo Signal (22) yielded the least amount of seeds (2.5kg/ha) compared to Basilisk , MG4 (25kg/ha) and Congo Signal (15kg/ha) (P<0.01). Although the number of inflorescence per unit area is the main indicator of the potential to produce seed in forage plants (Hare *et al.*, 2015), this was not the case for all *Brachiaria* grasses. Other factors such as failure to set seed and form caryopsis in some florets, the shedding of seed before maturity and diseases may have interfered with seed production in this site. The seed yield in the following year was lower than in the year of establishment for all the varieties with a mean of 44kg/ha and 17kg/ha respectively. Hare *et al.* (2015), observed a similar trend in Thailand. Seed yields obtained in this study were low, 2.5-85kg/ha compared to 300-400kg/ha recommend as satisfactory,.by Hare *et al.* (2015),

There was no direct relationship between the number of vegetative tillers and seed yield. This is in agreement with the findings of Monteiro *et al.* (2016).

The seed failed to germinate two months after harvesting. This may have been caused by failure to form caryopsis, abscission and seed dormancy (Araujo *et al.* 2007). In this study failure of the seed to germinate was attributed to dormancy which is broken by soaking seed in sulfuric acid for 10 minutes or by storage for over six months (Koech *et al.*, 2014). The seed was not scarified and it was planted after only two months of storage. Nevertheless, some of the seeds that fell on the ground were observed to emerge in the plots.
**Table 2:** Components of seed yield and seed yield of *Brachiaria* grass cultivars in 2014

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Plants/m2</th>
<th>Tillers/plant</th>
<th>Number of days to flowering</th>
<th>Number of inflorescence</th>
<th>Yield Kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>First appearance</td>
<td>50%</td>
<td>per plant</td>
</tr>
<tr>
<td>Basilisk</td>
<td>8.5abc</td>
<td>62.8abc</td>
<td>81</td>
<td>117</td>
<td>5c</td>
</tr>
<tr>
<td>MG4</td>
<td>10.5a</td>
<td>58.0ab</td>
<td>84</td>
<td>154</td>
<td>6b</td>
</tr>
<tr>
<td>Congo Signal</td>
<td>6.8bc</td>
<td>73.8a</td>
<td>81</td>
<td>151</td>
<td>7a</td>
</tr>
<tr>
<td>Marandu</td>
<td>8.3abc</td>
<td>45.8b</td>
<td>183</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Piata</td>
<td>8.0abc</td>
<td>52.8b</td>
<td>120</td>
<td>172</td>
<td>7a</td>
</tr>
<tr>
<td>Xaraes</td>
<td>5.0cd</td>
<td>51.0b</td>
<td>231</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mulato II</td>
<td>5.5cd</td>
<td>62.0ab</td>
<td>150</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Llanero</td>
<td>9.3ab</td>
<td>0.0c</td>
<td>184</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Humidicola</td>
<td>2.3d</td>
<td>0.0c</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>7.1</td>
<td>45.1</td>
<td>122</td>
<td>147</td>
<td>6</td>
</tr>
<tr>
<td><strong>LSD</strong></td>
<td>3.6</td>
<td>19.4</td>
<td>NS</td>
<td>NS</td>
<td>1.8</td>
</tr>
<tr>
<td><strong>P-Value</strong></td>
<td>0.0025</td>
<td>0.0001</td>
<td>0.0005</td>
<td>0.0054</td>
<td>0.0073</td>
</tr>
</tbody>
</table>

Means with similar superscript in the same column are not significantly different at p=0.05.

**Insect and Disease damage**

*Brachiaria* cultivars in the study were susceptible to spider mites (*Tetranychus urticae*) and ergot disease (*Claviceps purpurea*). Spider mite incidence was higher (P<0.01) on Marandu, Mulato II, Piata, Basilisk and Congo Signal than on the other cultivars (Table 3). The extent of damage followed the same trend. Ergot infected the inflorescence after the shedding of pollen during the humid wet conditions. Both incidence and extent were less severe in the year of establishment than the following year (Table 3). It is possible spider mites and ergot affected the seed yield as observed by Monteiro et al. (2016) that diseases and pests are among the causes of low seed production in *Brachiaria* grasses.

**Table 3:** Incidences and extents of damage by Spider mites and Ergot in *Brachiaria* cultivars

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Basilisk</td>
<td>2.75^cd</td>
<td>2.50^bc</td>
<td>1.25^ab^cd</td>
<td>1.13^ab</td>
<td>3.13^ab</td>
<td>2.38^ab</td>
<td>2.88^b</td>
<td>2.22^cd</td>
</tr>
<tr>
<td>MG4</td>
<td>2.50^de</td>
<td>2.00^cd</td>
<td>1.63^abc</td>
<td>1.38^ab</td>
<td>2.13^b</td>
<td>1.38^b</td>
<td>3.25^ab</td>
<td>2.75^abcd</td>
</tr>
<tr>
<td>Congo Signal</td>
<td>2.00^de</td>
<td>1.75^d</td>
<td>0.75^cde</td>
<td>0.63^bc</td>
<td>3.00^a</td>
<td>2.75^a</td>
<td>3.25ab</td>
<td>3.63^ab</td>
</tr>
<tr>
<td>Marandu</td>
<td>3.00^bc</td>
<td>2.75^b</td>
<td>-</td>
<td>-</td>
<td>2.88^ab</td>
<td>2.63^a</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Piata</td>
<td>1.75^c</td>
<td>1.50^d</td>
<td>0.63^cde</td>
<td>0.63^bc</td>
<td>3.25^a</td>
<td>2.38^ab</td>
<td>3.50^e</td>
<td>3.38^abc</td>
</tr>
<tr>
<td>Xaraes</td>
<td>3.75^ab</td>
<td>3.5^a</td>
<td>-</td>
<td>-</td>
<td>2.88^ab</td>
<td>2.38^ab</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mulato II</td>
<td>4.00^a</td>
<td>4.00^a</td>
<td>-</td>
<td>-</td>
<td>3.13^a</td>
<td>3.13^a</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Llanero</td>
<td>0.75^f</td>
<td>0.63^e</td>
<td>-</td>
<td>-</td>
<td>0.00^c</td>
<td>0.00^c</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Humidicola</td>
<td>0.13^f</td>
<td>0.13^e</td>
<td>-</td>
<td>-</td>
<td>0.00^c</td>
<td>0.00^c</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>0.2.30</td>
<td>2.08</td>
<td>1.04</td>
<td>0.90</td>
<td>2.29</td>
<td>1.89</td>
<td>3.22</td>
<td>3.00</td>
</tr>
<tr>
<td><strong>LSD</strong></td>
<td>0.82</td>
<td>0.72</td>
<td>1.20</td>
<td>0.90</td>
<td>1.07</td>
<td>1.16</td>
<td>1.33</td>
<td>1.27</td>
</tr>
<tr>
<td><strong>P-Value</strong></td>
<td>0.0002</td>
<td>0.0566</td>
<td>0.0741</td>
<td>0.1077</td>
<td>0.0002</td>
<td>0.0741</td>
<td>0.1077</td>
<td>0.0259</td>
</tr>
</tbody>
</table>

Column means with similar superscript are not significantly different at P=0.05.
**Conclusion and recommendations**

Western Kenya is not suitable for seed production for *Brachiaria* grass cultivars because the seed yield obtained in this study was very low with a mean yield of 44 and 17 kg/ha in the first and second year respectively. The study sites are too close to the equator for *Brachiaria* grass seed production. It is therefore recommendation that seed production of these cultivars be conducted elsewhere, where the conditions are suitable and the seeds be made available to the north western highlands of Kenya.

**Acknowledgement**

We are grateful to the Swedish International Development Agency (Sida) for funding this study. The study was conducted in collaboration with Kenya Agricultural and Livestock Research Organization (KALRO) and the Bioscience eastern and central Africa– International Livestock Research Institute (BecA–ILRI) Hub. We extend our gratitude to Director General, KALRO, Food Crops Research Institute Director and Centre Director, Kitale for enabling this work to be done. We highly appreciate all the technical staff who participated in data collection and the management of the trial and Mr. Roger Kamidi for data analysis.

**References**


Effect of induced water stress on ecotypes of *Cenchrus ciliaris* grass species and implication for drought tolerance

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Abstract

A study was done to evaluate the effect of induced water stress to ecotypes of *Cenchrus ciliaris* grass species. A total of eight ecotypes (KBK1, KBK2, KLF1, KLF2, MGD1, MGD3, TVT1 and TVT3) collected from selected areas in Arid and Semi-Arid lands (ASALs) of Kenya were planted in a greenhouse. Effect of water stress was varied among the ecotypes. Extreme stress was observed with KBK2 ecotype where plant height change, observed plant appearance score and relative leaf water content was significantly affected by water withdrawal. Leaf proline content was highest in water stressed than well-watered plants. Leaf proline levels were significantly affected by water stress in KBK2 and KBK1 ecotypes. Overall, the results indicated that KBK2 ecotype is significantly affected by water stress implying low drought tolerance than the rest.

Introduction

*Cenchrus ciliaris* is warm season tufted perennial grass species that has been widely used in reseeding the Arid and Semi-Arid Lands (ASALs) of Kenya. The species is commonly found in the ASAL habitats and is among the most preferred grass species due to its tolerance to grazing and drought, high biomass yield and ease of harvesting the seeds. It is apomictic in reproduction although sexually reproducing varieties have previously been found. Morphological characterization has observed a lot variation among its ecotypes that could be a result of adaptation to varied environments (Jorge et al., 2008). Early and late maturing ecotypes were identified among collections from Kenyan ASALs (Kirwa et al., 2016). Variation in adaptation to salt tolerance among ecotypes of *C. ciliaris* was observed by Al-Dakheel and Hussein (2016).

The ASAL environments are characterized by highly variable weather patterns particularly erratic and unreliable rainfall. Droughts are becoming more frequent occurring every 2-3 years. In addition, Kenyan ASALs are going through challenges of changing habitats such as land fragmentation and land use change particularly to crop production. Thus posing challenges of potential loss in diversity among ASAL adapted grass species as well as failure in ASAL grass reseeding initiatives.

Therefore this study aimed at evaluating ecotypes of *C. ciliaris* collected from the ASALs of Kenya for drought tolerance.

Methodology

Experimental design

The experimental design was the randomized complete block design with three replicates per treatment. There were two water treatments of with and without water. A total of eight ecotypes, namely, KBK1, KBK2, KLF1, KLF2, MGD1, MGD3, TVT1 and TVT3 were planted each in five pots per replicate. Thus a total 240 pots were planted.
Planting and management

Planting and management of the ecotypes was done in a greenhouse at KALRO Biotechnology Research Centre, Kabete. Planting of the ecotypes was done in plastic bags of size 6x9x150g using sterilized soil. The soil was moistened before placing the seeds. Five seeds per ecotype were placed on top of the soil and covered with a thin layer of fine soil. Thinning to four plants per pot was done after four weeks.

Watering was done daily for four weeks for all treatments then complete withdrawal of watering was started for the water-stressed treatment. The day of water withdrawal was treated as day zero. Water stress period lasted for 15 days then water was re-introduced.

Soil moisture in none water stressed pots was also monitored using the soil moisture meter where all the pots remained above the moist level.

Data collection

Data was collected for proline levels, plant appearance score, relative leaf water content, plant height and leaf width and length.

Relative leaf water content was recorded only at the end of water stress while scoring for plant appearance was observed at both the end and three days after re-introduction of water to score for recovery from stress.

Plant height, leaf length and width

Data for plant height and leaf width and length was collected on four plants per replicate at four weeks post planting that is, just before introduction of water stress and two weeks into the stress period. Leaf data was recorded on the second leaf with the width being measured at the widest point of the leaf.

Scoring for plant appearance

Scoring for plant appearance was done for each pot using a score of 1 to 5. The extremely wilted plants with completely rolled leaves were given a score of 5, wilted pots with leaves not rolled was 3 and 1 represented completely healthy plants in a pot with no signs of wilting or losing the greenness.

Relative leaf water content

Three leaves per replicate were randomly sampled for the study. Each sampled leaf was put into pre-weighed zip-locked bag and dry weight determined. The bags were filled with water and placed on a bench for four hours to rehydrate the leaves. The water was then poured out and the leaves weighed (turgid weight) before being dried in the oven at 65°C for 72 hours. The oven dried weight was recorded and used in the calculation of relative water content of the leaves using the following formula.

$$\text{RWC} (%) = \left( \frac{\text{FW} - \text{DW}}{\text{SW} - \text{DW}} \right) \times 100$$

Where FW is the fresh weight of leaves immediately after sample collection; DW is the dry weight after 3 days of drying in an oven at 65°C; SW is the turgid weight taken after soaking leaf samples in water for 4 hours at room temperature.

Analysis of free proline in C. ciliaris leaves

The ninhydrin test was used in analyzing the quantity of free proline amino acid in the leaves of eight C. ciliaris ecotypes (Bates et al., 1973). A standard curve of proline was prepared using a serial dilution of 1 mL of L-proline in 3% sulphosalicylic acid at 0, 50, 150, 200, 250 and 300µM. Using a fume chamber, 500 µL of each dilution was added to 500 µL of glacial acetic acid and 500 µL ninhydrin reagent (2.5 g Ninhydrin, 60 mL glacial acetic acid and 40 mL 6 M phosphoric acid dissolved at 70 °C and stored in the dark for not more than 24 hrs) in a 12 mL falcon tube and boiled for 45 minutes in a water bath and cooled on ice for 30 minutes. An equal volume of toluene was added to each sample, vortexed for 1 minute and centrifuged at 700 rpm for 5 minutes. The optical density of the toluene solution was measured at 520 nm using a spectrophotometer. The measurements were used to make a standard curve for proline. About 100
mg of fresh leaves harvested from the grass ecotypes which were well watered and those where water was withdrawn were ground separately in beaded vials with 1.0 mL of 3% sulphasalycylic acid using a genogrinder. The homogenized leaf samples were centrifuged at 7000 rpm for 5 minutes and 500 µL of the supernatant treated with 500 µL of ninhydrin reagent and 500 µL of glacial acetic acid in a 12 mL falcon tube. The optical density of the toluene solution was measured at 520 nm using a spectrophotometer and the proline content calculated using the standard curve generated (Figure 1).

Figure 1: Standard curve for proline, (A) and (B), brick red coloration increasing in intensity with proline concentrations

The gradient from the standard curve generated (y = 0.876x + 0.025) was used in calculating the concentration of proline in the measured samples. To calculate the concentration of proline per gram fresh weight, the following formula was applied according to Bates et al. (1973).

\[
\text{[µM proline} \times \text{mL toluene / 115.5} \text{µg/µM}] / [(\text{g sample}) / 1] = \text{µM proline / g of fresh weight material}
\]

Where: µM proline is worked out from the optical density using the gradient from the standard curve, mL toluene is the volume of toluene used, 115.5 µg/µM is the molarity of proline, g sample is the weight of the leaf sample used and 1 is the volume of sulphasalycylic acid used to homogenize the ground leaf samples.

Results

Plant height at day zero and day 15

Table 1 shows means of plant height, leaf length and width measured at day zero and 15 days after starting the water stress treatment. Mean height, leaf length and width differed between the ecotypes in each treatment. KBK2 and MGD1 ecotypes were the tallest during the well-watered treatments but under stress treatment MGD1 was not among the tallest by day zero. Analysis for mean increase in height between day zero and day 15 for the two treatments indicated that KBK2 was the only ecotype significantly affected by the water stress (Figure 1). The mean increase in height was lower (p<0.05) under water stress (12.8 cm) than in well-watered (30.2 cm).
Table 1: Means of morphological attributes among ecotypes of Cenchrus ciliaris observed before and after water stress treatment

<table>
<thead>
<tr>
<th>Ecotype</th>
<th>Plant height (cm)</th>
<th>Leaf length (cm)</th>
<th>Leaf width (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day zero</td>
<td>day 15</td>
<td>Day zero</td>
</tr>
<tr>
<td><strong>With water treatment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KBK1</td>
<td>40.3b</td>
<td>48.5b</td>
<td>25.2c</td>
</tr>
<tr>
<td>KBK2</td>
<td>47.5ab</td>
<td>77.6a</td>
<td>33.8ab</td>
</tr>
<tr>
<td>KLF1</td>
<td>41.4ab</td>
<td>56.0b</td>
<td>28.5bc</td>
</tr>
<tr>
<td>KLF2</td>
<td>39.1b</td>
<td>56.2b</td>
<td>27.8bc</td>
</tr>
<tr>
<td>MGD1</td>
<td>50.3a</td>
<td>74.3a</td>
<td>37.7a</td>
</tr>
<tr>
<td>MGD3</td>
<td>46.6ab</td>
<td>68.2a</td>
<td>33.8ab</td>
</tr>
<tr>
<td>TVT1</td>
<td>22.8c</td>
<td>36.6a</td>
<td>17.4d</td>
</tr>
<tr>
<td>LSD0.05</td>
<td>9.76</td>
<td>11.54</td>
<td>6.99</td>
</tr>
<tr>
<td>P value</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>Without water treatment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KBK1</td>
<td>40.4bcd</td>
<td>55.4b</td>
<td>27.4bc</td>
</tr>
<tr>
<td>KBK2</td>
<td>56.0a</td>
<td>68.9a</td>
<td>37.5a</td>
</tr>
<tr>
<td>KLF1</td>
<td>34.8cd</td>
<td>54.3c</td>
<td>25.0cd</td>
</tr>
<tr>
<td>KLF2</td>
<td>33.8de</td>
<td>44.5cd</td>
<td>23.3cd</td>
</tr>
<tr>
<td>MGD1</td>
<td>42.9bc</td>
<td>60.3ab</td>
<td>32.9ab</td>
</tr>
<tr>
<td>MGD3</td>
<td>44.4b</td>
<td>64.2ab</td>
<td>33.7a</td>
</tr>
<tr>
<td>TVT1</td>
<td>25.8e</td>
<td>40.7d</td>
<td>19.1d</td>
</tr>
<tr>
<td>LSD0.05</td>
<td>8.64</td>
<td>11.62</td>
<td>6.00</td>
</tr>
<tr>
<td>P value</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Figure 2: Mean height change and LSD (9.33 cm) among ecotypes of C. ciliaris in well-watered and water stressed treatments

Scoring for observed appearance after 15 days of water stress and 3 days after re-introduced watering

Table 2 shows the observed mean score during peak stress time and three days after start of watering. KBK2 ecotype had the highest score (3.3 and 3.0, respectively) in both data collection sessions which could be an
indication of most stress. By the 19\textsuperscript{th} day, the ecotype was significantly stressed than all except KLF2. However, the lower readings for KLF2 could be attributed to lower number of samples. There was very low germination with KLF2 and most of the few germinated plants were destroyed during Dry matter analysis.

**Table 2:** Mean score for appearance of the plants under the water stressed treatment at peak stress period and three days after resumption of watering

<table>
<thead>
<tr>
<th>Ecotype</th>
<th>KBK1</th>
<th>KBK2</th>
<th>KLF1</th>
<th>KLF2</th>
<th>MGD1</th>
<th>MGD3</th>
<th>TVT1</th>
<th>LSD\textsuperscript{0.05}</th>
<th>P_value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score at day15</td>
<td>2.5</td>
<td>3.3</td>
<td>2.7</td>
<td>2.4</td>
<td>2.6</td>
<td>2.7</td>
<td>1.9</td>
<td>0.900</td>
<td>0.2</td>
</tr>
<tr>
<td>Score at day19</td>
<td>1.64\textsuperscript{b}</td>
<td>3.01\textsuperscript{a}</td>
<td>1.64\textsuperscript{b}</td>
<td>2.33\textsuperscript{ab}</td>
<td>1.63\textsuperscript{b}</td>
<td>1.55\textsuperscript{b}</td>
<td>1.38\textsuperscript{b}</td>
<td>0.996</td>
<td>0.009</td>
</tr>
</tbody>
</table>

**Relative water content**

The ecotypes KBK2, MGD1 and MGD3 of the seven ecotypes used in this study showed a significant difference in the RWC between the well-watered and the water stressed plants (Table 3). The RWC of the ecotypes was lower in the leaves of the water stressed plants than in the well-watered. The highest percent reduction was recorded by KBK2 at 67.0, followed by KLF1 with 56.3%.

**Table 3:** Percentage Relative Water Content (RWC) in seven C. ciliaris ecotypes after 2 weeks of treatment with adequate watering (T1) and water stress (T2).

<table>
<thead>
<tr>
<th>Ecotypes</th>
<th>KBK1</th>
<th>KBK2</th>
<th>KLF1</th>
<th>KLF2</th>
<th>MGD1</th>
<th>MGD3</th>
<th>TVT1</th>
<th>P_value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RWC (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>57.5±8.83</td>
<td>54.8±4.48</td>
<td>39.1±8.89</td>
<td>45.9±7.02</td>
<td>60.5±3.06</td>
<td>56.7±6.95</td>
<td>25.5±9.06</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>34.2±8.24</td>
<td>18.1±3.84</td>
<td>17.1±5.76</td>
<td>39.6±12.03</td>
<td>40.8±4.15</td>
<td>30.0±6.65</td>
<td>17.6±4.67</td>
<td></td>
</tr>
<tr>
<td>P_value</td>
<td>0.1257</td>
<td>0.0034</td>
<td>0.1063</td>
<td>0.6783</td>
<td>0.0185</td>
<td>0.0497</td>
<td>0.4801</td>
<td></td>
</tr>
<tr>
<td>% Reduction in RWC</td>
<td>40.5</td>
<td>67.0</td>
<td>56.3</td>
<td>13.6</td>
<td>32.7</td>
<td>47.1</td>
<td>31.1</td>
<td></td>
</tr>
</tbody>
</table>

**Proline quantity in C. ciliaris leaves of well watered and water stressed plants**

Between the seven ecotypes of *C. ciliaris* analysed in this study, there was a significant difference in proline concentrations in the two treatments (p = 0.009). Proline concentration was more in the leaves of plants where water was withdrawn, with a mean of 123.18 µM proline/g fresh weight in comparison to plants which received regular watering which had a mean proline concentration of 76.45µM proline/g fresh weight. At day zero (0) when the water withdrawal treatment commenced, the plants had the same level of proline, and after two weeks of water withdrawal (day 15), the proline levels had risen to 345 µM proline/g fresh weight in the water stressed plants (Figure 2).

Within the seven ecotypes of *C. ciliaris* however, proline concentration in the leaves was only significantly different in two ecotypes, KBK1 and KBK2 between the well watered and water stressed plants over the two week treatment period as presented in Table 4. Ecotype KBK2 accumulated the highest amount of proline, over 800 µM / g fresh weight, after two weeks of water stress. The variety KBK2 showed the highest variation in proline levels between the well watered and water stressed plants while varieties KLF2 had minimal variation observed in the accumulation of proline between the well watered and water stressed plants (Figure 4).
**Figure 3**: Mean proline concentrations in *C. ciliaris* leaves from seven ecotypes harvested from well-watered (T1) water stresses plants (T2) from zero to 24 days.

**Figure 4**: Proline concentrations in *C. ciliaris* leaves in 2 ecotypes, KBK2 and KLF2 harvested from well-watered (T1) and water stressed plants (T2) over a 15 day period (Day 3 to day 15).
### Table 4: Proline content (µM / gram fresh weight) in seven C. ciliaris grass ecotypes with normal watering and with water withdrawn over a 2 week period

<table>
<thead>
<tr>
<th>Day</th>
<th>KBK1</th>
<th>KBK2</th>
<th>KLF1</th>
<th>KLF2</th>
<th>MGD1</th>
<th>MGD3</th>
<th>TVT1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
<td>T2</td>
<td>T1</td>
<td>T2</td>
<td>T1</td>
<td>T2</td>
<td>T1</td>
</tr>
<tr>
<td>3</td>
<td>5.49±2.53</td>
<td>19.9±5.58</td>
<td>27.3±11.7</td>
<td>13.2±2.08</td>
<td>6.47±3.65</td>
<td>7.60±3.16</td>
<td>12.6±6.68</td>
</tr>
<tr>
<td>6</td>
<td>14.5±1.54</td>
<td>5.64±1.91</td>
<td>8.87±1.48</td>
<td>33.8±18.2</td>
<td>23.2±15.8</td>
<td>26.3±14.1</td>
<td>77.9±60.8</td>
</tr>
<tr>
<td>9</td>
<td>17.6±6.95</td>
<td>29.8±8.88</td>
<td>116.±47.7</td>
<td>278.±205.6</td>
<td>29.8±23.0</td>
<td>19.9±3.16</td>
<td>15.4±3.94</td>
</tr>
<tr>
<td>12</td>
<td>12.8±6.53</td>
<td>44.4±3.58</td>
<td>17.9±9.59</td>
<td>618.±31.0</td>
<td>26.7±20.8</td>
<td>197±105.2</td>
<td>14.7±4.93</td>
</tr>
<tr>
<td>15</td>
<td>13.0±5.79</td>
<td>307.±70.0</td>
<td>25.3±2.15</td>
<td>823.±374.5</td>
<td>39.1±30.7</td>
<td>289.±238.5</td>
<td>8.88±1.41</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>P_value</th>
<th>Day</th>
<th>&lt;0.0001</th>
<th>0.012753</th>
<th>0.1455</th>
<th>0.2252</th>
<th>0.2591</th>
<th>0.03241</th>
<th>0.01901</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>0.0002716</td>
<td>0.001474</td>
<td>0.6641</td>
<td>0.3966</td>
<td>0.7331</td>
<td>0.13989</td>
<td>0.18252</td>
<td></td>
</tr>
</tbody>
</table>

| P_value | Day: Treatment | 0.0008488 | 0.005216 | 0.49 | 0.8691 | 0.4281 | 0.43106 | 0.07973 |
Discussion

Introduction of water stress treatment negatively affected the potential increase in height for ecotype KBK2 between day zero and day 15. The lower change in height compared to other ecotypes may be due to extreme stress observed in the scored appearance of the ecotype. The ecotype had all plants in the water stressed pots wilted with total loss of greenness after 2 weeks of water withdrawal. Table 2 supports the observation that KBK2 had the highest scores for stress at 3.3 by week two.

Proline levels increased exponentially with increase in days exposed to water stress. The treatment and ecotype affected proline levels. Proline analysis indicated higher mean proline concentration in water stressed treatment (123.18 µM/g) than the well-watered (76.5 µM/g) indicating increase in proline production with stress. Hayat et al., (2012) notes that proline levels increase under different stress situations such as salinity and water stress. The pattern of increase in proline concentration varied between the ecotypes. Leaves of stressed plants of KBK1 and KBK2 had higher proline levels than the well-watered. This implies that leaves of water stressed plants in KBK1 and KBK2 ecotypes in this study had higher concentration of proline than those without the stress. This observation is supported by correlation results. The mean proline concentration recorded on 15th day positively significantly correlated with the plant appearance scores recorded on that day (r=0.9, p=0.005). Plants that were extremely affected by the stress also recorded highest levels of proline. Increase in leaf proline concentration in grasses due to water stress has been recorded in various studies (Bandurska and Jozwiak, 2010). Bandurska and Jozwiak (2010) observed significant increase in proline levels with induced water stress for Festuca rubra and Lolium perenne (ryegrass) grass species with about 6 fold difference between treatments in festuca. This results of high proline levels on the most affected ecotype is contrary to other proline analysis where high levels indicates more drought tolerance.

The percent relative water content (RWC) was reduced in all ecotypes but significantly in KBK2, MGD1 and MGD3. Similar results were recorded by Zygielbaum et al. (2009) and Arjenaki et al., (2012). RWC in wheat genotypes ranged from 74.4 to 59.3 % under drought stress with Arjenaki et al., (2012) and a reduction from 90 % to 50 % was observed by Zygielbaum et al. (2009). More drought tolerant plants have higher RWC than the others being compared with (Arjenaki et al., 2012). KBK2, KLF1 and TVT1 are among the ecotypes with the lowest RWC while MGD1 had the highest in both treatments. The RWC negatively significantly correlated with proline levels for day 15, which is the day RWC data was collected. This implies that ecotypes that had lower RWC also had higher proline levels.

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Conclusion and recommendations

The study shows varied responses from the ecotypes with induced water stress. Among the ecotypes tested, KBK2 ecotype was severely affected by water stress as was observed through reduced change in plant height, extreme stress in plant appearance score and 67 % reduced RWC. The results imply that KBK2 ecotype is less drought tolerant than the others in the study. TVT1 and KLF2 ecotypes were the least affected by water stress among the ecotypes.

However, a repeat of the study to increase test seasons and data sets for RWC is recommended to give more representative conclusion.

References


SUSTAINABLE LIVESTOCK PRODUCTION SYSTEMS

Upgrading the mutton value chain: A pilot community initiative in ASALs of Narok, Kenya

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Abstract

A pilot research to business (R2B) model was developed and tested in Narok County with the objective of upgrading the mutton sheep value chain in the region. The model involved on-farm communal feedlot finishing of Dorper weaner lambs donated by and belonging to a local community based organization (CBO). One hundred and thirty two, four months old weaner lambs were fattened for 3 months and collectively marketed under a public auction. The lambs attained an average market weight of 30 kilograms. Farmers were trained on strategic deworming as means to control helminths and improve the sheep productivity. Profitability analysis showed positive Net Present Value (NPV), Gross Margins (GM) and a Cost Benefit Ration (CBR). This means that the costs invested in the sheep lamb fattening scheme are recovered and high benefits realized. The project working with the CBO, managed to pioneer the sale of finished sheep lambs on live weight basis and at higher prices through public auction forum which was a new experience in the area. The fattening experiment observed that it was possible to finish and market sheep weaner lambs for a period of 3 months thus reducing the market age from the normal 2-3 years to about 8 months.

Key words: Sheep- Finishing Narok Kenya

Introduction

Pervasive low productivity, partly because of the relatively low degree of commercialization of the livestock production and the related limited adoption of modern technology in Kenya, is extensively reported albeit the wide and extensive body of knowledge and technology available in research domains in the country. (Hansen et al., 1986; Thompson, 1995). Quite often, the producers are reported to experience limited availability of knowledge of existing improved technologies to address: the feed challenge (LAPSSET, 2012; Manyeki, et al., 2013); poor breeding practices (Koskey, 2004); inappropriate routine husbandry practices (Koskey 2004); inappropriate helminth control practices (Gatongi et al., 1998; Nganga et al., 2006) and poor markets and marketing strategies (Juma et al., 2010). The situation is worse among the pastoralists (Ndathi et al., 2012). Therefore, there is urgent need to reverse this trend by availing current, best bet and most economical production techniques and upgrading strategies to the mutton chain players at the production segment. A baseline survey conducted in Narok County (Katiku et al., 2016; Maina, 2013) revealed major issues requiring intervention in sheep production to include: Limited knowledge on general sheep husbandry; Poor genetics (breeds and breeding); Finishing of sheep for market took more than 3 years; Lack of sheep management calendar; Poor housing structures for sheep; Poor nutrition of sheep (feeds and feeding); lack of written record keeping; sheep diseases; and lack of prudent sheep helminth control practices.

KALRO with the support of the International Centre for Agricultural Research in Dry Areas (ICARDA) implemented a project “Improving Integrated Agricultural Production Systems for the Poor and Vulnerable
in Dry Areas “ with the objective of upscaling of tested, economically feasible, gender sensitive and climate smart technologies within a research to business (R2B) model.

Figure 1: Map of Narok County

Problem statement

Materials and method

The rainfed wheat- small ruminant production system in lower Narok was the designated country site. One cluster site Nturumenti in Narok East/North was the implementation site.

Pasture establishment

Rhode grass, variety Boma was establishment on 0.75 ha in April 2015 on land donated by the community. The plot served as seed bulking plot for harvesting seeds for expansion of the current study and distribution to farmers. An additional 4 ha pilot plot was planted with forage for the feedlot (mixture of Rhodes grass-Boma Rhodes sown with wheat variety Njoro II BW ) in Osinon village, Nturumenti Sub-location, Ongat-Nadoo location to validate the model. The plot was located at Mr Kanaange ole Roiko farm (father to Chairman of AFAPO CBO), who freely donated the land for the activity. The site is about 2 km from Nturumenti centre and 1.5 km off on the right of Ntulele - Mosiro road. The feedlot plot was enclosed into paddocks, feeding and watering troughs, hay barn and sheep pen constructed with the inputs donated by the project.
Finishing Trial

A pilot flock of 132 lambs aged 4 months were chosen for finishing. The lambs were allowed to freely graze on the herbage in the feedlot for 8 hours per day. Later, they were allowed to a supplement mixture consisting of wheat straw, lucerne hay and molasses per day and allowed to lick on balanced mineral (Vital kondooR) salt on ad libitum. They were allowed to access water on every other day from a water pan located 300m from the feedlot facility. The feed ration of the sheep lambs was determined based on nutrient requirement and consisted of the following; Boma Rhodes+lucerne hay+ wheat straw+ molasses + mineral+water. The supplement consisted of wheat straw and lucerne hay mixed with molasses and was fed communally based on requirement for fattening sheep. The wheat straw and lucerne hay were processed prior to mixing and feeding by chopping with a manual chaff cutter and fed in half split plastic drum feeding troughs. Each lamb was allowed to consume 0.75 kg of forage, 0.75 kg wheat straw, 0.5 kg lucerne hay, 0.209 kg molasses and 0.03 kg of mineral per day. The materials were fed as is. A commercial mineral supplement for sheep, Vital KondooR was fed ad libitum. The lambs were watered every other day in a rain filled water pan and penned at night in an open enclosure.

Capacity building on strategic deworming

The members of the CBO were trained on helminth control during a capacity building session where other important aspects of sheep management were covered. The training on helminth control started with an introduction of the different classes of helminths that infect livestock, particularly ruminants. The farmers were also shown preserved specimens of the helminths to enable them recognize them and understand the hazards of each of the classes. The classes displayed included nematodes or roundworms (resident in the stomach or intestines), trematodes or flatworms (resident in the liver and fore stomachs) and cestodes or tapeworms (resident in the intestines, liver, muscles and viscera).

Control of helminth infestations in the feedlot sheep

At day Zero, the sheep lambs were treated with a broad-spectrum anthelmintic (ValbazenR 10%) and a pour-on acaricide (SpotonR) applied for the control of ectoparasites. The sheep were faecal sampled at the day of introduction to the feedlot (Day 0), once in the middle of the fattening (Day 84) and at the end of the trial (Day 99).

Sheep monitoring during fattening

The lambs were castrated and introduced to the feedlot in December 2015. Their health was monitored and similarly to other production parameters. Among the health parameters recorded during this period were worm egg counts, body condition scores and live weights. An initial evaluation of the packed cell volumes was done to ascertain the possible level of anaemia, possibly associated with haemonchosis. Data were recorded and entered in the computer using excel spread sheet.

Data management and analysis

Data records generated included, Lamb identification number, live weight changes, amounts of feed given, sick case and treatment given, amount of dewormer and date given, packed cell volumes, body scores, faecal egg counts, market value of lambs at time of entering the feedlot and at time of auction were collected in data sheets. The data were entered in the computer using Microsoft Excel Version 8 for storage and further synthesis. Qualitative data were coded, cleaned and stored for analysis. The response variables were analysed for means, standard error of mean, standard deviation and variance using General statistics (Gen Stat 15th edition) program. Significance was tested at 0.05. Regression analysis was conducted for correlated attributes. The analysis results were presented in tables, graphs and figures.
Results and Discussion

Weight gain during period of fattening

The lambs entered the feedlot at a mean weight of 24.8 (s.e 0.52) kilograms (kg) and progressively gained weight rapidly up to day 42, stagnated then picked on 99 day (Figure 2).

Figure 2: Growth curve of feedlot sheep at Nturumenti

Lambs castrated prior to entering the feedlot performed better but not significantly different (P>0.05) than the lambs castrated on the day of entering the feedlot (Figure 3) perhaps because of the stress induced by
the closed burdizzo castration and hence prior castration is better. The findings in the current study are consistent with those reported elsewhere. Baredo et al., (2013) working with a pastoral community in Ethiopia, reported that farmers shortened the fattening period by 50%, from six months to three months. The finished sheep fetched better prices than their contemporaries. These authors associated the fast weight gain to better feeding of the sheep. However, such studies are rare in Kenya. Weight gain is associated with breed type, feeding and health among other factors. In the economies where sheep finishing is advanced, the exotic breed of sheep lambs must gain at least 300gm/day to be profitable. In the current study, sheep lambs, mainly crosses of the local RM breed (Katiku et al., 2013, Maina 2013) gained at least 47.68 gm/day. This average daily gain was lower than that reported elsewhere (Khan et al., 2014). Khan et al (2014) studied a local breed of Thali sheep lambs that recorded weight gain of 104 gm/day.

Figure 3: Effect of time of castration in fattening lambs

**Strategic deworming and Helminths control**

In the feedlot sheep, results showed that *Haemonchus* was the most predominant nematode genera (64%) followed by *Trichostrongylus* (24%), *Strongyloides* (8%) and *Oesophagostomum* (4%). The PCV were within the normal range (14% to 45%). These genera, especially *Haemonchus* or stomach worm which is blood sucker, are among the common and most pathogenic nematodes in grazing ruminants. The results of the faecal egg counts over the three sampling periods are summarized on Table 1. The level of infection with gastrointestinal nematodes remained fairly constant throughout the fattening period based on the faecal egg counts. This was in spite of the anthelmintic treatments on Day 0 and Day 84. Upon comparisons of the three breeds in the flock, the Red Maasai had a higher mean worm egg counts followed by the Red Maasai x Merino crosses and Red Maasai respectively. This was consistent with known breed susceptibilities to gastrointestinal nematodes (Mugambi, et al., 1997). The possible explanation for the observed moderate infections even after interventions could be the confined grazing which could have predisposed the lambs to high larval challenge. This confinement is not common in the traditional grazing system in the trial area where animals are allowed to graze in a wide and dispersed area, thereby exposing them to low helminth challenge.

Pooled faecal samples were cultured and a differential larval (L3) counts carried out on Day 0 samples. This was to determine the common nematode genera in grazing sheep in the trial area.
The aim of strategic deworming is to prevent buildup of parasitic infections to the level of affecting production in a flock of sheep. This means reducing or eliminating environmental contamination and should include several key goals: Sheep should be as free as possible of parasites during periods of low or reduced nutrition such as during the dry season, The ewes should be free of parasites at lambing time and Recontamination of wet season pastures should be eliminated or reduced for the first three months. It was explained that the control strategies depend on the type of worm(s) involved. It was explained that certain features of the project area could be used to inform the application of strategic helminth control in small ruminants. These features included the following: Transmission of nematode helminths is seasonal and a significant portion of the year is too dry for worm larvae to survive on pasture. Treatments can be targeted at times of the year helminth challenge was highest. These targeted treatments can also help alleviate chronic infections during the subsequent dry season. During the dry season, invading worm larvae may enter a period of delayed or arrested development in the animals (hypobiosis) and treatment can be effectively be targeted at these using the classes of anthelmintics that are effective against these larvae. This can reduce infection rates during the ensuing dry season and reduce pasture contamination in the next wet season. Stocking rate may be low but at certain places, including watering points and bomas, this may be high.

Gastrointestinal parasitism in sheep adversely affects their productivity through reduced breeding efficiency, lowered milk production, reduced weight gains, decreased hair quality, reduced feed efficiency and negatively affect the immune system by decreasing the animal’s ability to fight off other health problems.

**Table 1:** Comparison of helminth infection amongst the sheep at the day of introduction to the feedlot and at the day of auction.

<table>
<thead>
<tr>
<th>Day of sampling</th>
<th>Number sampled</th>
<th>Mean worm egg counts (epg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>91</td>
<td>1140</td>
</tr>
<tr>
<td>84</td>
<td>65</td>
<td>800</td>
</tr>
<tr>
<td>99</td>
<td>95</td>
<td>1024</td>
</tr>
</tbody>
</table>

**Other diseases encountered**

During the fattening scheme, two disease outbreaks were observed in the flock. These were sheep pox and blue tongue. The outbreaks were associated with the introduction of sheep from different farms, some of which could have been incubating the diseases. The two diseases were later contained through vaccination, sheep pox by the project team while blue tongue vaccine was administered with the help of the county veterinary office. The blue tongue outbreak also affected farmers’ animals in and around the trial site. Sheep pox is a highly contagious viral disease of sheep characterized by nodules in the mouth, skin, and nose. The nodules can also appear in the tongues and udder. The disease is spread by insects or through contaminated equipment. It is controlled through strict biosecurity and vaccination.

Blue tongue is a viral, non-contagious viral disease that affects many domestic animals although sheep particularly affected. It is characterized by eye and nasal discharges, drooling, fever and swellings in the mouth, head and neck, lameness and respiratory problems. It is controlled through vaccination. Both sheep pox and blue tongue are important diseases of trade because they are notifiable disease whose outbreaks are followed by quarantine and restriction of animal movements.

A total of six deaths, equivalent to a mortality of 4.5%, occurred during the fattening scheme. This is consistent with observed in sheep farming, particularly in extensive systems. Although no post mortem examinations were carried out, these deaths were associated with complications from the disease outbreaks experienced. However, observations made by farmers on three of the dead sheep indicated impaction in the
large intestines. They associated this observation to feeding of the sheep with molasses. This could not be independently verified.

**Body condition monitoring during fattening period**

The health and nutritional status of the lambs in the feedlot was monitored at the point of entry into the fattening scheme and at the end of trial using body condition scoring. The scoring criteria were based on the method for sheep described by Boundy (1982). The details of the criteria are summarized in Table 5.

**Table 2: Body condition scoring in sheep**

<table>
<thead>
<tr>
<th>Body condition score</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Very thin</td>
<td>Spinous process very prominent and sharp; transverse process also easily felt and sharp; fingers can be pushed easily under ends; loin muscle shallow, concave; no fat over muscle, under skin.</td>
</tr>
<tr>
<td>2</td>
<td>Thin</td>
<td>Spinous process prominent but less sharp; transverse process smoother on ends; fingers can be pushed with little pressure under ends; loin muscle more depth and fullness; no discernible fat covering</td>
</tr>
<tr>
<td>3</td>
<td>Average</td>
<td>Spinous process easily felt with finger pressure but smooth not sharp; transverse process smooth and fat covered; firm pressure needed to push fingers under edge; loin muscle full</td>
</tr>
<tr>
<td>4</td>
<td>Fat</td>
<td>Spinous process can be felt with considerable finger pressure; transverse process cannot be felt, end discovered with fat; loin muscle full with cover of fat.</td>
</tr>
<tr>
<td>5</td>
<td>Very fat</td>
<td>Spinous process cannot be felt; back broad with hollow; transverse process cannot be felt; loin very wide and thick over loin edge; evidence of fat around dock extending forward on rump.</td>
</tr>
</tbody>
</table>

Figure 5 shows a comparison of the body condition scores before and after finishing. The body condition of the weaner lambs improved during the period of finishing. The body condition scores for a majority of the sheep at the beginning of the fattening was between 1 (very thin) and 2 (thin), comprising 69.7% of the flock. This compared to 28.4% in condition 3 (average) and 1.8% in condition 4 (fat). There was none in the 5 score. The corresponding figures for the last day of the finishing (Day 99) were 35.2% for conditions 1 and 2, 47.6% for condition 3, 16.2% for condition 4 and 1.0% for condition 5. A chi-square analysis of the body condition data showed that time was significantly related to the sheep body condition score (p<0.001). This indicated that the finishing process improved the overall performance of the flock over time and therefore increased their marketability. This was corroborated by analyses comparing the live weights and the body condition score. The results shown on Table 8 indicated a close relationship between the body condition scores and live weight.

The body condition scores were also compared across breeds (Table 6) and this shown similarities in the distribution of the body condition scores across the breeds represented in the scheme.
Table 3: A comparison of the body condition scores and the mean live weights for the sheep at the feedlot

<table>
<thead>
<tr>
<th>Body condition</th>
<th>Mean live weight (kg)</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.2</td>
<td>1.39</td>
</tr>
<tr>
<td>2</td>
<td>24.4</td>
<td>0.46</td>
</tr>
<tr>
<td>3</td>
<td>29.5</td>
<td>0.52</td>
</tr>
<tr>
<td>4</td>
<td>37.0</td>
<td>1.06</td>
</tr>
<tr>
<td>5</td>
<td>44.0</td>
<td>4.61</td>
</tr>
</tbody>
</table>

Table 4: The comparison of body condition scores across breeds

<table>
<thead>
<tr>
<th>Breed</th>
<th>Body condition scores</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Dorper</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RM_Merino crosses</td>
<td>9</td>
<td>78</td>
</tr>
<tr>
<td>Red Maasai</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>102</td>
</tr>
</tbody>
</table>

Public auction of fattened lambs

The public auction was successful and an initial flock of 60 finished lambs weighing 30(kg) and above sold out and on live weight basis as the project intended. The remainder was disposed-off within a week. The project working with the CBO, managed to pioneer the sale of finished sheep lambs on live weight basis and through public auction forum which was a new experience in the area. The fattening experiment observed that it was possible to finish and market sheep for a period of 3 months rather than keeping them a year or so as is the normal practice. The prices realized from sold sheep lambs were far much better than the prices obtained when similar lambs are sold on visual appraisal at farm gate. The AFAPPO CBO got a contribution of ten percent from the sale proceeds from each animal, amount totalling to KES 61000, money that is being used for table banking and as capital for loaning to individual community members to meet family expenses and therefore improving their livelihoods. The project pioneered a leaders meeting that brainstormed on the idea of establishing a livestock market yard in the village.

Estimation of economic profitability of sheep fattening scheme

Economic profitability of sheep lamb fattening scheme was evaluated (Table 5) through estimating the expected cost benefit parameters (net present value (NPV), gross margin (GM), benefit cost ratio (BCR) and internal rate of return (IRR)) for 2 batches of finished lambs within a year. The estimation were based on an Inflation rate of price per annum of 10%, a Depreciation on capital asset of 5%, a discounting rate of 11.50% which is the Current Central Bank of Kenya Interest Rate and Mortality rate per season4.5%.
### Table 5: Cash Flow Analysis and projections for Lamb Fattening

<table>
<thead>
<tr>
<th></th>
<th>YEAR 1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Input Costs</strong></td>
<td><strong>1st Batch</strong></td>
</tr>
<tr>
<td>Balance B/F</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td><strong>Capital expenditure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rams pen - Materials only</td>
<td>13,250.00</td>
<td>662.50</td>
</tr>
<tr>
<td>Shepherd shelter - Materials only</td>
<td>9,520.00</td>
<td>476.00</td>
</tr>
<tr>
<td>Equipment - Chaff Cutter</td>
<td>20,000.00</td>
<td>1,000.00</td>
</tr>
<tr>
<td>Hay barn - Materials only</td>
<td>60,440.00</td>
<td>3,022.00</td>
</tr>
<tr>
<td>Fencing - Materials only</td>
<td>186,600.00</td>
<td>9,330.00</td>
</tr>
<tr>
<td>Feeding and watering troughs - Materials only</td>
<td>25,000.00</td>
<td>1,250.00</td>
</tr>
<tr>
<td>Cost of Labour (Fencing, Pen, Hay barn, Toilet, normal maintenance)</td>
<td>49,224.00</td>
<td></td>
</tr>
<tr>
<td><strong>Total of capital expenditure</strong></td>
<td></td>
<td>364,034.00</td>
</tr>
<tr>
<td><strong>Recurrent expenditure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of Lambs* (Market value of weaner lambs)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cost of pasture establishment and hay harvesting (10 acres)</td>
<td>211,333.33</td>
<td>106,333.33</td>
</tr>
<tr>
<td>General Animal Husbandry Practices</td>
<td>87,551.00</td>
<td>87,551.00</td>
</tr>
<tr>
<td>Gum boots for farmers</td>
<td>2,610.00</td>
<td>-</td>
</tr>
<tr>
<td>Metal tool box</td>
<td>1,400.00</td>
<td>-</td>
</tr>
<tr>
<td>Cost of Veterinary care</td>
<td>24,670.00</td>
<td>24,670.00</td>
</tr>
<tr>
<td>Cost of feed, protein and energy concentrates</td>
<td>148,760.00</td>
<td>148,760.00</td>
</tr>
<tr>
<td>Auction Cost</td>
<td>8,850.00</td>
<td>8,850.00</td>
</tr>
<tr>
<td><strong>Total of recurring expenditure</strong></td>
<td></td>
<td>485,174.33</td>
</tr>
<tr>
<td><strong>Total costs</strong></td>
<td>849,208.33</td>
<td>391,904.83</td>
</tr>
<tr>
<td>1% Miscellaneous</td>
<td>8,492.08</td>
<td>3,919.05</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td>857,700.42</td>
<td>395,823.88</td>
</tr>
<tr>
<td><strong>Benefit</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sale of lambs</td>
<td>973,912.00</td>
<td>973,912.00</td>
</tr>
<tr>
<td>Hay</td>
<td>11,200.00</td>
<td>31,111.11</td>
</tr>
<tr>
<td>Wheat grain (30Bags)</td>
<td>90,000.00</td>
<td>-</td>
</tr>
<tr>
<td>Value of sheds and equipment @ depreciation of 5% per year</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Revenue</strong></td>
<td>1,075,112.00</td>
<td>1,005,023.11</td>
</tr>
<tr>
<td><strong>Net Benefit</strong></td>
<td>217,411.58</td>
<td>830,529.86</td>
</tr>
<tr>
<td><strong>Cost Benefit Analysis</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GM</td>
<td>217,411.58</td>
<td>609,199.23</td>
</tr>
<tr>
<td>Present Value of Costs (PVC) @ 11.50%</td>
<td>769,238.04</td>
<td>354,999.00</td>
</tr>
<tr>
<td>Present Value of Benefits (PVB) @ 11.50%</td>
<td>964,226.01</td>
<td>901,366.02</td>
</tr>
<tr>
<td>NPV @ 11.50% per batch</td>
<td>194,987.97</td>
<td>546,367.02</td>
</tr>
<tr>
<td>Cumulative NPV</td>
<td></td>
<td>3,663,439.80</td>
</tr>
<tr>
<td>Benefit Cost Ratio (BCR)</td>
<td>1.3</td>
<td>2.6</td>
</tr>
<tr>
<td>IRR</td>
<td>&gt;500%</td>
<td></td>
</tr>
</tbody>
</table>

*Cost of Lambs refers to the market value of weaner lambs.*
The calculations are based on scenario where the farmers come together and contribute 132 sheep lambs for fattening under feedlot system. Under this scenario, the computed cost benefit parameters gave a positive NPV and GM and a CBR above one. This means that the costs invested in the sheep lamb fattening scheme are recovered and high benefits realized. The discounted NPV was far above zero implying that it is worthy investing in sheep lamb fattening for enhanced future benefit with a very high IRR of above 500%.

**Utilization of the proceed by gender after sale of sheep**

Utilization of proceed of sales by gender was analyzed. The share of proceed was high for men (56%) followed by youth (23%) and lowest was women with 21%.

**Table 5**: Utilization of the proceed by gender after sale of sheep

<table>
<thead>
<tr>
<th>Gender</th>
<th>% share of benefit (N=16)</th>
<th>Reason(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>56%</td>
<td>• For general farm management&lt;br&gt;• School fees and other emergencies&lt;br&gt;• For use in purchasing farm inputs</td>
</tr>
<tr>
<td>Women</td>
<td>21%</td>
<td>• Food and clothing for children and other members’ of the family</td>
</tr>
<tr>
<td>Youth</td>
<td>23%</td>
<td>• Buying cloth and personal affairs&lt;br&gt;• School fees</td>
</tr>
</tbody>
</table>

**Conclusion**

The fattening experiment observed that it was possible to finish and market sheep for a period of 3 months under communal platform as opposed to rearing them for a year or so as is the normal practice. The prices realized from finished sheep lambs and sold through public auction and on live weight basis were far much better than the prices obtained when similar lambs are sold on visual appraisal at farm gate.

**Recommendations and way forward**

- The following were given as lessons learnt and recommendations for sheep fattening/health:
- It is good to start with lambs aged 4 months and castrated one month before commencement of the fattening phase.
- It is important to vaccinate sheep prior to introduction into the feedlot. In liaison with the county veterinary authorities, the common diseases in the locality can be identified and targeted vaccinations carried out. For example in Nturumenti, vaccinate against, sheep pox, blue tongue and enterotoxaemia.
- Feeding should include both forages and concentrates. Preferably feeds high in energy such as grains are good in supplementing the energy sources of forages, molasses and protein concentrates. Mineral licks should consist of balanced commercial products.
- The equipment for processing forages should be motorized since manually operated are laborious to use.
• The animals getting into the feedlot should be dewormed 48 hours before so that the grazing paddock for finishing is not subjected to heavy larval contamination, hence heavy helminth infection challenge.
• The ages and live weights for the sheep in the feedlot were not uniform and this could have contributed to the observed variance in the parameters monitored. In future the animals should be similar to enable them respond better to the interventions like diet, deworming, etc.
• The implementation of the weaner lambs finishing experienced some challenges and in future some of the interventions could be handled differently. These include the feeding of the sheep including preparation of the ration, increasing farmer’s participation in the scheme and data recording by the farmers and the stockman, especially on events as they happen.
• There are useful lessons learnt during the implementation of the finishing scheme and these will come in handy in future projects.
• Farmers maximize returns by fattening and marketing lambs when sold on live weight basis.
• Targeted finishing of sheep lambs can be embraced by farmers as a commercial activity that promises to improve their livelihoods.

Acknowledgement

The project was implemented on collaborative basis. The success was because of the contributions of all the stakeholders namely scientists, extension officers, donors and more importantly the consumers and beneficiaries of the interventions, the farmers. The donor funding agency, ICARDA through IFAD and the support offered by the Director-General KALRO is highly appreciated.

References


Study on Peri-urban camel production systems on mount Marsabit: Opportunities, challenges and future prospects

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Abstract

The Climate change has contributed towards the setting up of peri-urban camels keeping system on Mt. Marsabit, owing to abundance of browse around centres and improved access to Marsabit town. In the past, indigenous camel keepers i.e., Gabbra and Rendille, were shunning mountainous areas mainly due to biting flies, tick loads, camel skin diseases and cold temperatures. Demand for camel milk by huge urban population in centre due to rural urban migrations as a result of improved infrastructure and devolved system has led to the setting up of peri-urban camels production systems in Marsabit mountain. The main challenges facing camel production include: slippery ground during rainy season, limited water sources, high tick load, high infestation of biting flies, limited land size and crop-human-camel conflict among others. Opportunities lie in the camel being resistant to severe droughts and provision of milk throughout the year unlike cattle. Tarmac road and Proximity to town which offers higher prices for milk. This study examined camel production, opportunities, challenges and future prospects on Peri Urban camels on Mt. Marsabit in 2015. The findings of this study revealed that Mount Marsabit is suited for Peri-urban camel production owing to abundance of browse, good means of transportation and proximity to Marsabit town which provides a good market for camel milk. In the past, indigenous camel keepers i.e., Gabbra and Rendille, were shunning mountainous areas mainly due to biting flies, tick loads, camel skin diseases and cold. With modern livestock drugs, climate change, high demand for camel milk by the high population in Marsabit town, camel have been introduced on Mount Marsabit. This study came up with the following recommendations, that there is need to empower the peri-urban camel keepers on camel husbandry and milk traders. The traders should consider selling their milk in other towns such as Isiolo, Nanyuki and Nairobi since the means of transport is efficient. Value addition of camel milk should be encouraged to make it more appealing to non-camel keeper’s consumers.

Key words: Camel keepers, milk, Mt. Marsabit, Peri-urban, production

Introduction

Kenya has the fifth largest population of camels in Africa, after Somalia, Sudan, Mauritania and Ethiopia. The country has an estimated population of about 1.6 million camels (MoLD, 2010). They are mainly concentrated in former North-Eastern (54%), Eastern (Marsabit, and Isiolo Counties (29%), Rift Valley (13%) and Coast regions (4%). The Arid and Semi-Arid lands (ASALs) hold about 80% of Kenyan camels. The camel’s unique physiological, anatomical and ecological adaptations enable the camel to produce and supply milk to pastoral households throughout the year (Farah, 1996). Other uses include: supply of meat, blood, draught power, transport, recreation, wool and fibre production, leather, bones for making jewellery, cultural and religious significance (Kuria, 2007). Their ability to survive droughts surpasses any other domestic livestock. Humidity is the main factor limiting wider distribution of camels. The Southern limit of the dromedary range is approximately 400-500 mm isohyets (Huelsebusch, 2002). In the face of recurrent droughts, more and more communities that were not traditional camel keepers are increasingly turning to camel rearing to ensure food and nutrition security. Additionally, camel rearing within peri-urban areas for the purpose of supplying milk and meat to the increasing human population in the town centres is emerging as a new production system. This study therefore reviews the opportunities, challenges and future prospects of peri-urban camel production system on Mt. Marsabit.
Methodology

Study area

This study examined camel production, opportunities, challenges and future prospects on Mount Marsabit focusing on Saku constituency. The Mountainous area of Mt. Marsabit has a suitable environment for camel rearing because of its shrubs and trees which are abundant throughout the year. The evergreen vegetation includes olea Africana (Ejers, croton megalorpus, acaia ssp, euphobia tircullii etc are abundant. Camels feeding habit of up to 2.5mts high gives it advantage over cows, and its behaviour of dispersing over a wide area while feeding and are very selective and requires between 10-12hrs of feeding depending on season. The study was carried out in the following areas (Ula ula, karare, Kamboi, Marsabit town, Gabbra scheme, Sagante, Dub Gindolle, Badasa, Dirib Gombo, Kubi Bagasa, Malka lakole, Qachacha, and Gar Qarsa) Marsabit Mountain. Camels were first introduced on Marsabit Mountain in early 1990 through rural urban migration, persistent droughts and by adaptors as a result of recurring droughts decimated of the livestock populations rendering local communities destitute and devoid of their livelihoods. As a consequence camel production on Mt. Marsabit is taking tall.

Figure 1: Map of Marsabit mountain

Droughts and floods in particular have devastating consequences on the environment, society and the wider economy.

Data collection

The sources of data included: the Rendille, Gabbra, Borana and Samburu camel keeping communities, the area chiefs, primary schools owning camels, milk traders/ transporters, herdsmen. Data was collected using checklists administered through key informant interviews. Personal observations through transect walks was also used to gather information. The participants (KI) were purposefully selected and other additional criteria factored in the sampling were sex and age. Check list was used to collect the data at each site. The interview took between 1-1.5 hrs. Answers and discussion points generated were recorded in a notebook.
Statistical analysis

The answers from the different study sites were clustered and synthesized. Data and information was organized into thematic areas, statistically analysed using SPSS, and reports generated for logical conclusion.

Results and discussion

Herd Structure

Weaners constituted highest proportion of the camel herds, followed by lactating females and calves subsequently. Dry pregnant fall in fourth position followed by breeding bulls. While the castrates constituted least in the herd structure. Weaners formed the highest proportion in the herds mainly because adaptors purchase Weaners to begin with as shown below.

Figure 2: Herd structure on Mt Marsabit

The breeds of camels kept are dominantly Somali but few Rendille/Gabra breeds were also reported. The Rendille and Gabra camels had been relocated from the lowlands by the migrants while the Somali were bought by either the adopters or migrants. Somali camels were the largest with body weight of 450-700kgs depending on sex and type, (hoor, shidar and gelab) milk 3-5 litres, heavy feeder and mainly creamy in colour. Rendille camels are smaller compared to Somali (350-450kgs). has milk production of 2-3lts per day, dose well in poor pastures and rough terrain, mainly cream or brown in colour.

Production System

Camels are kept under extensive production system on the periphery of farms, few farmers also keep camels in untilled areas of their farms. During rainy season, camels are moved from farming areas to the open areas at the foot of the mountain. Keepers reported that during rainy season insect infestation is very high and camel do not also withstand high precipitation coupled with cold temperatures and fogs. Camels kept on the mountain during rain seasons would suffer from pneumonia, cough, skin diseases and trypanosomiasis. During dry seasons camels are moved back to the farms where they mainly feed on Euphorbia tirucalli and crop residues.
Uses of camels in Mt. Marsabit

Camels are kept/adopted for several reasons:

- Milk: The camel provide milk throughout the year for household use and excess marketed.
- Mountain has plenty of camel browse and camels would not go far from home in search of browse.
- Camel are not prone to drought. Recurrent droughts lead to death of cattle and keepers adopted camel as alternative livelihood.
- Camel have higher market value compared to cattle.
- Camel bull have more meat compared to cattle bull.
- Rural urban migration: the pastoralists in low lands moved to farm on the Mountain and thus came in with their camels and provide market for camel products.
- Camel plough up to 4 acres a day and oxen only plough 1 acre.
- Camel adaptors realized that Somali breeds of camels do well in mountainous areas than in lowlands.
- Cattle rustling on Mount Marsabit forest is a menace and camel rustling is not common as it just browses at the periphery of the forest.

Distribution of camels on Mt. Marsabit

The total number of camels kept on the mountain captured by this study is 955 heads and are distributed as follows in the following areas: Karare 205 camels, Kamboi 91, UlaUla 178, Sagante 37, Dub Gindolle 28, Gabbra scheme 46, Badasa 7, DiribGombo 32, Kubibagasa 216, Goro Rukesa 28, Qachacha, 32, Gar Qarsa pry 25 and Manyatajillo primary 30. 93% of camels kept on the mountain are of Somali breeds and 6% are crosses of rendille/Gabbra and Somali crosses and 1% Rendille breed 9% are indigenous keepers.

![Peri-urban Camel distribution in Mt. Marsabit](image)

**Figure 3** Distribution of camels in Mt. Marsabit
Most preferred camel forage in the study area

<table>
<thead>
<tr>
<th>Local names</th>
<th>botanical names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ano</td>
<td>Euphorbia tirucalli.</td>
</tr>
<tr>
<td>dahar</td>
<td>Acacia tortilis.</td>
</tr>
<tr>
<td>Itit/bilhel</td>
<td>Acacia mellifera</td>
</tr>
<tr>
<td>Hinjim- Ildokonyanto</td>
<td>duospermaemropholia</td>
</tr>
<tr>
<td>Loyapasei</td>
<td>Aspilliamossambicensis</td>
</tr>
<tr>
<td>Ngujit/ngojet/ows-</td>
<td>grass.</td>
</tr>
<tr>
<td>Lmaraga/harcha.</td>
<td>Blispharislinalofia</td>
</tr>
<tr>
<td>Sucha</td>
<td>Barleriaeranthemoides</td>
</tr>
<tr>
<td>Siteti</td>
<td>grewiatenaxs</td>
</tr>
<tr>
<td>Lgogomi</td>
<td>grewiabicola.</td>
</tr>
</tbody>
</table>

**Disease**

The most common diseases are:

**Camel Calves disease**

<table>
<thead>
<tr>
<th>Diseases-English</th>
<th>Rendille/Samburu</th>
<th>Borana</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sarcoptic mange.</td>
<td>Ngamunyani</td>
<td>Chito/laqayo/kurtubale</td>
</tr>
<tr>
<td>Ring worm</td>
<td>Nabahar</td>
<td>Robi</td>
</tr>
<tr>
<td>Orf</td>
<td>Afturo</td>
<td>Dumburur/abthara</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>Ngiriata</td>
<td>Alpati</td>
</tr>
<tr>
<td>Camel pox</td>
<td>Lpepedo/ado</td>
<td>Fino/chitoraba</td>
</tr>
<tr>
<td>Pneumonia.</td>
<td>Namonywa</td>
<td>worans</td>
</tr>
<tr>
<td>Sudden death</td>
<td></td>
<td>Qurtama</td>
</tr>
<tr>
<td>Tick paralysis</td>
<td></td>
<td>Shilmi/vagal/vaqil</td>
</tr>
<tr>
<td>External abscess.</td>
<td>Qarfat</td>
<td>Qarfat</td>
</tr>
<tr>
<td>Swollen joints</td>
<td></td>
<td>didis</td>
</tr>
<tr>
<td>Boil</td>
<td></td>
<td>Dula</td>
</tr>
<tr>
<td>cough</td>
<td></td>
<td>Qufa</td>
</tr>
</tbody>
</table>

**Mature camel disease**

<table>
<thead>
<tr>
<th>Diseases-English</th>
<th>Rendille/Samburu</th>
<th>Borana</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bronchial influenza/pneumonia</td>
<td>Ilchama</td>
<td>Furi</td>
</tr>
<tr>
<td>External abscess</td>
<td>Qarfat/ngoboh</td>
<td>Shilmi</td>
</tr>
<tr>
<td>Ticks</td>
<td>ilmanjer</td>
<td>Tite</td>
</tr>
<tr>
<td>Biting flies</td>
<td>Lajingani</td>
<td>Qandich/Qando</td>
</tr>
<tr>
<td>Swollen gland</td>
<td>Ilngaringari/kanid</td>
<td>Ganthi/simpiro/daasi</td>
</tr>
<tr>
<td>Trypanosomiasis</td>
<td>Omar/daasi/daasi</td>
<td>Mini</td>
</tr>
<tr>
<td>worms</td>
<td>Inthumai</td>
<td>qufaa</td>
</tr>
<tr>
<td>cough</td>
<td>yaar</td>
<td></td>
</tr>
</tbody>
</table>
Camel Milk Marketing

Camel milk is utilised for both domestic use and for marketing. Most respondent’s sell between 3-20 litres of milk on a daily basis in Marsabit town. The study also captured milk traders in Marsabit town. There are about 3 main traders for camel milk: 1. Shed oboya 2. Ibrahim Boru 3. Boru Elema, all the three sale about 150 litres of camel milk on daily basis. i.e. 450 litres of milk per day. There is also significant amount of camel milk coming from Turbi every morning with a buses and mini buses. Milk from Turbi was reported to be 300 litres on a daily basis. Milk around mountain is mainly transported by Motorbikes and Matatus

A camel dairy group supported by Agricultural sector development support programme (ASDSP) was established recently and their major role is to bring to order camel milk marketing sub-sector in Marsabit town.

Opportunities

The study findings revealed that camels are preferred due to many factors. Their adaptation makes them survive rainless seasons on the scantiest feed and exist in areas where other livestock species cannot survive. Camels and their products fulfill many socio-economic functions among the livestock keepers. Camel meat and milk is consumed by the pastoral communities, especially during the time of drought. Although camels are rarely slaughtered, during the dry season they are slaughtered and their meat is preserved, so that many households depend on the dry meat for a longer period. Camels produce 4 to 6 litres of milk per day, which is consumed by camel keepers whenever the camels are near the home sites, during dry and drought periods and some is sold which brings income to the households. When milk is plentiful, it is fermented into a product called mala. Camel milk is highly regarded by the camel keepers as it is believed to have medicinal value to cure various diseases such as diabetes, ulcers and stomach-related problems. There is a ready market for camel milk in Marsabit town since there are many employees from the government and NGOs. It is easy to transport milk from Marsabit Moutains to the small towns along Marsabit moyale road since the road has been tarmacked. In addition, camels are used as means of transport for camel keepers. They offer good means of transport to the pastoralists when migrating as they carry their household goods and the materials of their traditional houses. Camels carry old people, the ill, toddlers, pregnant women and those who have just given birth.

Key constraints in camel production

1. Marsabit Mountain is very slippery during rainy season and occasionally leading to fracture of camels,
2. Water sources for camels are limited and camel also require longer time to drink water (over 6 hours). Competition of water with other livestock species and human beings,
3. Injuries from trees and stumps is very common in mountainous area,
4. Tick and biting flies a major problem and cost of their management very high. Washing with acaricides done on a weekly basis and camels injected against trypanosomiasis twice a year,
5. The forested areas have deep galleys which is very dangerous to heavy breeds i.e. fall into the gully leading to fracture or death,
6. Camel dispersing grazing behavior in forested areas results into herding difficulties i.e., frequent straying of camels from herds,
7. Salts requirements are very high compared to cattle. All water sources in the mountains are soft water. Camel salt daily requirement is high compared to other livestock species,
8. The land size to rare camels is small, most land are used for farming and settlement,
9. The high rate of camel adaption would mean high camel population and by extension lead to depleted forage resources,
10. Difficult to get a herder- Most children go to school and herding is no longer attractive livelihood,
11. Crop- camel conflict- in farming areas camels don’t fit at all especially during cropping season but during dry season camels are brought to graze on Euphobia tirucalli.

Conclusion and Recommendations

This study examined camel production, opportunities, challenges and future prospects on Peri Urban camels on Mt. Marsabit in 2015. The findings of this study revealed that Mount Marsabit is suited for Peri-urban camel production owing to abundance of browses, good means of transportation and proximity to Marsabit town which provides a good market for camel milk. In the past, indigenous camel keepers i.e., Gabbra and Rendille, were shunning mountainous areas mainly due to biting flies, tick loads, camel skin diseases and cold. With modern livestock drugs, climate change, high demand for camel milk by the high population in Marsabit town, camel have been introduced on Mount Marsabit. This study came up with the following recommendations, that there is need to empower the peri –urban camel keepers on camel husbandry and milk traders. The traders should consider selling their milk in other towns such as Isiolo, Nanyuki and Nairobi since the means of transport is efficient. Public transport i.e., Buses and mini buses can be used to transport the milk. Value addition of camel milk should be encouraged to make it more appealing to non-camel keeper’s consumers.

References


Assessment of growth rate, milkyield and nutrition of sahiwal and their crosses with Small East African Zebu cattle in Magadi, Kajiado county, Kenya

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Abstract
This study was carried out to determine the suitability of Sahiwal and their crosses with Small East African Zebu (SEAZ) in Magadi since this area is the driest in Kajiado County. Specifically the study aimed at determining farmers’ perception on the suitability of Sahiwal and their crosses with SEAZ, determining the performance of Sahiwal and their crosses with SEAZ and come up with recommendation domains on use of Sahiwal in upgrading SEAZ in Kajiado and future research areas. The project was designed to purposely target farmers owning SEAZ, Sahiwal and crosses of Sahiwal and SEAZ cattle. A questionnaire was used to collect data and information which included the following parameters; Lactation length, Daily milk yield, Age at weaning, Market age, Supplementation strategies, and Liveweight. The data collected was analyzed using SPSS computer package. Sahiwal was ranked number one breed of preference because of high milk yield and high growth rate. The distance to agro-vet shops where mineral supplements could be obtained was reported to be 26km which was too long for most of the pastoralists.

Keywords: Sahiwal, Small East African Zebu, Arid areas, Growth rate, Milk yield, Nutrition

Introduction
Kajiado County is largely comprised of ecological zones (IV) and (V) which is characterized by little and unreliable rainfall that is less than 500mm per annum (Pratt and Gwynne 1977), frequent droughts, high livestock disease challenge among others. However, according to Bekure et al (1991) most part of the County lies in the semi-arid and arid zones (zones V and VI). In spite of this harsh environment, the SEAZ cattle have been known to thrive relatively well because they are indigenous and have adapted to the prevailing environmental conditions. In a study to characterize the (SEAZ) cattle in Kajiado, (Rege et al, 2001; Mwacharo and Druck 2005) realized that most of the Maasai pastoralists still applied traditional management regime to their indigenous SEAZ zebu cattle, Sahiwal and crosses of Sahiwal and SEAZ cattle. This study by Rege et al, (2001) covered only the SEAZ and therefore there is a paucity of information about the production of Sahiwal and their crosses with the SEAZ in Magadi.

Literature has been reviewed on performance levels of the first lactation economic traits viz. age at first calving, first lactation 305-day or less milk yield and first service period in Sahiwal cattle. Various studies showed that the estimates of age at first calving, and first service period ranged from 879.00 ± 9.00 days to 1579.00 days, 1183 ± 31 kg to 2585.00 ± 86.00 kg and 68.07 ± 2.3 days to 271 ± 8.7 days, respectively in Sahiwal cattle (Dongre et al 2011).

Sahiwal and their crosses fulfill several roles in the lives of Maasai pastoralists in Kenya. These roles include using the Sahiwal for breeding (mainly upgrading the SEAZ) and other objectives that include insurance against risks and social functions (Ilatsia et al 2010). This study was not specific to performance of Sahiwal and their crosses in the different climatic or ecological environments in Kajiado. It is necessary to determine the performance of these genotypes in the different environments in order to understand the
extent of introducing Sahiwal into Kajiado and other arid and semi-arid lands. This shows that there is a knowledge gap regarding the suitability of Sahiwal and their crosses in Kajiado. Furthermore, the study was carried out in Kajiado south contrary to other drier parts of the district like Magadi. A study by Maichomo et al. 2009, in Magadi showed that there was no significant difference in performance between Orma and Sahiwal x Orma crosses. This could be attributed to trypanotolerance ability of the Orma and the trait was transmitted to the Sahiwal crosses with the Orma. There is therefore a need to study the performance of the Sahiwal and their crosses with the SEAZ. It was hypothesized that the drier zones could not meet the requirements of crosses with the high-performing Bos taurus breeds, and that improved Bos indicus breeds, with lower nutritive requirements and greater adaptability to drought conditions, would be more suited to the more arid environments, even though their production response capability was relatively low. For these arid areas, the Sahiwal breed was considered a suitable dual-purpose dairy and beef breed to replace the indigenous SEAZ (J.C. M Trail and K. E. Gregory, 1981). This may not be the case especially now when challenges caused by environmental change are being felt.

Over the years, there has been an introduction of animal genetic resources mainly Sahiwal bulls from KARI-Naivasha and other places to Kajiado County for upgrading of local SEAZ. Sahiwal are dual purpose cattle with higher milk yield and growth rate under relatively improved management system than the SEAZ cattle. Sahiwal on average can produce about 5 kg of milk per day (Mwandoto 1986) whereas SEAZ can produce about 2 kg per day (Rege et al. 2001). However, their performance under arid and semi-arid conditions may or may not surpass that of the SEAZ. This reduces the capacity of stakeholders to make informed decisions on the appropriateness of Sahiwal and their crosses with the SEAZ in Arid and Semi-Arid Lands (ASAL).

Recent surveys to characterize SEAZ cattle in Kajiado revealed presence of Sahiwal blood in approximately 50% of the herds owned by Maasai pastoralists. It was established that these Sahiwal had been introduced into Kajiado in form of bulls, specifically to upgrade the SEAZ [Meyn et al; 1977]. Farmers in Kajiado have been acquiring Sahiwal bulls from KARI-Naivasha since the early 1970s (Muhuyi: Personal communication). However, Sahiwal may not perform optimally in Kajiado contrary to Naivasha. These farmers have been using the Sahiwal bulls to upgrade the local SEAZ cattle to improve milk yield.

The production potential of Sahiwal and their crosses with the SEAZ needs to be studied to ascertain their performance and adaptability/preference in ASAL in general and particularly in Kajiado County. There is also need to find what use is made of F1 crosses. There is a possibility of F1 bulls being used to breed unimproved SEAZ, hence downgrading the Sahiwal genes and retrogressing towards the original SEAZ status. There is also the possibility that the pastoralists continue to bring in new Sahiwal bulls to breed the F1 crosses, an activity which leads to production towards pure Sahiwal.

**Overall objective:**

The overall objective was to determine the suitability of Sahiwal and their crosses with the SEAZ in Kajiado County.

**Specific objectives:**

The specific objectives were:

1. To determine farmers’ perception on the suitability of Sahiwal and their crosses with SEAZ
2. To determine the performance of Sahiwal and their crosses with SEAZ.
3. Recommendation domains on use of Sahiwal in upgrading SEAZ in Kajiado and future research areas
Materials and Methods

Study site

The study was conducted in Kajiado County and specifically Magadi Sub-County.

Study design and data analysis

The project was designed to purposely target farmers owning SEAZ, Sahiwal and crosses of Sahiwal and SEAZ cattle. These farmers were then selected at random in each of the two sub-Counties. A questionnaire was then used to collect data and information from the farmers. The data and information collected from the selected farmers were based on the following performance parameters: Lactation length, Daily milk yield, Age at weaning, liveweight, market age, Supplementation strategies. The data collected was analyzed using SPSS computer package.

Results and Discussion

Background information

Majority of the household heads were males just like the respondents. Livestock and especially cattle information is given by men (Table I). Therefore decision making regarding cattle is made by men as the household head.

Table 1: Age, sex and years in school of Household Head (HH) and respondent

<table>
<thead>
<tr>
<th>Sex HH</th>
<th>Male(97)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years in school HH</td>
<td>8.2±5.8</td>
</tr>
<tr>
<td>Occupation of HH</td>
<td>Farmer(53), Teacher(30)</td>
</tr>
<tr>
<td>Age of respondent(yrs)</td>
<td>43.4±13.5</td>
</tr>
<tr>
<td>Sex respondent</td>
<td>Male(87)</td>
</tr>
</tbody>
</table>

Numbers in parenthesis ( ) are the number of questionnaires administered.

Cattle population

In a livestock and wildlife census conducted by Kenya Wildlife service in collaboration with other organizations, Livestock population had reduced by 56% and 62% for cattle and goats respectively (KWS report 2010). The average population of cattle per household in Magadi was estimated at 11, 12, and 14 for Small East African Zebu (SEAZ), Sahiwal and Sahiwal x SEAZ crosses respectively (Table 2).

Table 2: Cattle population, management system and herd size trend per household

<table>
<thead>
<tr>
<th>Breed</th>
<th>Number</th>
<th>System of management</th>
<th>Herd size trends</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEAZ</td>
<td>11±2</td>
<td>Extensive(90)</td>
<td>Increasing(47)</td>
</tr>
<tr>
<td>Sahiwal</td>
<td>12±3</td>
<td>Extensive(89)</td>
<td>Increasing(60)</td>
</tr>
<tr>
<td>Sahiwal x SEAZ</td>
<td>14±2</td>
<td>Extensive(91)</td>
<td>Increasing(78)</td>
</tr>
</tbody>
</table>

Although the census did not categorize the loss according to breed, it is worth noting that the 56% loss was highly significant. Such a loss could impoverish the pastoralists rendering them vulnerable to food insecurity, school dropouts, increased child mortality and other consequences associated with poverty. The pastoralists tend to keep large herds of cattle irrespective of the breed in total disregard of the different quantitative feed requirements.
There are different systems of ruminant livestock management like intensive, semi-intensive and extensive systems. In a study to characterize the (SEAZ) cattle in Kajiado, it was realized that most of the Maasai still apply traditional management regime to their cattle, including Sahiwal and their crossbreds (Rege et al., 2001; Mwacharo and Druck 2005). This system mainly involves extensive grazing with minimal supplementation. Mineral supplements are provided from commercial sources or natural licks. According to the survey, the main system of management practiced was extensive system (Table III). According to Ilatsia et al (2011) the proportion of Sahiwal crossbreds with the SEAZ was higher in Narok than in Kajiado County although the proportion of households with pure Sahiwal cattle was higher in Kajiado than Narok. Kajiado is more arid than Narok and it is ironical that there were more pure Sahiwal here than in Narok.

**Breed Preference**

Pastoralists in Magadi prefer to keep Sahiwal more than any other breed (Table III).

**Table 3: Breed preference**

<table>
<thead>
<tr>
<th>Breed</th>
<th>*Rank</th>
<th>Reasons for breed preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEAZ</td>
<td>3(52)</td>
<td>1. High milk yield</td>
</tr>
<tr>
<td>Sahiwal</td>
<td>1(46)</td>
<td>2. High growth rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Good market</td>
</tr>
<tr>
<td>Sahiwal x SEAZ</td>
<td>2(46)</td>
<td></td>
</tr>
</tbody>
</table>

*Rank = 1 and 4 represent most preferred and least preferred respectively*

However there were more crosses of Sahiwal and SEAZ followed by Sahiwal (Table 2). Pastoralists preferred Sahiwal because of high milk yield, high growth rate and good market price of the animal. This is because the crossbreed has high meat production and milk yields compared to the traditional zebu according to SORALO report, 2010. This shows that the Maasai prefer crosses of Sahiwal and zebu more than the pure traditional zebu which is confirmed by the results of this study. According to Meyn et al., 1977 Sahiwal have been introduced into Kajiado in form of bulls, specifically to upgrade the SEAZ.

In a study to determine cattle trait preference by pastoralists, Ouma et al 2004 found out that pastoralists had high preference for traits linked to high liveweight, trypanotolerance and herd increase such as fertility in bulls and reproductive performance in cows. This is an indication that given a choice between Sahiwal and the indigenous zebu, pastoralists would prefer Sahiwal because of the higher liveweight. A study carried out in Kajiado showed that pastoralists were experimenting with adding improved Boran and Sahiwal cattle to their herds of SEAZ (Randall et al 2006).

**Livestock Feeding**

Cattle in Magadi rely almost entirely on pasture for their nutrition. This is evidenced by the type of management practiced which is mainly extensive or free grazing in the field (Table II) and natural pasture being the main source of feed (Table IV). In a study to characterize the Small East African Zebu (SEAZ) cattle in Kajiado, it was realized that most of the Maasai still apply traditional management regime to their cattle, including Sahiwal and their crossbreds (Rege et al., 2001; Mwacharo and Druck 2005). Grass is the cheapest source of livestock feed in Kenya as observed by Pratt and Gwynne (1977).
Table 4: Dry season Livestock feeding

<table>
<thead>
<tr>
<th>Type of feed</th>
<th>Source</th>
<th>Distance to source(km)</th>
<th>Reliability of source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural pasture</td>
<td>Communal grazing area</td>
<td>6</td>
<td>Reliable</td>
</tr>
<tr>
<td>Mineral supplements</td>
<td>Agrovet shops</td>
<td>26</td>
<td>Reliable</td>
</tr>
<tr>
<td>Crop residues</td>
<td>Own farm</td>
<td>2</td>
<td>Reliable</td>
</tr>
</tbody>
</table>

**Feed supplementation**

In this study 85.4% of the pastoralists reported that they do not give any feed supplements to their cattle. For most part of the year range grasses are in form of standing hay which is low in quality. The disadvantage of standing hay is that it continues to increase in lignin content and decreases in nitrogen even if it is apparently very dry as long as it is left attached to its roots. According to Madsen et al (1997), the most critical point for many tropical forage plants is the low nitrogen content apart from the low digestibility of the carbohydrates. This low quality pasture does not meet the nutritional requirements of the animals.

**Production Performance**

**Milk yield**

The different breeds of cattle kept in Magadi exhibit different performance in terms of milk yield as shown in Table V. Sahiwal is the highest milk yielder whereas the SEAZ is the lowest yielder according to this study. The daily yields were 2.4, 7.4 and 4 litres for SEAZ, Sahiwal and crosses of Sahiwal and SEAZ respectively (Table V). Sahiwal on average can produce about 5 kg of milk per day (Mwandoto 1986) whereas SEAZ can produce about 2 kg per day (Rege et al 2001). A study carried out in Kajiado and Narok counties showed that the Maasai kept Sahiwal cattle mainly for milk production (Ilatsia et al 2011). According to Rege et al. (2001), SEAZ cattle attain sexual maturity at over three to four years. Cows give birth to their first calf at four to five years and then on average the calving interval is 15 months. Milk production is below 1000 litres per lactation. The SEAZ can also produce substantial amount of milk. The Nandi zebu for instance can yield 1300kg of milk per lactation with a butterfat content of 5.8% (Epstein 1971). Milking was done twice a day, that is morning and evening. First lactation milk yield in Sahiwal was reported to range from 1183 ± 31 kg to 2585.00 ± 86.00 kg according to work done by Dongre et al 2011.

**Growth rate**

Apart from milk yield, another cattle performance indicator is growth rate. Growth is affected by both environmental conditions and the animal’s genetic make-up. In this study the pastoralists in Kajiado indicated that the growth rate of the Sahiwal was highest among the breeds considered. The breed ranked lowest in terms of growth rate was SEAZ (Table 6). Dongre et al 2011 found out that age at first calving and first service ranged from 879.00 ± 9.00 days to 1579.00 days and 68.07 ± 2.3 days to 271 ± 8.7 days respectively. The SEAZ can attain significant growth rate when given supplementary feeding using Acacia tortilis pods and cotton seedcake as demonstrated in a study by Bii et al 2010.

**Table 5: Milk yield and growth rate**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>BREED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SEAZ</td>
</tr>
<tr>
<td>Daily milk yield(litres)/animal</td>
<td>2.4</td>
</tr>
<tr>
<td>Growth rate(Rank)</td>
<td>3</td>
</tr>
</tbody>
</table>

*Rank: 1 and 3 represent most preferred and least preferred respectively*
Age at maturity
Pastoralists consider marketable age as an important factor used to measure the productivity of cattle. According to Rege et al. (2001), SEAZ cattle attain sexual maturity at over three to four years. Cows give birth to their first calf at four to five years and then on average the calving interval is 15 months. Farmers in Magadi reported that their cattle attain reproductive maturity or age at first service at two to three years of age depending on the breed (Table 6).

Table 6: Marketable age and Reproductive age

<table>
<thead>
<tr>
<th>Breed</th>
<th>Marketable age(yrs)</th>
<th>Reproductive maturity age(yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEAZ</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Sahiwal</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>SahiwalxSEAZ</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Conclusion and Recommendation

In Magadi, individual land holdings are small (aprox. 13 acres per household) which is not usually the case as would have been expected in extensive ranching. This scenario is attributed to land ownership in the area where cropping under irrigation is practiced. This takes place largely in the Nguruman escarpment using water from numerous springs and river Ewaso-Nyiro. Land in the rest of the sub-county is utilized communally for grazing in spite of group ranches having been subdivided. Technologies on pasture improvement had not been adopted in Magadi since there was no land under improved pasture. There was higher population of Sahiwal and SahiwalxSEAZ crosses than SEAZ which shows that farmers were upgrading the SEAZ to Sahiwal. This might have a long term effect on survival of the relatively more vulnerable Sahiwal and generally cattle in the entire arid sub-County. There is likely to be minimum mineral supplementation due the long distance to the source. Sahiwal was reported to be the highest milk yielder and therefore could be promoted for milk production in the sub-County. It can be concluded that Sahiwal can do well in Magadi where cropping is done especially in Nguruman area where crop residues can be used as a supplement during the dry season. It is also necessary to promote pasture production in Magadi so as to support the more feed demanding Sahiwal and also carry out actual data collection on milk yield and liveweight parameters.

Acknowledgement

The authors acknowledge most sincerely the Director General of Kenya Agricultural and Livestock Research Organization for funding this project under Kenya Agricultural Productivity and Agribusiness Program (KAPAP). The authors are also indebted to the Magadi Sub-County Agriculture, Livestock and Fisheries Extension officers and the interviewed farmers for their participation, invaluable support and cooperation during implementation of this project.

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Hygiene Practices and Microbial status of Raw Bovine Milk in Loitokitok, Kajiado County, Kenya

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Abstract

Loitokitok sub-County in Kajiado County, produces an estimated 5million litres of milk at gross income of about KES 297million annually. This study aimed to assess the dairy value chain in the area. One of the key objectives was to evaluate status of milk handling and hygiene at household level. A multistage sampling was used in interviewing 200 respondents using a semi structured questionnaire to collect socio demographic and production data. Additionally, 39 raw milk samples were analyzed for total viable counts (TVC), coliform counts (CC), aflatoxin milk1(AFM1) using recommended standard methods. The total Mean±SEM milk yield per household from all animals was 12.3±1.1 litres from mean number of 3 lactating cows mainly of cross breed exotic cattle. About 81% of respondents screened animals before milking compared to about 20% who did not (P value: χ² = <0.001) with traditional gourds and plastic containers being used to store milk thus predisposing milk to contamination. Mean ±SEM TVC was 2.9 x 10⁸±2294cfu/ml (p=0.199) with 74% of sample being above the Kenya Bureau of standards (KeBs) threshold of (<2 x 10⁶ cfu/l). On the other hand Mean CC was 1.65 x 10⁷±67.8 cfu/ml (P=0.02) with 56.4% (p<0.001)) failing to meet the KeBs threshold (500,000 cfu/ml). The Mean of AFM1 was 56.04±8.08 ppt (p<0.001). About 53.8% did not meet the recommended standards for AFM1 level in raw milk. Escherichia coli, Staphylococcus aureus and Bacillus species were the main microbial flora found in milk samples. Milk hygiene still remains a constraint with major sources of contamination emanating from environmental factors. Training on hygienic handling of milk be supported as anchored on proper dairy business model under well-structured milk collection system.

Key words: milk hygiene; Loitokitok; AFM1, TBC and coliforms

Introduction

According to reports by the State Department of Livestock Development (2015), Loitokitok sub-County has, 2,798 dairy cattle giving annual milk supply of 5 million litres. Additionally, a substantial number of zebu cattle provide 1.55 million litres of milk annually. Translating into a mean output of 4.9 litres per cow per day, still below the national milk out of 5-10 litres per cow. Currently, raw milk retails at KES 60.00 per litres hence translating into annual gross income of KES 297 million compared to KES 4.5Billion nationally.

In 2015, Kenya Agricultural and Livestock Research Organization (KALRO) in collaboration with the Loitokitok sub-County Livestock Department and a private company, Inua Maisha initiated a project aimed at improving milk production and nutrition of dairy farmers in the area. Given the multifaceted nature of the project, the support implication therefore required a multidisciplinary and multiagency approach to address the constraints. In this arrangement KALRO was to provide Knowledge, Information and Technologies (KIT) and build the capacity of partners on use of KIT. Capacity building therefore focused on improvement of feed availability and quality, milk hygiene and support of Inua Maisha in development of milk collection system to create market for dairy farmers. The Inua Maisha handled community
mobilization and fast tracked the establishment of milk bulking and cooling facility as farmers would only be motivated once milk buying was initiated.

In order to measure impacts of these interventions, a baseline survey was designed to help generate information on existing practices with regard to feeds and feeding practices, animal husbandry practices, milk hygiene, handling and marketing in the area. The study mainly focused on key parameters of milk hygiene such as aflatoxin M1, total viable counts (TVC), coliforms, and selected isolates such as E.coli, salmonella and brucellosis. This paper presents baseline information on status of milk production levels, quality and utilization among dairy producers in Loitokitok. The information shared is expected to assist in designing capacity building efforts towards improved quality of marketed milk in Loitokitok.

Materials and Methods

Study sites

The study was conducted in Loitokitok sub-County, one of the administrative units of Kajiado County. The sub-county covers an estimated area of 6,356.3 km². It is situated between longitudes 36° 5’ East and 37°5’ East and between latitudes 1°0’ South and 3 °0’ South. The high altitude belt along the slopes of Mt. Kilimajaro (Ecological zone II-III) is suitable for production of high value agricultural crops and intensive dairy farming while the semi-arid (Ecological zone IV-V) climate conditions across the vast swathe of Loitokitok lowlands is suitable for the extensive beef and small ruminant production. Rainfall is bimodal and ranges between 900-1250mm per year with long rains falling in October to December, while short rains fall between March and May (MoLD, 2015; Jaetzold et al., 2006)

Design and Sampling Procedure

This was a cross-sectional study conducted between September and October 2016 among small scale dairy farmers and agro-pastoralists living in Loitokitok. A multistage sampling method was used in selection of respondents. The study site was first stratified into 5 divisions/wards namely Kimana, Mbirikani, Rombo, Central and Entonet. Additionally, agro-ecological zonation was used to capture differences in production systems within each ward hence giving a total of 8 locations and 9 specific sampling sites where actual data was collected. All households owning dairy cattle formed the sampling frame from which a total of 200 respondents were distributed among the sites using probability proportional to population size (PPS) method (Mugenda and Mugenda, 1999). To attain randomization in each site, landmarks such as roads and river and water pipelines were used as reference points along which households were selected. Using a systematic sampling, the 1st household was selected randomly by rolling a bottle in the middle of the village then every 5th household from point of reference and along the major road and on both sides was selected.

Data collection

Household baseline questionnaire survey was conducted to collect data on marital status, age, household size, education levels, livestock numbers and income levels (in Kenya shillings (KES), milk yield in litres and utilization of the same in litres was collected by trained enumerators whose education background was pegged on post-secondary education. The enumerators were supervised by the authors. All farmers with dairy animals formed the sampling frame where 200 household were selected and interviewed. Only one person who preferably the household head or spouse was interviewed in each household using semi structured questionnaires. Additionally, 4 Focused Group Discussions (FGD), involving about 10 farmers knowledgeable on dairy farming and livestock management was conducted in Central, Entonet, Mbirikani using a checklist with open ended question on key production issues.

Milk sampling and microbial analysis

Pooled raw bovine milk samples were collected from dairy households in Rombo (n = 10, Entonet (n = 5), Kimana (n = 16) and central (8) locations. Thirty nine (39) milk samples were collected in sterile 50 ml falcon bottles and immediately put in cool box with icepacks. Out of the 39 samples 11 samples were
collected at the Loitokitok Farmers Dairy Cooperative whereas the rest were collected at household level. The cooperative started the milk business 2 months preceding the survey and buys raw milk from farmers and sells it unprocessed to consumers in Loitokitok town. The collected samples were taken to Analabs Laboratory services in Nairobi for analysis.

Laboratory analysis of milk quality

Enzyme Linked Immune-Assay (ELISA) for aflatoxin M1 (AFM1) in milk

In this study Aflatoxin M1 Assay ELISA Kit (HelicaBiosystem INC; Cat. No: 961AFLM01M), USA, for AFLM1 was used to analyze the concentration of AFM1 in raw milk. Helica Aflatoxin Assay is a solid phase competitive enzyme immunoassay used for detection of aflatoxin M1 in milk and milk products (Mohammad et al., 2016). The protocols described by the manufacturer (HelicaBiosystem INC) were applied. Briefly, in the HELICA Aflatoxin M1 Assay, a solid phase competitive enzyme immunoassay, an antibody with a high affinity for aflatoxin M1 was coated onto polystyrene microwells before the standard or sample was added to the appropriate well. Where aflatoxin M1 was present it was bound to the coated antibody. Subsequently, aflatoxin bound to horse -radish peroxidase (HRP) was added and it bound to the antibody not already occupied by aflatoxin M1 present in the sample or standard. The contents of the wells were decanted, washed and an HRP substrate was added which developed a blue colour in the presence of the enzyme. The intensity of the color was directly proportional to the amount of bound conjugate and inversely proportional to the amount of aflatoxin M1 in the standard or sample. Therefore, as the concentration of aflatoxin M1 in the sample or standard increased, the intensity of the blue colour would decrease. An acidic stop solution was added which changed the chromogen colour from blue to yellow. Then the microwells were measured optically by a micro-plate reader with an absorbance filter of 450nm (OD450). The optical densities of the samples were compared to the OD's of the kit standards and an interpretative result. The results were then compared to Kenya Bureau of Standards (KeBS) and EU recommended cut off values of 50 Parts per trillion (PPT) (Obade et al., 2015; Kangethe and Lang’at, 2009).

Bacterial load and isolation

Assessment of bacteria load involved serial dilutions of milk samples using peptone water (Himedia, 0000046823, Mumbai, India) and total viable counts (TBC) were determined using standard plate count agar (Oxoid, 1682552, Basingstoke, England) incubated at 37°C for 48 h. In this study, the coliforms were determined using Violet Red Bile Agar (Himedia, 0000266115, Mumbai India). The number of colony forming Units (cfu/mL) of original sample was enumerated using the procedures by Health Protection Agency (D2 HPA, 2005) National procedures for TBC and D4 HPA) for coliforms (HPA 2005). In terms of bacterial isolation, this study focused on selected microorganism which included Salmonella, E. coli, Staphylococcus aureus which are the most notorious in milk contamination from environmental and animal source. Isolation of the candidate microorganisms was done using Blood Agar (Himedia, 0000268841), MacConkey agar (Oxoid, 1604243) and Todd Hewitt, Oxoid, 1726798 using the methods of Carter and Cole 1990. To identify presence of Brucella antibodies in the sample, Milk Ringing Test (MRT) method was used by subjecting the samples to Brucella antigen (Institute Pourquier, Lot: 253).

Data Analysis

The data was entered, cleaned and analyzed using the IBM SPSS statistics version 20 (2011). Independent samples t-test was carried out on quantitative data while descriptive statistics were carried on the qualitative data and test for significance done using chi-square where applicable.
Results and Discussion

Socioeconomic and demographic characteristics

Social and demographic characteristics of the study population are summarized in Table 1. Majority (82.5%) of the households were headed by males with most respondents having a mean age of 50 years. The mean household size was 5 with literacy found to be low with more than 70% of the respondents having attained up to primary school level compared to 25.1% who had attained secondary education. Reliance on remittances from children, sale of livestock especially cattle and livestock products contributed a significant proportion of family income. Although income from salaried employment was singularly high, it was restricted to only 17.5% of total population in the area. This implies that most households eked their living from farming as the major economic activity.

Table 1: Population characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of respondent (count: N=200)</td>
<td>50.35</td>
<td>1.19</td>
</tr>
<tr>
<td>Sex of household head: (Male: n=165)%; (Female:n=35)%</td>
<td>82.50</td>
<td>17.50</td>
</tr>
<tr>
<td>Household size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total household members (N=200)</td>
<td>4.74</td>
<td>0.21</td>
</tr>
<tr>
<td>Total male in the household (n=165)</td>
<td>3.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Total females in household (n=200)</td>
<td>2.29</td>
<td>0.12</td>
</tr>
<tr>
<td>Education Level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary (n=88)%</td>
<td>51.50</td>
<td></td>
</tr>
<tr>
<td>Secondary (n=43)%</td>
<td>25.10</td>
<td></td>
</tr>
<tr>
<td>Adult education (n=40)%</td>
<td>23.40</td>
<td></td>
</tr>
<tr>
<td>Estimated Gross household Income (KES)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salaried employment by household head (n=35)</td>
<td>50,000</td>
<td>0.00</td>
</tr>
<tr>
<td>Pension income (n=33)</td>
<td>7,000</td>
<td>0.00</td>
</tr>
<tr>
<td>Income received by the children of the house hold (n=66)</td>
<td>22,500</td>
<td>930.26</td>
</tr>
<tr>
<td>Sale of milk and milk products (n=68)</td>
<td>6,603</td>
<td>427.41</td>
</tr>
<tr>
<td>Sale of cattle last month (n=68)</td>
<td>27,868</td>
<td>1526.46</td>
</tr>
<tr>
<td>Sale of Hides and skin (n=63)</td>
<td>13,627</td>
<td>1361.50</td>
</tr>
</tbody>
</table>

Milk Production and utilization

Milk production and utilization at household level is summarized in Table 2. The mean±Standard Deviation (SD) of gross milk off-take was 8.12±8.7 (p<0.05) litre/household. With mean number of 3 lactating cows at the time of survey, this translated into a gross of 6.02 litres per cow per day but varied between the ward depending on the prevailing AEZ and management. In Loitokitok, the Ministry of agriculture figures indicate an average of 3.3 l of milk output per cow per day for exotic cattle and 0.7L for zebu (MoLD, 2014 and 2015) but far below the national production output per cow which varies between 5 to 10 litres (Kurwijila and Bernnet, 2011; Easterling et al., 2013; Mugambi et al., 2015; MoLD, 2013 and FAO, 2011). Of the total milk produced across the wards there was no significant differences in utilization of milk produced especially for home consumption, portions were fed to calves and sold to consumers in nearest market. With household size of about 5 people, amount consumed at home translated to between 0.6 l to
0.96 l per person per day almost close to daily recommended intake levels. This presents a good condition for commercialization of milk without affecting milk intake by children.

Table 2: Mean ± SD Daily Milk Production and utilization (in Litres)

<table>
<thead>
<tr>
<th></th>
<th>Kimana</th>
<th>Rombo</th>
<th>Imbirikani</th>
<th>Total (N=28)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily yield per cow</td>
<td>7.3421±7.64</td>
<td>3.8333±2.71</td>
<td>3.6±3.65</td>
<td>6.0167±6.52</td>
<td>0.354</td>
</tr>
<tr>
<td>Daily Household production</td>
<td>9.03±9.88</td>
<td>6.5±4.04</td>
<td>6.3±6.98</td>
<td>8.18±8.70</td>
<td>0.769</td>
</tr>
<tr>
<td>Home consumption</td>
<td>5.625 ± 9.45</td>
<td>2.9375 ± 2.24</td>
<td>3.1667 ± 1.51</td>
<td>4.775 ± 7.80</td>
<td>0.714</td>
</tr>
<tr>
<td>Fed to calf</td>
<td>5.57 ±8.2</td>
<td>1.75</td>
<td>5.00</td>
<td>5.08 ± 7.2</td>
<td>0.911</td>
</tr>
<tr>
<td>Sold</td>
<td>4.92±4.41</td>
<td>3.25±2.63</td>
<td>5.25±6.72</td>
<td>4.61±4.14</td>
<td>0.799</td>
</tr>
</tbody>
</table>

Milk Hygiene practices by dairy households

Practicing production of clean and hygienic milk not only insures health and nutrition of households but also ensures quality products that can fetch premium price at the market. Milk can be contaminated within the udder when a lactating cow gets infected. It can also be contaminated by environmental factors. The main cause of milk contamination is normally from mastitis infection. The study established high level of awareness of mastitis among the respondents. About 81% of respondents reported checking for physical signs for udder health before milking compared to about 20% who did not (P value: χ² = <0.001). According to the focus group discussion (FGD), a majority of farmers understood mastitis when it had reached clinical level where visible signs can be noted such as swelling of the udder, blood spots in milk, flakes in fresh milk when teat is squeezed among others. Additionally there was limited knowledge on use of reagents such California Mastitis Test reagents to detect the condition at subclinical level. The most critical stage of mastitis where control methods based on farm hygiene is most important. If not controlled, it can reduce milk output by about 50% (FAO, 2014) Poor hygiene can also be contributed by use of difficult to clean containers. Use of traditional containers such as gourds especially among the pastoral and agro pastoralists was higher (50%; n=68) compared to 25.7% (n=35) plastic containers and metal cans (p<0.001) among highland communities. Metal cans were more common (24.3%; n=33) with households that kept exotic cattle. Pouring milk on dark surface (50% n=68) to check for clots or blood spots in milk in addition to observing for swollen udder (50%, n=68) were the major signs used by most farmers to detect mastitis (χ² = p<0.001). Previous studies indicate that these could be signs for later stages of the diseases (Pandey andVoskuil, 2011) hence most farmers may not be aware of the subclinical phase of the diseases (Peters et al., 2015; Ogola et al., 2007). In the event that farmers detect mastitis in milk, 68% of farmers preferred to offer such milk as feed to weaker livestock compared to 32% who poured away (χ²: p<0.001).

Microbial quality of raw milk as measured level of TVC, CC and AFM1

Table 7 presents a summary of total viable counts, coliform count and aflatoxin M1 in the samples. The mean TVC count was very high in all the samples analyzed compared to recommended cut off values according to Kenya Bureau of Standards (2.0 x 10⁶). Comparatively, 74% of the samples did not meet the KeBs standards compared to 25.6% which failed to meet the KeBs standards. The mean coliforms in the samples was high (p=0.002) with 56.4% of the samples failed to meet the Kenya Bureau of standards (500,000 cfu/l). Kimana had the highest number of samples that failed to meet the KeBs limits for coliform (CC) cut off values(p<0.001). Table 11 gives summary of selected bacterial isolates analysed in this study. The study E. coli remained the most dominant isolate in milk samples followed by Bacillus species and Staphylococcus aureus(p<0.001).

The mean values aflatoxin milk 1(AFM1) which is a hydroxylated form of aflatoxin B1 (AFB1) was significantly high (p<0.001) in milk samples analyzed (table 7). About 53.8% compared to 46.2% (p=0.027)
of the milk samples were above the European health protection Association (HPA) and Kenya Bureau of Standards (KeBs) recommended cut off values (50ppt) for AFM1.

**Table 3:** Microbial status of raw milk as measured by TVC, Coliforms Count and AFM1 (N=39)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SEM</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Viable Counts</td>
<td>2997.24</td>
<td>2294.36</td>
<td>0.199</td>
</tr>
<tr>
<td>(cfu/mL) x10⁵</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coliforms (cfu/mL)</td>
<td>165.27</td>
<td>67.80</td>
<td>0.02</td>
</tr>
<tr>
<td>x10⁵</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aflatoxin M1 (PPt)</td>
<td>56.04</td>
<td>8.08</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 4:** Percent of samples within KeBs recommended level of TVC (<2000000); P=0.490

<table>
<thead>
<tr>
<th></th>
<th>Kimana (n=16)</th>
<th>Entonet (n=5)</th>
<th>Rombo (n=10)</th>
<th>Central (n=8)</th>
<th>Total (N=39)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passed</td>
<td>10.3</td>
<td>0.0</td>
<td>7.7</td>
<td>7.7</td>
<td>25.7</td>
</tr>
<tr>
<td>Failed</td>
<td>30.8</td>
<td>12.8</td>
<td>17.9</td>
<td>12.8</td>
<td>74.3</td>
</tr>
<tr>
<td>% of Total</td>
<td>41.0</td>
<td>12.8</td>
<td>25.6</td>
<td>20.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Table 5:** Percent of samples within recommended Coliform cutoff level <500000 (χ²= 0.061)

<table>
<thead>
<tr>
<th></th>
<th>Kimana (n=16)</th>
<th>Entonet (n=5)</th>
<th>Rombo (n=10)</th>
<th>Central (n=8)</th>
<th>Total (N=39)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passed</td>
<td>10.3</td>
<td>2.6</td>
<td>17.9</td>
<td>12.8</td>
<td>43.6</td>
</tr>
<tr>
<td>Failed</td>
<td>30.8</td>
<td>10.3</td>
<td>7.7</td>
<td>7.7</td>
<td>56.4</td>
</tr>
<tr>
<td>Total</td>
<td>41.0</td>
<td>12.8</td>
<td>25.6</td>
<td>20.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Table 6:** Percent of samples within the recommended AFM1 quality mark, 50 Parts Per Trillion (PPt) (P; χ²= 0.027)

<table>
<thead>
<tr>
<th></th>
<th>Kimana (n=16)</th>
<th>Entonet (n=5)</th>
<th>Rombo (n=10)</th>
<th>Central (n=8)</th>
<th>Total (N=39)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passed</td>
<td>28.2</td>
<td>7.7</td>
<td>2.6</td>
<td>7.7</td>
<td>46.2</td>
</tr>
<tr>
<td>Failed</td>
<td>12.8</td>
<td>5.1</td>
<td>23.1</td>
<td>12.8</td>
<td>53.8</td>
</tr>
<tr>
<td>Total</td>
<td>41.0</td>
<td>12.8</td>
<td>25.6</td>
<td>20.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>

**Table 7:** Percent occurrence of microbial Isolates in the samples

<table>
<thead>
<tr>
<th>Isolate</th>
<th>Kimana (n=16)</th>
<th>Entonet (n=5)</th>
<th>Rombo (n=10)</th>
<th>Central (n=8)</th>
<th>Total (N=39)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. coli</td>
<td>20.5</td>
<td>7.7</td>
<td>12.8</td>
<td>7.7</td>
<td>48.7</td>
</tr>
<tr>
<td>Staphylococcus spp</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Bacillus sp</td>
<td>2.6</td>
<td>5.1</td>
<td>2.6</td>
<td>0.0</td>
<td>10.3</td>
</tr>
<tr>
<td>Coliform organism</td>
<td>17.9</td>
<td>0.0</td>
<td>10.3</td>
<td>10.3</td>
<td>38.5</td>
</tr>
<tr>
<td>Total</td>
<td>41.0</td>
<td>12.8</td>
<td>25.6</td>
<td>20.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Conclusion

Awareness on mastitis was high among the dairy producers although knowledge of the disease was still restricted to clinical stages where farmers can see the visible symptoms. Quality of milk was being compromised by use of poor containers such as traditional gourds especially from the pastoralist and agro-pastoral communities and plastic containers for communities in the highland areas. Most of the samples tested did not meet the European Union and Kenya Bureau of standards cut of values for total viable counts (TVC), coliform counts (CC) and aflatoxin milk 1 (AFM1). *Escherichia coli* was more prevalent in milk compared to other microorganism isolates indicating that most contaminants may have emanated from environmental factors.

Recommendation

Awareness on hygienic handling and harvesting of milk should be intensified to help improve quality of milk consumed at home and sold to the market. With over 50% of milk below recommended quality standards, the dairy value chain actors need to be sensitized on the basic dairy practices so as to assist in production and delivery of quality milk to intended market. Poor feed storage noticed in the area may have contributed to high aflatoxin levels found in milk hence proper feed conservation is required.

Acknowledgement

We would like to acknowledge the European Commission through the ASAL APRP national coordination unit for availing the funds that facilitated this work. The Director General, Kenya Agricultural and Livestock Research Organization (KALRO) for giving us the opportunity to conduct this research. The Institute and Centre Directors in SGRI in Marsabit and ALRI Kiboko for excellent logistical and technical support during the study. The County Government of Kajiado through the Loitokitok sub county livestock department, Inua Maisha and local leaders for their cooperation and participation in data collection.

Reference


Fish farming as an alternative livelihood in Makueni county, Kenya

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Abstract

This study sought to determine an enabling environment for fish farming as an alternative livelihood in Arid and Semi-Arid Lands (ASAL) of Makueni County, Kenya. A sample size of 146 fish farmers was used to rank enterprises engaged by a household. The costs and returns method was used to compare fish enterprise Nile tilapia (Oreochromis niloticus), African catfish (Clarias gariepinus) and tomatoes (Lycopersiconesulentum). Tomato production topped the enterprise rankings, while fish farming was seventh. Tomatoes production competed for similar scarce resources as those used in fish farming. The Profit cost ratio of catfish was (0.663, 0.561) and (0.652, 0.518) for tomatoes during the two seasons. Benefit cost ratio for catfish and tomatoes enterprises were greater than 1. One Kenyan shilling (KES) (note 100 KES= 1US$) invested in catfish and tilapia production returned KES 1.51 and KES0.79 respectively. The comparable return for tomato enterprise was KES 1.52 for one season. Catfish was the most profitable enterprise. Proximity to water sources and black clay soil sites were the best enablers of fish farming. Based on fish farming yields/returns per unit, it was recommended that catfish production can complement tomato farming

Key words: ASAL, catfish, compare, tilapia, tomatoes, Kenya

Introduction

Makueni has diverse farming activities that include agricultural crops, livestock and fishery (MOA, 2013). Aquaculture is an emerging enterprise in Makueni County encouraged by the National government beginning in the 1990s and promoted during the 2009-2012 Economic Stimulus Program (MCFD, 2013). Tilapia and catfish are the two types of fish farmed (MCFD, 2014). Costs and returns of fish farming and tomato farming were analyzed to determine an enabling environment for fish farming as alternative livelihood. Aquaculture is the farming of aquatic organisms in inland and coastal areas, involving intervention in the rearing process to enhance production with individual or corporate ownership of the stock being cultivated (Food and Agriculture Organization (FAO), 2005). This study focused on herbivorous and omnivorous finfish specifically Nile Tilapia (Oreochromis niloticus) and African Catfish (Clarias gariepinus). Herbivorous and omnivorous finfish are defined as fish species that have low protein requirements of less than 20 percent that can be derived from both plant and animal sources (Tacon et al., 2009). The group includes grass carp, common carp, other cyprinids, tilapias, milkfish and catfish, all of which require around 5 percent fishmeal content in their feeds. Kenya’s annual aquaculture production exceeded 12,000 Metric tonnes (Mt) in 2010 (FAO, 2010). The former Ministry of Fisheries Development (MOFD) broke down a total of 12,153Mt of fish into: Nile tilapia 9,115Mt, African catfish 2,118Mt and carp 729Mt. These were harvested from 23,478 ESP ponds and 8,399 Non ESP ponds (MOFD, 2010). By 2013, according to the Kenya National Bureau of Statistics, Kenya’s total fish production was 152,711, tonnes of which 23,501 tonnes were sourced from aquaculture (KNBS, 2014) as a result of adopters of the concluded ESP in 2012, tomatoes accounts for 6.72% of the total Kenyan horticultural crops (GoK, 2012). Makueni annual tomatoes production was 17,552 Metric tons in 2012 mostly grown using open field production system (HCDA, 2013). According to the Government of Kenya (GOK, 2009), the national average tomatoes production per hectare is 30.7 Metric tons. Average tomatoes production per hectares
assuming two cycles of planting and a farmer maximizes on the utilization of recommended inputs. Six tomatoes varieties commonly grown in Kenya are Romana V F, Cal J, Onyx, Beauty, Money Maker and Anna F1 (KARI, 2007). In Makueni county Onyx, Cal J and Money Maker dominate the tomatoes produced due to their adaptability to the warmer climate (MOA, 2012). Onyx is preferred by farmers due to its added advantages of being a high yielder, longer shelf life and resistant to diseases/pests (Waiganjo et al, 2006). Three major techniques used to determine comparative farm enterprise profitability are gross margin, budget analysis and return per unit input. These techniques are common partial measures selected although they do not follow the law of diminishing returns to scale (Whittaker et al, 1995). In this study, gross margin (GM) was used due to its simplicity and flexibility in determining enterprise profitability. Whittaker et al, 1995 further stipulate that gross margin relies on a number of assumption that farmers used different production and technology; the sale price used were those current during the production period for each of the farm enterprise for each operator.

Materials and Methods

Study area
Makueni County is located in the Eastern region of Kenya and its coordinates are 1° 48' 0" South, 37° 37' 0" East (GoK, 2015). The County borders Kitui to the East, Machakos to the North, Kajiado to the West and TaitaTaveta to the south. The County was formerly called the larger Makueni District. It is comprised of 9 Sub Counties which include: Makueni, Kathonzweni, Mbooni East, Mbooni west, Nzaui, Mukaa, Kilungu, Makindu and Kibwezi. The County’s population is 887,547 persons (KNBS, 2009). The area is mainly semi-arid and it experiences a bimodal rainfall pattern. The annual rainfall is bimodal with short rains occurring in October-December and long rains in March-May. The annual precipitation ranges from 200-600mm in the lower parts and 1340-1900mm- mm in the upper parts (Nyangito et al, 2011). The study was done in the larger Kibwezi that consists of Makindu and Kibwezi East Sub- Counties of Makueni County. Kibwezi was taken as a representative sample of the fish farmers in the County. The rationale behind this selection is that most of the fish farmers whether active ESP farmers or inactive ESP farmers are situated there with very few sparsely distributed in the remaining four Sub-Counties. The map of Makueni County is shown in Figure 1.

![Figure 1: Makueni (MtitoAndei to Nguu Corridor)](image)

Source: (Maina et al, 2017)
This study used a sample size of 146 respondents representing the target population of 1300 enrolled ESP fish farmers as established from secondary data from Makueni County Fisheries. As at the close of 2014 there existed 850 active and 450 inactive fish farmers (MCFD, 2014). Kibwezi had 300 farmers in 2011 and by 2014 it had stabilized at 192 active fish farmers and 124 inactive/dropout fish farmers. Due to limited resources, purposive sampling was used to select two sub-Counties; Makindu and Kibwezi East out of the six sub-counties in Makueni. The study used both focus group discussion and household questionnaires to collect primary data from respondents.

The sampling procedures used were as follow

1. Purposive sampling (Makueni/Kibwezi),
2. Stratification to differentiate between active/inactive) fish farmers.
3. Systematic simple random to select the 146 respondents.
4. Purposive to select farmer code 107 for the comparison between tomatoes and fish enterprises

Data collection

To determine enterprise ranking 146 respondents indicated order of enterprises’ contribution to the household income on a questionnaire. To determine an enabling environment, the researcher collected tomatoes profit and loss data for farmer code 107. The farmer was used since he had both enterprises in his operations. Secondly, his operations had the best farming practices among farmers in Makueni. Comparable data of fish and tomatoes was collected between June, 2015 and May, 2016, variable expenses were entered by a Research Assistant on operating sheets over that period. Fixed costs were recorded on semi-structured questionnaire that was administered by the Researcher. The collected primary data included the cost of production and income generated from the sale of the fish and tomatoes. Regarding the amount of funds utilized by the government to support the projects, secondary data was used (MCFD, 2013).

Data analysis

Both data for fish and tomatoes was entered and analyzed using Excel software. Data for tomatoes as a competing enterprise from farmer code 107 was used to compare the costs and returns between fish and tomatoes. Gross margins, net cash and net income for respective enterprises were computed. Data was entered into Excel and SPSS 22 spreadsheets. The quantitative analysis used gross margins, net fish income, benefit-cost ratio and profit analysis. Descriptive analysis used frequencies and percentages for key variable. Data on the Profit and Loss statement section of the questionnaire was entered and analyzed using Excel 2007 to get total revenue, gross margins. Total variable costs, total fixed cost, total cost and net fish income. Gross margin (GM) for fish farming was the difference between the total revenue (TR) and the total variable cost (TVC) of fish farming (GM = TR – TVC) while the gross margin ratio (GMR) is equals to (TR-TVC)/TR. A ratio of 0.35 or higher is more desirable (Olasunkami, 2012). In profit analysis, Profit was the positive difference between total revenue and total cost of the fish enterprise (Profit = TR – TC), if negative then it was considered a loss. Profit-cost ratio (PCR) was equals total cost divided by total revenue (PCR= TC/TR), a ratio of 0.65 or less is preferable (Olasunkami, 2012). Net Fish Income (NFI) was profit less non-cash adjustments to income plus gains/loss on capital assets sale. Benefit-cost ratio (ROR) was equal to total revenue divided by total cost (ROR=TR/TC)

Results and Discussion

Ranking of enterprises

Fish enterprise was in seventh position among enterprises ranked Makueni farmers. Tomatoes and cattle enterprises were in first and second position respectively as shown in Table 1.
Table 1: Ranking of other enterprises available to a general farmer

<table>
<thead>
<tr>
<th>Enterprise</th>
<th>Score</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomatoes</td>
<td>1.59</td>
<td>1</td>
</tr>
<tr>
<td>Cattle</td>
<td>1.89</td>
<td>2</td>
</tr>
<tr>
<td>Fruits (mangoes &amp; oranges)</td>
<td>2.1</td>
<td>3</td>
</tr>
<tr>
<td>Maize (Corn)</td>
<td>2.37</td>
<td>4</td>
</tr>
<tr>
<td>goats/sheep</td>
<td>3.09</td>
<td>5</td>
</tr>
<tr>
<td>Poultry</td>
<td>3.09</td>
<td>5</td>
</tr>
<tr>
<td>Fish (tialapia &amp; catfish)</td>
<td>3.22</td>
<td>7</td>
</tr>
</tbody>
</table>

The costs and returns for tomatoes and fish enterprises are shown in Table 2 and Table 3.

Table 2: Tomatoes gross margin and net income from 0.05ha in KES*

<table>
<thead>
<tr>
<th>Variable</th>
<th>units</th>
<th>KES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Revenue (TR)</strong></td>
<td>25cases @120Kg@50</td>
<td>150,000.00</td>
</tr>
<tr>
<td>Land preparation</td>
<td></td>
<td>7,000.00</td>
</tr>
<tr>
<td>Seedlings</td>
<td></td>
<td>10,000.00</td>
</tr>
<tr>
<td>Pesticides</td>
<td></td>
<td>7,500.00</td>
</tr>
<tr>
<td>Labor</td>
<td>72mdys@200mdy</td>
<td>14,400.00</td>
</tr>
<tr>
<td>Fertilizer (manure+ Dap)</td>
<td></td>
<td>3,550.00</td>
</tr>
<tr>
<td>Harvesting</td>
<td>25cases @KES100</td>
<td>2,500.00</td>
</tr>
<tr>
<td>Transport</td>
<td>25cases @KES200</td>
<td>5,000.00</td>
</tr>
<tr>
<td><strong>Total Variable Cost</strong></td>
<td></td>
<td>49,950.00</td>
</tr>
<tr>
<td><strong>Gross Margin</strong></td>
<td>$M_2= 100,050/500=KES200.10</td>
<td>100,050.00</td>
</tr>
<tr>
<td>Land lease</td>
<td></td>
<td>5,000.00</td>
</tr>
<tr>
<td>Equipment</td>
<td></td>
<td>20,000.00</td>
</tr>
<tr>
<td>Commissions</td>
<td></td>
<td>15,000.00</td>
</tr>
<tr>
<td>Fuel</td>
<td>78litres@100</td>
<td>7,800.00</td>
</tr>
<tr>
<td><strong>Total fixed costs</strong></td>
<td></td>
<td>47,800.00</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td></td>
<td>97,750.00</td>
</tr>
<tr>
<td><strong>Net Cash Income</strong></td>
<td></td>
<td>52,250.00</td>
</tr>
<tr>
<td>Depreciation</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Loss on machinery</td>
<td></td>
<td>10,000.00</td>
</tr>
<tr>
<td><strong>Net Tomatoes Income</strong></td>
<td>$M_2= 42,250/500=KES84.50</td>
<td>42,250.00</td>
</tr>
</tbody>
</table>

Source: (Author, 2015) * 100 KES=1 U.S $
### Table 3: Fish gross margin and net income from 0.05ha in KES*

<table>
<thead>
<tr>
<th>Item</th>
<th>Catfish(^1)</th>
<th>Tilapia(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unit</td>
<td>Unit</td>
</tr>
<tr>
<td>Total revenue</td>
<td>1800Kg+@KES360</td>
<td>416Kg@360</td>
</tr>
<tr>
<td>Variable costs</td>
<td>3000@KES15</td>
<td>2000@KES10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20,000.00</td>
</tr>
<tr>
<td>Feeds</td>
<td>2635Kg@KES54</td>
<td>1035Kg@KES54</td>
</tr>
<tr>
<td>Labor</td>
<td>896mhrs@KES60</td>
<td>400mhrs@KES60</td>
</tr>
<tr>
<td>Fertilizer(manure)</td>
<td>300Kg@KES7</td>
<td>79Kg@KES7</td>
</tr>
<tr>
<td>Transport</td>
<td></td>
<td>2,000.00</td>
</tr>
<tr>
<td>Total Variable Cost</td>
<td>336,650.00</td>
<td>142,440.00</td>
</tr>
<tr>
<td>Gross Margin</td>
<td>311,350.00</td>
<td>5,560.00</td>
</tr>
<tr>
<td>Fixed costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pond preparation</td>
<td>1 @ KES 60,000</td>
<td>1 @ KES 60,000</td>
</tr>
<tr>
<td>Land lease</td>
<td>5,000.00</td>
<td>5,000.00</td>
</tr>
<tr>
<td>Equipment</td>
<td>19,460.00</td>
<td>19,460.00</td>
</tr>
<tr>
<td>Commissions</td>
<td>64,800.00</td>
<td>14,800.00</td>
</tr>
<tr>
<td>Fuel</td>
<td>90litres@100</td>
<td>62litres@KES100</td>
</tr>
<tr>
<td>Total fixed costs</td>
<td>98,260.00</td>
<td>45,460.00</td>
</tr>
<tr>
<td>Total Costs</td>
<td>434,760.00</td>
<td>187,900.00</td>
</tr>
<tr>
<td>Net Cash Income</td>
<td>213,240.00</td>
<td>(39,900.00)</td>
</tr>
<tr>
<td>Depreciation</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>machinery loss</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Net Income</td>
<td>213,240.00</td>
<td>(39,900.00)</td>
</tr>
</tbody>
</table>

Source: (Authors, 2015) * 100 KES=1 U.S $; Fish production Kgs/ M\(^2\): \(^1\)= 6; \(^2\)=1.39

Fish production is normally measured using Kilograms per cubic water meter. The total sold tomatoes output (Q\(_f\)) was 3,000Kgs per 0.05 hectares (FPA). The computed per hectare (H=1) production (Q\(_h\)) is 60 Metric tons using the formula:

\[
Q_h = \frac{H}{FPA} \times Q_f / 1000
\]

Where

- Q\(_h\) is the computed average production per one hectare.
- H is an hectare equals 10,000M\(^2\)
- FPA is fish pond area equals to 500M\(^2\)
- Q\(_f\) is the total tomato output per fish pond area (FPA)

The per hectare computed tomato output collaborates with other global studies (Tschirley et al, 2004) but is inconsistent with the Kenya small scale farmer national average yield of 12 Metric tons (Atheron and Rudich, 1986) and 30.7 Metric tons for a progressive farmer (GoK, 2012). The results of tomato production in Table 2 found gross margin of KES.200.10/M\(^2\) and net profit of KES.84.50/M\(^2\) in returns. These returns are comparable higher than in Wachira et al, (2014) study that found a gross margin of KES.14.92/M\(^2\) and a net profit of KES.12.99/M\(^2\) in open field production system in Nakuru County, Kenya. This differential might be attributed to the fact that in Makueni, a progressive farmer was used as opposed to small-scale farmers in Nakuru who were sampled.

The gross margin and net profits were KES. 311,350.00 and KES. 213,240.00 respectively from catfish production output of 1,800 kilograms. In this study, catfish production was 6Kgs/M\(^2\) which is in contrast
with 1.11Kg/ M² found in Okechi study (2004). Tilapia gross margin was KES. 5,560.00 with a loss of KES. 39,900.

Calculated rate of return in Table 4 indicated that for one Kenyan shilling invested in catfish and tilapia enterprises returned (KES 1.51, 1.78) and (KES0.79, 1.46) respectively for the two season. The comparable returns for tomato enterprises were (KES 1.54, 2.08).

Table 4: Comparison of tomato and fish (catfish and tilapia) costs and returns ratios

<table>
<thead>
<tr>
<th>Measure</th>
<th>Catfish</th>
<th>Tomatoes</th>
<th>Tilapia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st Crop</td>
<td>2nd Crop</td>
<td>1st Crop</td>
</tr>
<tr>
<td>Total revenue in KES*</td>
<td>648,000.00</td>
<td>907,200.00</td>
<td>150,000.00</td>
</tr>
<tr>
<td>Gross Margin (GM) in KES</td>
<td>371,350.00</td>
<td>585,852.00</td>
<td>100,050.00</td>
</tr>
<tr>
<td>Gross margin Ratio(GMR)</td>
<td>0.573</td>
<td>0.656</td>
<td>0.667</td>
</tr>
<tr>
<td>Profit or (Loss)</td>
<td>218,240.00</td>
<td>398,472.00</td>
<td>52,250</td>
</tr>
<tr>
<td>Profit cost Ratio (PCR)</td>
<td>0.663</td>
<td>0.561</td>
<td>0.652</td>
</tr>
<tr>
<td>Benefit cost ratio (BCR)</td>
<td>1.508</td>
<td>1.783</td>
<td>1.535</td>
</tr>
</tbody>
</table>

Source: (Authors, 2015); 100 KES=1 U.S $

The Profit cost ratio of catfish was 0.561 and 0.518 for tomatoes during the second season. These are within the recommended profitability parameter. The results of benefit cost ratio for all three enterprises were greater than 1 except for tilapia during the first crop as indicated in Table 4. A farmer with a BCR of greater than 1 implies that farmers met their costs and was left with net cash income to invest. These profit indicators are good because it means that the enterprise is sustainable. In studies done in Nigeria by Olasunkami (2012) and in Egypt by El-Naggar et al., (2010) found that BCR must be greater than 1 and PCR must be less or equal to 0.65 for an enterprise to be sustainable.

Based on the results of Tables 3, two costs of pond construction and fuel costs are implicitly not magnified. This is because of good site selection where ponds were built within 300 metres of a permanent source of water (River Kiboko). Secondly, the black clay soils does not allow water seepage which help in pond water retention. Fish farmers used pumped water thus close proximity to the water source minimizes the cost outlay in pipes and fuel. It can be concluded that close proximity to water source and black clay soils are enablers to fish farming.

From Tables 3 and 4 it is apparent that the catfish culture is more profitable than tilapia. The average weight of harvested tilapia and catfish is 290grams and 550grams respectively after six months. The local wholesale price for both fish is KES360.00 per kilogram from a price perspective it is advantageous to rear catfish. The tilapia production levels in Makueni are insignificant in relationship to quantity demanded by local consumers. To meet this demand local traders sourced tilapia and Nile perch from western Kenya.

Based on the results of the consumer survey, consumers in Makueni preferred catfish that was above one kilogram in weight. The implication for this is that a catfish farmer has to rear catfish for a period that ranges between nine months and one year and that makes the average weight of catfish to be 1.3kgs. Main reason for the preference was that a catfish of that weight tasted similar (fillet texture was firm and sweet) to the one hatched in the wild. It is important that more research on fish taste be done to validate this consumer perception.

Fish markets infrastructure and management, in Kenya, institutional and policy bottlenecks impede the development and sustainable management of fish markets. For example the ESP built ponds and subsidized...
feeds without investing in postharvest storage cooling and refrigeration facilities. To have a viable fish markets farmers have to have easy access to good postharvest storage to preserve the surplus. Thus good postharvest cold surplus was a facility that would have encouraged fish farming.

With regard to management, no stocking rotation among the farmers was organized such that the fish matured at the same time causing logistical harvesting problems resulting in fish oversupply in the local market. The problem was noted by county fishery officials during pre-survey interviews (MCFD, 2014). An enabling solution would be for farmers to organize as groups and stagger their production over the year.

Local input infrastructures and long commuters to input markets present a major constraint in securing key input. Fingerlings and feeds, the main inputs of fish production were sourced from distant input markets. Fingerling were mainly sourced from Sagana and Western Kenya, and hence increased procurement costs for local farmers. Few farmers could afford to secure feeds from Nairobi while the rest were unable to feed their fish adequately. The added cost on the two items negatively impacted fish farming profitability.

The enablers of reducing input costs is establishment of one feed plant and upgrading the four hour hatcheries such that fingerling produced can be high quality. The excess fingerling supply could be marketed out of county.

Focus group discussion results indicated that there was no political will to support fish farming. Reasons advanced were it uses a lot of the available scarce water and a majority of politicians thought it benefited only a small part of the county that has permanent rivers.

Conclusion

Farmers who are engaged in other enterprises like tomatoes, cattle, goats, fruits, etc. also practiced fish farming in Makueni. Study findings revealed that catfish is the most profitable of the culture fish. Catfish farming was a very competitive option to tomato production. Additionally, proximity to water sources and black clay soil sites were the best enablers of fish farming. Based on fish farming yields/returns per unit, it was recommended that catfish production can complement tomato farming.

Acknowledgement

This study was funded by Partnership for Enhanced Engagement in Research (PEER) Science Program and Rita Waudo. We are grateful to the anonymous reviewers who provided helpful comments. We sincerely thank all respondents, University of Nairobi, Ministry of Agriculture, Livestock and Fisheries especially Ruth Kyatha and her staff for their cooperation. Thanks to Jeff Miruka, Nelly Tanyai, Joshua Ng’ombe, Philip Wangia, Benson Mwengi, Joan Opot and Jackson Muchiri for their logistic and technical support during the field survey in Makueni County.

References


Genetic variation of cultured populations of the African Catfish in Kenya

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Abstract
Fisheries are an important source of nutrition and livelihood in Kenya. Catfish (Clarius gariepinus) makes up a fifth of the total fish produced in the country. This study genetically characterized cultured populations in Kenya using molecular genetic markers for potential to improve breeding in production. Catfish samples from four hatcheries distributed in the country were used: Athi River, Kisii FPC, Jewlett and Sagana. The samples were characterized using genetic mitochondrial markers. The mitochondrial DNA data was used to verify population distinctiveness and haplotype variations in the hatcheries. The populations were differentiated with some of the populations sharing up to three haplotypes with some haplotypes occurring in single populations. The genetic information indicated similarities of catfish populations as some population overlapped. The genetic variation analysis gave insights into the current status of the catfish population and possible origin of the population in different parts of the country.

Keywords: Catfish, Populations, River, DNA, Hatcheies

Introduction
The African catfish is a widely distributed species endemic in Africa and in the country Kenya. There has been much interest in the culture of C. gariepinus to increase seed production and availability (Musa et al., 2012; Barasa et al., 2014) since the introduction of the Economic Stimulus Programme 2009. Genetics is an important tool in ensuring quality fingerling. Characterization of the populations was thus done using mitochondrial DNA in the current study to distinguish populations and assess diversity.

Materials and Methods

Study Area
Catfish samples were obtained from four hatcheries across the country. These were Athi hatchery, Jewlett hatchery, The Kisii Fingerling Production Centre and Sagana Centre.

DNA Extraction and Polymerase Chain Reaction (PCR) Amplification
A sterile scalpel was used to excise tissue from each sample to avoid cross contamination. The DNA extraction was done using the Qiagen extraction kit (Qiagen Valencia, CA USA) following the manufacturer’s instructions with a few modifications. Presence and quality of the extracted genomic DNA was assessed using gel electrophoresis. Gel was prepared using 1% agarose gel in 1× TAE Buffer and run on an electrophoresis apparatus.

Amplification of the targeted mitochondrial region in the extracted DNA, ~550bp, was by conventional polymerase chain reaction. The primer set used were forward primer L16473 (5′-CTAAAAGCATCGGTCTTGTAATCC-3′); reverse primer H355 (5′CCTGAAATGAGGAGGAACCAGATG-3′) (Nazia et al., 2010).

The protocol for amplification of the D-loop region was adapted from (Barasa et al., 2014 and Nazia et al., 2010) Qiagen PCR purification kit (Qiagen Valencia, CA USA) following manufacturer’s instructions. PCR products of seventy individuals were using an automated BigDye Terminator cycle chemistry (Sanger sequencing) by Genewiz® United Kingdom.
Genetic Analysis

The resulting sequences were retrieved from Genewiz in multifasta formats. The sequences were edited using Bioedit version 7.1.9 and then aligned by using ClustalW. MEGA V 7.0 (Kumar et al., 2016) was used to construct the evolutionary phylogenetic trees. The data was then exported to DNASP V5.10.01 (Librado and Rozas, 2009) for the haplotype diversities. The arlequin software version 3.5 (Excoffier and Lischer, 2010) was used to group the data for analysis of molecular variance (AMOVA). DNASP V5.10.01 (Librado and Rozas, 2009) was used for genetic differentiation and gene flow estimates. The programme Network 5.0 version 8 was used to visualize the haplotypes in the populations using median joining tree.

Results

Genetic Diversity and Phylogeny

The evolutionary history was inferred using maximum likelihood function as shown below.

![Figure 1: Molecular Phylogenetic analysis of catfish samples from Kisii, Jewlett, Athi River and Sagana](image)

The evolutionary history was inferred by using the Maximum Likelihood method based on the Tamura-Nei model. The analysis involved 70 nucleotide sequences. There were a total of 430 positions in the final dataset. Evolutionary analyses were conducted in MEGA7.
A total of 21 haplotypes of the 51 polymorphic sites (Table 1) were found from the 433 nucleotide sites of the control region. The haplotype diversity of all the samples was Hd: 0.828 ±0.031 and the nucleotide diversity (π) was 0.02363 ± 0.02603 with 24 singleton variation sites and 27 parsimony informative sites.

**Table 1:** Table showing haplotype diversity of the African catfish from four sampled hatcheries in comparison to two Kenyan lakes

<table>
<thead>
<tr>
<th>Population</th>
<th>N</th>
<th>Polymorphic sites</th>
<th>Haplotypes</th>
<th>Haplotype diversity ± SD</th>
<th>Nucleotide diversity ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Athi river</td>
<td>22</td>
<td>47</td>
<td>9</td>
<td>0.775 ±0.081</td>
<td>0.03035 ±0.00503</td>
</tr>
<tr>
<td>Kisii FPC</td>
<td>20</td>
<td>8</td>
<td>7</td>
<td>0.711 ±0.089</td>
<td>0.00307 ±0.00088</td>
</tr>
<tr>
<td>Jewlett</td>
<td>20</td>
<td>14</td>
<td>9</td>
<td>0.779 ±0.085</td>
<td>0.00579 ±0.00153</td>
</tr>
<tr>
<td>Sagana</td>
<td>8</td>
<td>23</td>
<td>4</td>
<td>0.643 ±0.184</td>
<td>0.01337 ±0.00966</td>
</tr>
</tbody>
</table>

**Haplotype Distribution**

The population at Athi River has the same number of haplotypes as Jewlett although of different types. Six haplotypes: 2, 5, 7, 9, 13, 16 occurred in more than one population as shown in Table 7. Haplotypes 5 and 9 were shared in three populations of Athi River, Kisii and Jewlett. Haplotype 2 occurred in Athi River and Sagana. Haplotype 7 occurred in Athi River and Jewlett. Haplotype 13 occurred in Jewlet and Kisii populations. Haplotype 16 occurred in Kisii and Sagana.

The median joining tree was used to illustrate the haplotype distribution and linkage of the haplotypes among the populations as shown in Figure 1.

**Figure 2:** Median Network tree of African catfish mitochondrial DNA control region segments of Athi River, Jewlett, Sagana and Kisii populations.
Genetic differentiation and AMOVA

Genetic Differentiation was based on both haplotype (Hs) and (Ks) nucleotide statistics (Hudson et al. 1992). Table 2 shows the pairwise differences. The overall Hs was 0.788. The overall Ks was 8.01

The AMOVA estimated 49.95% variation among populations and 50.05% variation to be from within populations with a p value <0.05. The Fst value for the populations was 0.499.

Table 2: Hierarchical analyses of molecular variance showing amount of population genetic structure.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>Percentage of variation</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Among populations</td>
<td>3</td>
<td>49.95</td>
<td>0.000</td>
</tr>
<tr>
<td>Within populations</td>
<td>66</td>
<td>50.05</td>
<td></td>
</tr>
</tbody>
</table>

Discussion

Genetic differentiation and diversity

The heirarchical analysis of molecular variance demonstrated average levels of differentiation in the selected populations. Forty-nine point nine five (49.95%) of variation was significantly accounted for among population variation. Nazia et al., 2010 observed high levels of within population variations but limited within population variations unlike the current study. The variation between populations in the current study was low and although they are geographically isolated, a common origin of broodstock having transported by humans for aquaculture purposes may have resulted in the almost equal among and within population variation.

Genetic diversity analysis revealed 21 haplotypes and 51 polymorphic sites. The population haplotype diversities ranged from 0.779 -0.643 accommodating 0.754 and 0.741 of Lake Victoria and Lake Kanyaboli respectively (Barasa et al., 2014). The nucleotide diversities ranged from 0.01337-0.03035. Lake populations have higher diversity than cultured populations as demonstrated by Li Q et al., (2004).

Phylogeny

Based on the neighbor joining tree two clades were observed differentiating most of the samples. Athi river samples dominated one of the two clades with the others mostly occurring in the second clade. The phylogenetic analysis showed there were differences between the catfish populations by the tree topology.

Some haplotypes were shared between the three populations indicating that there could be intermingling of individuals. The mixed haplotypes supports that some brooders in the hatcheries could have been obtained from the same source such as Lake Victoria.

The neutrality test indicates how much a population has significantly deviated from neutral selection. In this case the deviations were present but insignificant. (Maggio et al., 2006).

Conclusion

From the current study, mitochondrial DNA revealed maternal linkage of the population as in other studies of the African catfish. Athi River had the highest diversities and number of polymorphic sites hence high potential for source of broodstock for farmers rearing catfish in Kenya.

Acknowledgement

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References


Effect of replacing complete grower diet with ground *Prosopis juliflora* pods on performance of improved Indigenous Chicken in Kenya

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Abstract

Ninety-six KALRO improved chicken (KIC) aged 8 weeks were used to study the effect of feeding diets incorporated with different levels of ground *Prosopis juliflora* pods (GPJP) on growth performance. A commercial grower feed, without GPJP, was used as the control diet. Experimental diets were formulated by replacing the commercial diet with GPJP at 0% (T₁), 10% (T₂), 20% (T₃) and 30% (T₄). Feed intake and live weight gains were monitored for eleven weeks and used to calculate feed conversion efficiency (FCE). Two birds from each pen were slaughtered to determine carcass weight. Feed intake and live weight gain for chicken offered T₄ reduced significantly (p<0.05) compared to chicken offered all the other diets. Pullets offered T₄ diet had a significantly (p<0.05) higher FCR than cockerels on the same diet. Each treatment had a significant (p<0.05) difference in dressed cold weight (DCW), eviscerated weight (EW) and leg weight (LW) in cockerels. T₄ had significantly (p<0.05) lower weights for DCW, EW and LW in pullets. Diets with 20% and 30% of GPJP were the least cost diets for pullets and cockerels respectively. Findings showed that GPJP can be included at the level of 20% for both pullets and cockerels diets without affecting performance at the least cost. Cockerels in this study utilized higher levels of GPJP in the diet more efficiently than the pullets.

Key words: Carcass weight, feed conversion efficiency, feed intake, KARLO improved chicken, *Prosopis juliflora* pods, Performance.

Introduction

The demand for poultry and their products in Kenya is on the increase (Bettet et al., 2012). However, poultry production is constrained by many factors among them feed quality and quantity (Kingori et. al., 2010). Studies by Chemjor, (1998), Birech, (2002) and Kingori, (2003) reported that nutrition, in terms of both quality and quantity, is a major factor limiting the attainment of full production potential of indigenous chicken (IC) in Kenya. The limitation is attributed to high cost and inadequacy of ingredients to formulate the feeds. A number of studies have been carried out using *Prosopis juliflora* pods. Such studies recommended up 20% GPJP in laying diets (Meseret et al., 2011b) and 20% in broiler diets (Meseret et al., 2012; Odero-Waititu et al., 2016). This study determined the performance of KIC offered diets with increasing levels of GPJP to determine the optimum inclusion level for the grower phase.

Materials and methods

Study site

An on-station feeding trial using KARLO improved chicken (KIC) was conducted at KALRO Non-ruminant Institute at Naivasha. The station is 100 km west of Nairobi at an altitude of 1900 m above sea level and has a bimodal rainfall pattern with an annual mean of 620 mm. The average day and night temperatures are 26°C and 8°C respectively and a relative humidity range between 60 and 75% (Herrero et al., 2010).
**Dietary treatments**

Four dietary treatments consisting of a Control with 0% GPJP and three other diets formulated by replacing commercial grower diet total diet with GPJP at 10%, 20% and 30% as presented in Table 2. Gross energy was determined using a bomb calorimeter.

**Experimental design**

A complete randomized design (CRD) was used with 24 growers per treatment. The diets were randomly allocated to the KIC. Free access to feed and clean water was allowed throughout the experimental period. Sex of the birds, either pullet or cockerel was used as the blocking factor. All the 96 KIC growers were offered the respective treatments and daily feed intake (feed offered minus feed remains from 7am to 6pm) recorded. The refusals were weighed each morning before the fresh feed was offered. Weekly feed conversion ratio was calculated as the ratio of feed intake per bird to the body weight gain per bird (average daily feed conversion ratio per week). Average live weight gain for each experimental unit was represented by the average change in pen weight for a given period of time. Weight gain of the growers was monitored by weighing the birds weekly at 0900 hours (before morning) feeding from the 10th to 20th week of age.

**Carcass evaluation**

On the 20th week, two birds per pen were randomly selected and fasted for 12 hours with free access to drinking water. They were then weighed and sacrificed and the carcass dissected into various cuts. Carcass measurements included pre-slaughter live weights, cold dressed weight, prime cuts (breast, back, legs (drumstick and thigh), wing, neck and shank) weights, giblets (gizzard, liver, and heart) weights and featherweight. The dressing percentage was calculated as a ratio of carcass weight to pre-slaughter live weight.

**Cost of feeding**

In the determination of cost of feeding, the following parameters were calculated: total feed intake in kilograms, feed cost per kilograms in Kenya shillings (Ksh) and total live weight change in kilograms for the entire period of 70 days. These parameters were used to calculate feed cost per live weight change.

**Chemical analyses**

Feeds samples were dried and ground to pass through a 1mm screen using a Wiley mill. The samples were then analyzed for dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF) and ash while calcium and phosphorus were analyzed by atomic absorption spectrophotometry using the methods of AOAC (1990).

**Statistical analyses**

All data was subjected to a two-way analysis of variance (ANOVA) using the PROC GLM (SAS, 2002) and means separated by Tukey’s test. The birds were assigned to the four treatments in a completely randomized design (CRD). Each treatment had four pullets and four cockerels replicated three times

\[ Y_{ij} = \mu + T_i + E_{ij} \]

Where;

- \( Y_{ij} \) is the observation of the \( i^{th} \) treatment
- \( \mu \) is the overall population mean
- \( T_i \) -is the \( i^{th} \) treatment factor (4 pullets and 4 cockerels)
- \( E_{ij} \) is the random error effect Results
Results

Nutrient composition of the diets

The chemical composition of Prosopis pods is shown in Table 1 and the proportion of ingredients in the experimental diets are shown in Table 2.

Table 1. Chemical composition of ingredients used in diet formulation

<table>
<thead>
<tr>
<th>Parameters</th>
<th>GPJP</th>
<th>Maize</th>
<th>Fish meal</th>
<th>Soybean</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM (% DM)</td>
<td>89.30</td>
<td>89.90</td>
<td>92.24</td>
<td>90.00</td>
</tr>
<tr>
<td>CP (% DM)</td>
<td>13.89</td>
<td>11.47</td>
<td>54.04</td>
<td>42.20</td>
</tr>
<tr>
<td>EE (% DM)</td>
<td>6.38</td>
<td>6.13</td>
<td>14.17</td>
<td>19.11</td>
</tr>
<tr>
<td>CF (% DM)</td>
<td>18.14</td>
<td>2.36</td>
<td>1.36</td>
<td>11.89</td>
</tr>
<tr>
<td>Ash (% DM)</td>
<td>6.40</td>
<td>3.50</td>
<td>21.60</td>
<td>12.86</td>
</tr>
<tr>
<td>Ca (% DM)</td>
<td>0.37</td>
<td>0.07</td>
<td>4.30</td>
<td>0.32</td>
</tr>
<tr>
<td>P (% DM)</td>
<td>0.17</td>
<td>0.03</td>
<td>2.69</td>
<td>0.68</td>
</tr>
</tbody>
</table>

DM = Dry Matter; CP = Crude Protein; EE = Ether Extract; CF = Crude Fibre; Ca = Calcium; P = Phosphorus; GPJP = Ground *Prosopis juliflora* pod

The experimental diets formulated for IC were iso-caloric and iso-nitrogenous, around 13.38MJ/Kg on average and 23% CP respectively (Table 2) with crude fibre increasing as the level of GPJP increased.

Table 2. Composition of the experimental diets

<table>
<thead>
<tr>
<th>Ration composition</th>
<th>Treatments</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPJP</td>
<td>0.00</td>
<td>10.00</td>
<td>20.00</td>
<td>30.00</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>64.00</td>
<td>57.60</td>
<td>51.20</td>
<td>44.80</td>
<td></td>
</tr>
<tr>
<td>Fish meal</td>
<td>7.50</td>
<td>6.75</td>
<td>6.00</td>
<td>5.25</td>
<td></td>
</tr>
<tr>
<td>Soy bean</td>
<td>24.50</td>
<td>22.05</td>
<td>19.60</td>
<td>17.15</td>
<td></td>
</tr>
<tr>
<td>Vegetable oil</td>
<td>2.50</td>
<td>2.25</td>
<td>2.00</td>
<td>1.75</td>
<td></td>
</tr>
<tr>
<td>DCP</td>
<td>0.65</td>
<td>0.59</td>
<td>0.52</td>
<td>0.46</td>
<td></td>
</tr>
<tr>
<td>Iodized salt</td>
<td>0.50</td>
<td>0.45</td>
<td>0.40</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>Vitamin premix*</td>
<td>0.35</td>
<td>0.32</td>
<td>0.28</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

Chemical composition

<table>
<thead>
<tr>
<th>Parameters</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM (% DM)</td>
<td>89.40</td>
<td>90.10</td>
<td>90.20</td>
<td>89.60</td>
</tr>
<tr>
<td>CP (% DM)</td>
<td>23.04</td>
<td>23.70</td>
<td>23.51</td>
<td>22.90</td>
</tr>
<tr>
<td>EE (% DM)</td>
<td>8.61</td>
<td>7.21</td>
<td>6.98</td>
<td>6.58</td>
</tr>
<tr>
<td>CF (% DM)</td>
<td>4.59</td>
<td>5.56</td>
<td>6.50</td>
<td>7.71</td>
</tr>
<tr>
<td>Ash (% DM)</td>
<td>7.80</td>
<td>8.22</td>
<td>8.35</td>
<td>8.36</td>
</tr>
<tr>
<td>NFE (% DM)</td>
<td>45.36</td>
<td>45.41</td>
<td>44.85</td>
<td>44.04</td>
</tr>
<tr>
<td>Ca (% DM)</td>
<td>1.00</td>
<td>0.98</td>
<td>1.03</td>
<td>1.01</td>
</tr>
<tr>
<td>P (% DM)</td>
<td>0.45</td>
<td>0.46</td>
<td>0.44</td>
<td>0.49</td>
</tr>
<tr>
<td>ME (MJ/Kg DM)</td>
<td>13.71</td>
<td>13.42</td>
<td>13.38</td>
<td>13.02</td>
</tr>
</tbody>
</table>
Feed intake
There was a significantly (p≤0.05) lower feed intake for birds offered T₄ (30%) as compared to all other treatments for cockerels, pullets and both combined (Table 3).

Daily gain
Cockerels and pullets on T₄ had significantly (p≤0.05) lower ADG while results for grouped birds indicate that T₁ and T₂ were not significantly (p>0.05) different. However, cockerels had dissimilar ADG from T₃ and T₄ which were also significantly different from each other (Table 3).

Feed conversion ratio
FCR was significantly (p≤0.05) higher for pullets on T₄ and for the grouped birds but in cockerels, there was no effect of the levels of GPJP on FCR (Table 3).

Final live weight and live weight change
Cockerels and pullets fed diet T₁ had significantly (p≤0.05) low FLW and LWC as compared to all other treatments. Effect of T₄ on grouped birds indicates that FLW and LWC were significantly lowered as compared to all other treatments although birds receiving T₃ were lighter and significantly lower FLW than T₁ (Table 3).

Table 3. Productive performance of KIC

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Treatment</th>
<th>T₁ (0 %)</th>
<th>T₂ (10 %)</th>
<th>T₃ (20 %)</th>
<th>T₄ (30 %)</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average feed intake</td>
<td>P</td>
<td>70.99a</td>
<td>70.56a</td>
<td>69.02a</td>
<td>61.31b</td>
<td>1.37</td>
</tr>
<tr>
<td>(g/day)</td>
<td>C</td>
<td>94.24a</td>
<td>92.67a</td>
<td>87.64a</td>
<td>79.46b</td>
<td>1.92</td>
</tr>
<tr>
<td>_daily gain</td>
<td>E</td>
<td>12.91a</td>
<td>12.15a</td>
<td>11.66a</td>
<td>9.08b</td>
<td>1.18</td>
</tr>
<tr>
<td>(g/day)</td>
<td>P</td>
<td>20.65a</td>
<td>19.37a</td>
<td>18.83a</td>
<td>15.95b</td>
<td>1.25</td>
</tr>
<tr>
<td>FCR</td>
<td>E</td>
<td>16.83a</td>
<td>15.81ab</td>
<td>15.25b</td>
<td>12.42c</td>
<td>0.82</td>
</tr>
<tr>
<td>(g feed/g weight gain)</td>
<td>P</td>
<td>5.50b</td>
<td>5.80b</td>
<td>5.92b</td>
<td>6.81a</td>
<td>0.16</td>
</tr>
<tr>
<td>FLW (g/bird)</td>
<td>E</td>
<td>4.57a</td>
<td>4.78a</td>
<td>4.67a</td>
<td>4.99a</td>
<td>0.14</td>
</tr>
<tr>
<td>(g/bird)</td>
<td>E</td>
<td>5.00b</td>
<td>5.27b</td>
<td>5.32b</td>
<td>5.94a</td>
<td>0.11</td>
</tr>
<tr>
<td>LWC</td>
<td>P</td>
<td>1340.59a</td>
<td>1311.81a</td>
<td>1304.08a</td>
<td>1078.27a</td>
<td>43.51</td>
</tr>
<tr>
<td>(g/bird)</td>
<td>E</td>
<td>1812.94a</td>
<td>1747.68a</td>
<td>1685.87a</td>
<td>1532.06b</td>
<td>75.25</td>
</tr>
<tr>
<td>LWC</td>
<td>E</td>
<td>1580.31a</td>
<td>1533.77ab</td>
<td>1499.58b</td>
<td>1293.00c</td>
<td>41.83</td>
</tr>
<tr>
<td>LWC</td>
<td>P</td>
<td>994.10a</td>
<td>935.88a</td>
<td>897.96a</td>
<td>699.20b</td>
<td>27.17</td>
</tr>
<tr>
<td>LWC</td>
<td>E</td>
<td>1590.08a</td>
<td>1491.37a</td>
<td>1449.92a</td>
<td>1228.18b</td>
<td>36.37</td>
</tr>
<tr>
<td>LWC</td>
<td>E</td>
<td>1295.59a</td>
<td>1217.16ab</td>
<td>1173.94b</td>
<td>956.65c</td>
<td>24.92</td>
</tr>
</tbody>
</table>

abc means with different superscripts differ significantly (P<0.05) within a row; P = pullet; C = cockerel, E= both pullet and cockerel combined T₁ = diet containing 0% GPJP of the whole diet; T₂ = diet containing 10% GPJP of the whole diet; T₃ = diet containing 30% GPJP of the whole diet; T₄ = diet containing 30% GPJP of the whole diet; GPJP = ground Prosopis juliflora pods
Carcass and carcass weights evaluation

All treatments were significantly different (p≤0.05) for DCW, EW and Leg W for cockerels. T₁ and T₃ had the same yield for BW but was different from T₂ and T₄ (Table 4). T₄ had significantly (p≤0.05) lower weights for DCW, EW and Leg W in pullets but T₂ and T₃ had similar weights for the same parameters. BW was similar for T₂, T₃, and T₄.

Table 4: Carcass performance of KIC

<table>
<thead>
<tr>
<th>Sex of KIC</th>
<th>Parameters</th>
<th>T₁</th>
<th>T₂</th>
<th>T₃</th>
<th>T₄</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cockerel</td>
<td>PSW (g)</td>
<td>2150.00</td>
<td>2147.60</td>
<td>2148.09</td>
<td>2150.52</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DCW (g)</td>
<td>1915.65</td>
<td>1902.99</td>
<td>1890.32</td>
<td>1899.34</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>DP (%)</td>
<td>89.10</td>
<td>88.61</td>
<td>88.00</td>
<td>88.32</td>
<td>6.67</td>
</tr>
<tr>
<td></td>
<td>EW (g)</td>
<td>1816.46</td>
<td>1782.38</td>
<td>1782.04</td>
<td>1777.43</td>
<td>5.39</td>
</tr>
<tr>
<td></td>
<td>EP (%)</td>
<td>84.42</td>
<td>82.92</td>
<td>82.94</td>
<td>82.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Breast W (g)</td>
<td>321.66</td>
<td>290.31</td>
<td>311.85</td>
<td>287.84</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Breast P (%)</td>
<td>14.92</td>
<td>13.52</td>
<td>14.54</td>
<td>13.34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leg W (g)</td>
<td>522.85</td>
<td>493.24</td>
<td>508.27</td>
<td>489.81</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leg P (%)</td>
<td>24.24</td>
<td>22.91</td>
<td>23.62</td>
<td>22.61</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wing P (%)</td>
<td>9.48</td>
<td>9.88</td>
<td>9.39</td>
<td>9.54</td>
<td></td>
</tr>
<tr>
<td>Pullet</td>
<td>PSW (g)</td>
<td>1580.39</td>
<td>1579.99</td>
<td>1579.90</td>
<td>1579.22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DCW (g)</td>
<td>1401.02</td>
<td>1399.08</td>
<td>1388.26</td>
<td>1389.40</td>
<td>9.61</td>
</tr>
<tr>
<td></td>
<td>DP (%)</td>
<td>88.65</td>
<td>88.55</td>
<td>87.87</td>
<td>87.98</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>EW (g)</td>
<td>1307.89</td>
<td>1291.52</td>
<td>1264.97</td>
<td>1299.21</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EP (%)</td>
<td>82.69</td>
<td>81.72</td>
<td>80.05</td>
<td>82.30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Breast W (g)</td>
<td>247.06</td>
<td>232.32</td>
<td>225.40</td>
<td>260.21</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Breast P (%)</td>
<td>15.52</td>
<td>14.66</td>
<td>14.22</td>
<td>16.56</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leg W (g)</td>
<td>339.65</td>
<td>334.74</td>
<td>318.45</td>
<td>323.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leg P (%)</td>
<td>21.41</td>
<td>21.14</td>
<td>20.13</td>
<td>20.47</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wing P (%)</td>
<td>9.46</td>
<td>9.98</td>
<td>8.71</td>
<td>9.70</td>
<td></td>
</tr>
</tbody>
</table>

abcd means for same sex with different superscripts differ significantly (P<0.05) within a row; PSW = pre-slaughter weight; DCW = dressed carcass weight; DP = dressing percentage; EW = eviscerated weight; EP = eviscerated percentage; W = weight; P = percentage; T₁ = diet containing 0% GPJP of the whole diet; T₂ = diet containing 10% GPJP of the whole diet; T₃ = diet containing 30% GPJP of the whole diet; T₄ = diet containing 30% GPJP of the whole diet; GPJP = ground Prosopisjuliflora pods
Cost of feeding

Treatment with 20% and 30% of GPJP were the least cost diets for the pullets and cockerels chicken respectively (Table 5). Cockerels offered T_4 had the least feed cost per weight gain across pullets and cockerels.

Table 5: Cost of feeding

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sex of chicken</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pullet</td>
<td>T_1</td>
<td>T_2</td>
<td>T_3</td>
<td>T_4</td>
</tr>
<tr>
<td>Total feed intake (kg/bird)</td>
<td>5.47</td>
<td>5.43</td>
<td>5.32</td>
<td>4.72</td>
<td></td>
</tr>
<tr>
<td>Feed cost/kg (Ksh)</td>
<td>67.81</td>
<td>62.74</td>
<td>57.65</td>
<td>52.59</td>
<td></td>
</tr>
<tr>
<td>Total feed cost (Ksh)</td>
<td>370.63</td>
<td>340.91</td>
<td>306.35</td>
<td>248.25</td>
<td></td>
</tr>
<tr>
<td>Feed cost/wt gain (Ksh)</td>
<td>372.83</td>
<td>364.27</td>
<td>341.16</td>
<td>355.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cockerel</td>
<td>T_1</td>
<td>T_2</td>
<td>T_3</td>
<td>T_4</td>
</tr>
<tr>
<td></td>
<td>7.26</td>
<td>7.14</td>
<td>6.75</td>
<td>6.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>67.81</td>
<td>62.74</td>
<td>57.65</td>
<td>52.59</td>
<td></td>
</tr>
<tr>
<td></td>
<td>492.02</td>
<td>447.73</td>
<td>388.99</td>
<td>321.74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>309.43</td>
<td>300.22</td>
<td>268.29</td>
<td>261.97</td>
<td></td>
</tr>
</tbody>
</table>

Ksh = Kenya’s unit of currency; US$ 1.00 = Ksh 100; wt= weight; T_1 = diet containing 0% GPJP of the whole diet; T_2 = diet containing 10% GPJP of the whole diet; T_3 = diet containing 30% GPJP of the whole diet; T_4 = diet containing 30% GPJP of the whole diet; GPJP = ground *Prosopis juliflora* pods

Discussion

Various studies have been carried out using different levels of *Prosopis juliflora* pods in rations. Meseret *et al.*, (2011a), reported that 30% inclusion of *Prosopis juliflora* pods reduced feed intake, and lowered body weight in the finisher phase while in starter phase it resulted to lower FLW as compared to lower levels of *Prosopis juliflora* pods. These results are similar to findings of this study where 30% GPJP reduced the feed intake. This could be due to high crude fibre (CF) levels resulting in gut fill (Meseret *et al.*, 2011a) as well as anti-nutritive factors that depresses feed intake (Shahidi, 1997). The results are also in congruence with with 20% of *Prosopis juliflora* pods inclusion in broiler rations (Odero-Waititu, 2015). It can be inferred, therefore, that 20% of *Prosopis juliflora* pods in KIC diets was also the optimal inclusion level with no further processing of GPJP to reduce the effects of anti-nutritive factors and CF content.

The results of this study are in agreement with the findings of Meseret *et al.*, 2011a; Yusuf *et al.*, 2008; Choudhary *et al.*, 2005 who reported lower ADG at higher levels of GPJP in broiler diets. *Prosopis juliflora* contain factors such as condensed tannins and phenols (Annongu and TerMeulen, 2000) that negatively depresses digestion (AL-Mazooqiet *et al.*, 2015) resulting in reduced ADG when fed at levels of 30% as reported in this study without further processing.

Results for pullets and combination of pullets and cockerels indicate that 30% level of GPJP resulted in high FCR which are similar to Meseret *et al.*, (2011) findings. The treatments did not have an effect on FCR for cockerels. The results suggest that cockerels have a better capacity to derive nutrients from *Prosopis juliflora* pods as compared to pullets and hence better performance.

Carcass yield recorded in this study contradicted results of Abdullah *et al.*, (2010) and Meseret *et al.*, (2011) who found no significant differences in dressing percentages, carcass weight and organ weight for different levels of *Prosopis juliflora* pods inclusion. Effect of GPJP on BW, LW in cockerels and EW, BW and LW for pullets is almost similar to the trend observed in live weight and feed intake. Considering biological performance and cost of feeding (Table 5), 20% GPJP inclusion gave the best option even in carcass yield especially for the primal cuts.
The cost of feeding was in agreement with that reported with broilers by Meseret et al., (2011a) where it was less costly to feed *Prosopis juliflora* pods based diets at 20% GPJP inclusion level without affecting the biological performance. The results of the cost of feeding indicate that T4 and T3 had apparently lower cost per weight gain mass compared to other treatments in cockerels and pullets respectively. In contrast, Yusuf et al., (2016) reported 5% as the best level of prosopis pulp replacing maize. Cockerels recorded the least feeding costs compared to pullets.

**Conclusion**

The *Prosopis juliflora* can be used as an alternative feed resource to address feed scarcity and affordability. An optimal inclusion rate of 20%, *Prosopis juliflora* pods can be incorporated in chicken diet to improve feed intake, body gain as well as reduce feed costs.

**Acknowledgement**

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**References**


Performance of indigenous chicken ecotypes in Kenya: egg weight, hatch weight and hatching yield

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Abstract

Over the last few decades, local or indigenous livestock have been globally recognized as important farm animal genetic resources for food and agriculture. The indigenous chicken (IC) possess unique adaptive traits such as stress resistance, disease and parasite tolerance, scavenging and nesting behavior, ability to fight or escape predators and ability to incubate eggs and raise chicks without assistance. The need to improve productivity of IC utilized in free-range and semi-intensive production systems while managing their genetic diversity calls for carefully designed and sustainable improvement strategies. Out of 5,138 incubated eggs, 910 were hatched. These constituted the incubated and hatched datasets, respectively. They were classified into 3 egg weight categories as small (≤44.9 g), medium (45.0-54.9 g) and large (≥55.0). The overall mean EW, HW and HY were 45.6 g, 32.1 g and 10.9 %, respectively. Egg weight ranged from 28.0 to 72.0 g, HW from 19.0 to 53.0 g and HY from 0.0 to 55.0 %. The CV for EW, HW and HY was 10.9, 9.0 and 64.4 %, respectively, while R² was 18.7, 55.8 and 28.6 %, respectively. This study has shown a wide variation in EW, HW and HY traits that can be manipulated through well designed breeding programs.

Key words: Ecotypes, indigenous chicken, Temperature, egg weight

Introduction

Over the last few decades, local or indigenous livestock have been globally recognized as important farm animal genetic resources for food and agriculture (FAO, 2007). The indigenous chicken (IC) possess unique adaptive traits such as stress resistance, disease and parasite tolerance, scavenging and nesting behavior, ability to fight or escape predators and ability to incubate eggs and raise chicks without assistance (Besbes, 2009). These traits permit them to survive and reproduce in harsh climatic, nutritional and managerial conditions typically associated with free-range and semi-intensive production systems. However, despite the adaptive traits, the low productivity of IC limits their potential to contribute to income generation and food security. For instance, although live body weight and body size are significant traits that influence market prices (Danda et al., 2010; Bett et al., 2011b), the average live body weight at market age of 20 to 24 weeks ranges between 1.3 and 1.8 Kg (Kingori et al., 2010b; Magothe et al., 2012). In an effort to improve the low productivity, various strategies have been and continue to be implemented by both public and private institutions. These strategies include introduction of exotic strains of hybrid chickens for cross breeding, supplementation using locally available feed resources, disease prevention and control measures, housing interventions and general management improvements (Magothe et al., 2012; Okeno et al., 2013). However, most of the interventions have proved unsustainable and introduction of exotic hybrid chickens for genetic improvement through crossbreeding has resulted in genetic dilution of IC thus endangering biodiversity (Udo et al., 2006; Nyaga, 2007).
The need to improve productivity of IC utilized in free-range and semi-intensive production systems while managing their genetic diversity calls for carefully designed and sustainable improvement strategies. Characterization is the first step in the design of such strategies and involves generating historical, genetic and phenotypic information in order to derive a good understanding of the available IC genetic resources (FAO, 2012b). The historical background of IC in Kenya has been reported (Maina, 2000; Magothe et al., 2012). Furthermore, the genetic diversity of some IC ecotypes and genotypes have also been reported (Maina, 2000; Mwacharo et al., 2007). In addition, IC production and marketing systems have been well characterized (Danda et al., 2010; Olwande et al., 2010; Bett et al., 2011b; Bett et al., 2012; Okeno et al., 2012) and several available IC ecotypes and genotypes as well as traits of economic importance identified (Kingori et al., 2010b; Ngeno, 2010; Bett et al., 2011a; Okeno et al., 2011; Magothe, 2012). However, the phenotypic performances of most traits have not been characterized. This study therefore aimed at characterizing egg weight, hatching weight and hatching yield performances of identified IC ecotypes with a view of providing information to develop sustainable improvement strategies.

Materials and methods

Egg source and incubation

Free-range eggs and live birds were purchased from rural farmers in nine administrative counties. The counties were: Kakamega, Bondo, Bomet, Narok, Turkana, West Pokot, Mwingi, Taita Taveta and Lamu. The live birds were transported to Egerton University (EU), quarantined for 14 days and then housed in deep litter pens for egg collection. The birds under intensive production system at EU were fed standard commercial layers mash and provided with clean water as recommended for hybrid layers. All eggs, either purchased from farmers or laid at EU, were transported to the Poultry Research Unit (PRU) of the Kenya Agricultural and Livestock Research Organization (KALRO) for incubation and data recording. The PRU is located at Naivasha, approximately 70 kms North-west of Nairobi at an altitude of 1,829 metres above sea level. The centre has an average annual rainfall of 680mm, mean annual temperature of 18°C with wide daily variations ranging from 8°C to 26°C and relative humidity of between 60% and 75%.

On arrival at the centre, the eggs were stored at room temperature until the following day. Each egg was then examined for cracks and unsuitable ones discarded. Each suitable egg was labelled to indicate its source and egg number, and weighed before incubation. The eggs were set at 99.6°F (37.6°C) and 55% humidity (Pas Reform, Zeddam, Netherlands). On the 7th day of incubation, each egg was candled and recorded as infertile, dead-embryo or live-embryo and only the live-embryo eggs re-incubated. After the 2nd candling on the 18th day of incubation, each live-embryo egg was placed in an individual compartment and transferred into a hatcher set at 98.6°F (37.0°C) and 60% humidity (Pas Reform, Zeddam, Netherlands). During harvesting on the 22nd day, each hatched chick was wing-tagged and weighed using a digital weighing scale calibrated to 0.5 g.

Data preparation

In both datasets, eggs out of 5,138 incubated eggs, 910 were hatched. These constituted the incubated and hatched datasets, respectively (Table were classified into 3 egg weight categories as small (≤44.9 g), medium (45.0-54.9 g) and large (≥55.0) (Githinji et al., 2010). Both datasets were then used to generate the number of incubated and hatched eggs for each combination of source, production system and egg category. A total of 54 combinations were generated and hatching yield (HY) for each calculated as (Alabi et al., 2012):

\[
\text{Hatching yield (\%) = (Number of chicks hatched ÷ Number of eggs incubated) x 100}
\]  

[1]
Data analysis

In all tests and analyses, SAS procedures were used (SAS, 2004). Before analysis, the incubated and hatched datasets were tested for normality using the Kolmogorov-Smirnov and Shapiro-Wilk tests, respectively, and found to be normally distributed. The hatching yield percentages were arcsine transformed before and back transformed after the analysis.

In both data sets, a linear model that accounted for the fixed-effects of source, production system and egg weigh category was fitted. The least squares means were separated using the probability differences option. The model was:

\[ Y_{ijkl} = \mu + S_i + P_j + C_k + \varepsilon_{ijkl} \]  \[4\]

where: \(Y_{ijkl} = \) Egg weigh, hatch weight and hatch yield; \(\mu = \) overall mean; \(S_i = \) effect of the \(i^{th}\) source (\(S =\) Kakamega, Bondo, Bomet, Narok, Turkana, West Pokot, Mwingi, Taita Taveta and Lamu); \(P_j = \) effect of the \(j^{th}\) production system (\(P =\) free-range and intensive); \(C_k = \) effect of the \(k^{th}\) egg weight category (\(C =\) small, medium and large); \(\varepsilon_{ijkl} = \) random error term associated with each measurement (0,\(\sigma^2\)).

Results and Discussion

Overall means

The overall means and ranges, coefficient of variation (CV) and coefficient of determination (\(R^2\)) are presented in Table 1. The overall mean EW, HW and HY were 45.6 g, 32.1 g and 10.9 %, respectively. Egg weight ranged from 28.0 to 72.0 g, HW from 19.0 to 53.0 g and HY from 0.0 to 55.0 %. The CV for EW, HW and HY was 10.9, 9.0 and 64.4 %, respectively, while \(R^2\) was 18.7, 55.8 and 28.6 %, respectively.

Whereas the coefficient of variation (CV) is an indicator of relative variability, the coefficient of determination (\(R^2\)) explains the proportion of variation in the dependent variable that can be attributed to the independent variables used. The CV for EW and HW in this study were low (10.9 and 9.0 %, respectively), while that for EWL and HY were moderate (22.0 %) and high (64.4 %), respectively. Although comparative studies are rare, Wolanski et al. (2007) reported comparably low range of 5.9 to 8.0 % for EW and 7.1 to 9.5 % for HW, while Alewi et al. (2012) reported a CV of 5.6 % for EW. In this study, whereas EW was more variable than HW, HY exhibited the highest variation. These phenotypic variations imply that the traits can be improved through manipulations such as selective or cross breeding. In addition, \(R^2\) for EW and HY were low (18.7 and 28.6 %, respectively), while for HW were moderate (46.1 and 55.8 %) indicating that other factors not considered in the analysis contribute to the traits variations and more so for EW and HY than HW. This implies that such factors need to be investigated before developing any improvement strategy.

Table 1: Descriptive statistics of incubated and hatched eggs datasets

<table>
<thead>
<tr>
<th>Traits</th>
<th>n</th>
<th>Mean (sd) (^1)</th>
<th>Minimum</th>
<th>Maximum</th>
<th>CV</th>
<th>(R^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg weight (g)</td>
<td>5138</td>
<td>45.6 (5.53)</td>
<td>28.0</td>
<td>72.0</td>
<td>10.9</td>
<td>18.7</td>
</tr>
<tr>
<td>Hatch weight (g)</td>
<td>910</td>
<td>32.1 (4.29)</td>
<td>19.0</td>
<td>53.0</td>
<td>9.0</td>
<td>55.8</td>
</tr>
<tr>
<td>Hatching yield (%)</td>
<td>910</td>
<td>10.9 (4.91)</td>
<td>0.0</td>
<td>55.0</td>
<td>64.4</td>
<td>28.6</td>
</tr>
</tbody>
</table>

\(^1\) sd = standard deviation
Egg weight

The size of an egg, measured as egg weight (EW), is an important economic trait for improvement in any production system. The overall mean EW of 45.6 g obtained in this study was in agreement with the range of 42.5 to 48.0 g reported for indigenous chicken (IC) in Kenya (Njenga, 2005; Magothe et al., 2006; Okitoi et al., 2009; Kingori et al., 2010a; Olwande et al., 2010). It was comparable to 44.1 g reported for local chickens in Tanzania (Mwalusanya et al., 2001), 42.2 g in Ethiopia (Lemlem and Tesfay, 2010) and 47.2 g in Nigeria (Sola-Ojo and Ayorinde, 2011). However, whereas the mean EW was higher than the range of 36.3 to 39.9 g reported for IC in Tanzania (Msoffe et al., 2001), Sudan (Mohammed et al., 2005), Ethiopia (Melesse et al., 2012), Benin (Youssao et al., 2011) and Nigeria (Apuno et al., 2011), it was lower than the range of 52.1 to 60.2 reported for pure breeds and hybrid layers (Farooq et al., 2001; Lemlem and Tesfay, 2010; Youssao et al., 2011). Interestingly, the mean EW in this study was comparable to the 45.0 g reported for crosses between Rhode Island Red and indigenous chickens in Kenya (Ndewa and Kimani, 1996). Comparable weights of between 42.5 and 48.0 g have also been reported for crosses of IC and various exotic pure breeds and hybrids in Benin and Ethiopia (Youssao et al., 2011; Alewi et al., 2012). These results therefore appear to indicate that IC in Kenya are crosses between the original chickens and various breeds and hybrids. Apart from the genetic background, however, many other factors such as age and body weight of hens, nutrition and environmental conditions including temperature, diseases and parasites are also known to significantly influence egg weight in chickens (FAO, 2003). These factors may explain the wide EW range observed in this study.

Hatch weight

Hatching weight (HW) is also an important trait in chicken production. Traditionally, hatch weight has been emphasized as a strong indicator of chick quality (Wolanski et al., 2007). Hatching weight has a strong influence on the fitness of chicks and is of great importance to their survival especially under scavenging conditions. Small chicks have higher surface area to weight ratios and therefore loose heat, and are more easily dehydrated than larger chicks. The mean HW of 32.1 g observed in this study was comparable to the range of 32.7 to 34.2 g reported for the Kenyan IC (Magothe et al., 2010; Ngeno, 2010) and 31.5 g for indigenous Venda chicken (Alabi et al., 2012). It was however higher than the range of 23.7 to 28.3 g reported for local chickens in Tanzania (Malago and Baitilwake, 2009) and Benin (Youssao et al., 2011), and lower than the range of 43.0 to 46.6 g for exotic hybrids (Wolanski et al., 2007; Youssao et al., 2011). As in the case of EW, the mean HW in this study is in close agreement with HW of crosses between IC and exotic breeds and hybrids reported by Sola-Ojo and Ayorinde (2011) and Youssao et al. (2011). Although numerous factors influence chick weight at hatch, egg weight has the greatest impact and a strong correlation between EW and HW has been reported (Wolanski et al., 2007; Malago and Baitilwake, 2009). Furthermore, egg yolk and albumen volume are important determinants of egg weight and hence chick weight at hatch and wide variations in the conversion of these egg contents into chick body mass has been reported (Wolanski et al., 2007). Therefore, as expected, the wide EW variation (28.0 to 72.0 g) may explain the corresponding wide HW phenotypic variation (19.0 to 53.0 g).

Hatching yield

Hatching yield (HY) refers to the proportion of chicks hatched from all eggs set, as opposed to hatchability which refers to the proportion of chicks hatched from fertile eggs set (Sahin et al., 2009; King’ori, 2011). It is an important trait that indicates the efficiency of an incubation process, whether naturally by the hen or artificially by an incubator. Efficiency is an important factor in determining, not only the profitability of hatchery operations, but also the number of chicks available for replacing aging stock in both subsistence and commercial chicken production systems (King’ori, 2011). The mean hatch yield of 10.9 % observed in this study was far lower than the range of 41.1 to 77.4 % reported by Ndewa et al. (2002) for IC in Kenya. Elsewhere, various studies have reported higher HY of between 39.3 and 84.0 (Molekwa and Umesiobi, 2009; Sahin et al., 2009; Lemlem and Tesfay, 2010; Alabi et al., 2012). Hatching efficiency is affected by many factors including genetic background of cocks and hens, fertility and hatchability, egg storage period.
and conditions, incubation conditions, egg weight and egg weight loss during incubation. Any one of these factors may be responsible for the low mean HY and the wide range of 0.0 to 55.0 % observed in this study.

**Conclusion**

This study has shown a wide variation in EW, HW and HY traits that can be manipulated through well designed breeding programs.

**Acknowledgement**

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Challenges of drought in the pastoral populations in Kenya

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Abstract

This paper examines the trend of drought incidences among pastoralists who inhabit fragile rangelands and are one of the most nutritionally vulnerable population groups in Kenya. The review is based on a synthesis of literature on pastoralist livestock feeds, food security and livelihoods in Kenya’s rangelands. Documents reviewed included food security assessment surveys, journal articles, case studies, reports from Non-Governmental Organizations and ‘grey’ literature. The main impact of drought is low or lack of precipitation leading to shortage of forage and pasture availability, low productivity and livestock deaths that eventually result to loss of livelihoods. Scarcity of milk at household levels may contribute to high malnutrition experienced during droughts, which have been worsened by increasing climate change. Availability of safe drinking water is a challenge, and pastoralists are frequently affected by water-borne diseases. Sedentarisation also presents negative nutritional consequences to pastoralists including rangeland degradation, lack of clean drinking water and fuelwood for cooking. Efforts to address the challenges should focus on capacity building, establishment of strategic livestock feed reserves and actualization of early warning systems. At the community level, there should be an integrated approach by all stakeholders establishing strategic feed reserves in pastoralist areas. At the national level, interventions should focus both on livestock relief and resilience building, and be tailor-made specifically for the pastoralist communities. The impact of such interventions needs to be realized. Although pastoralism is not an option for everyone living in dry regions like northern Kenya, the decrease in livestock feeds and high livestock mortalities during drought periods, should be part of decisions affecting social, economic, and health policy for pastoral regions.

Key words: Food security, livelihoods, feed reserves, pastoralists, rangelands,

Introduction

Drought is a hazard that originates from a deficiency of precipitation that results in water and forage shortage for livestock production. Highly variable rainfall causes wide fluctuations in forage productivity from short lived seasonal highs that cannot be optimally utilized to lows during frequent droughts that are insufficient to support resident livestock (Jaetzold, 1995). In Kenya the most seriously affected areas are the arid and semi-arid lands which are drought prone.

Pastoralists inhabit the arid and semi-arid lands (ASALs) of Kenya, where livestock keeping is the main livelihood activity. However, pastoralism has been seriously affected by worsening climate change. Instability of forage productivity is the major factor constraining pastoral production system. Droughts have become more frequent and severe, and are progressively diminishing pastoralist livelihoods without allowing these pastoralists sufficient time to recover (Mepeak, 2003). Drought increases the need to sell stock while simultaneously reducing market prices (Barret, 2001). During severe drought, when it is almost impossible to sell livestock, large number of animals may die destroying the pastoralists’ economic base leading to poverty. This results in a situation which threatens the survival of over of human and the livestock population in the country. It is important to point out that the presence of drought and its adverse effects on
livelihood of people is not a disaster on its own but that the lack of preparedness for drought can heighten disaster e.g fodder production and storage.

Contingency plans are generally activated too late to prevent the widespread loss of assets. This often leads to settling of former nomadic pastoralists around urban centers to receive humanitarian assistance. For most pastoralists, droughts over the past few decades have led to a pattern of poverty, food crises and dependence on food relief. Over 75% of the ASAL population live below poverty line and have limited livelihood options, resulting in serious food and nutrition insecurity implications for these communities (KDHS, 2015).

This paper reviews the drought events and challenges faced by the pastoralist populations in drought-prone Kenya’s ASALs and recommends appropriate interventions to overcome the challenges. The paper is based on a review of literature on forage condition trend, pastoralist food security, and livelihoods in Kenya’s ASALs. Documents reviewed included surveys on post disaster needs assessments, journal articles, case studies, Government and Non-Governmental Organisation (NGO) reports and the Kenya District Health Information System (DHIS) database. The review aims at highlighting the plight faced by pastoralists in terms of impacts on drought with a view of stimulating an integrated approach by all stakeholders to address multiple household vulnerabilities, which affect the nutritional status of the population. The findings have important implications for designing appropriate livestock interventions for pastoralists in Kenya and the horn of Africa.

Challenges of Drought Faced by Pastoralists in the Rangelands

Kenya is in the midst of a severe drought which is also affecting areas of Ethiopia, Somalia and Djibouti and to a lesser extent Sudan, South Sudan, Tanzania, Uganda and Eritrea. In Kenya the drought has mainly affected the counties that are classified as arid and semi-arid counties. In Kenya more than 2.5 million people have been affected by drought (GoK, 2017). The affected regions has seen a failure of the last two consecutive rainfall seasons. The drought has contributed to increase in livestock mortalities, loss of livelihoods and a rise in food prices across the country.

![Cost of drought during the period 1999-2011](image)

World Bank, 2011)

**High livestock mortalities**

Figure 1 below show the losses incurred due to drought in the years 1999 to 2011. Livestock was the sector that was most affected by the drought. According to the 2008-2011 Post Disaster Needs Assessment (PDNA, 2011) report, the livestock sector sustained negative effects of approximately Kshs 986 losses and damages. The damages value represents the death of animals due to the drought while losses were incurred from increased costs from water and feeds, veterinary care as well as production losses due to disease and
death of animals. Overall, compared to other sectors, the livestock sector incurred 72% of all losses and damages followed by Agriculture sector 13%, Water and Sanitation 9%, Energy 3% with other sectors at 1% each (PDNA, 2011).

In the year 2016 the country went through a serious drought situation arising from poor performance of the previous two failed rain seasons. The situation precipitated into alarming levels of concern particularly in coastal, Northern, North eastern and North West counties and resulted to high population of cattle at risk as shown in figure 2 below.

Cattle population at Risk

![Cattle Population at Risk](image)

Low precipitation leading to poor forage condition

Kenya experienced severe to extreme drought conditions for March to May season of 2009 and 2011 which is the main rainy season for the country. The June to August years some these same years also shows depressed conditions which could be partly due to the failure of the preceding rainy season. Like the Ethiopian case, the September to December 2011 brought exceptionally high rainfall and good vegetation condition for northern Kenya (ICPAC Atlas, 2017). Figure 3 and 4 shows a standard precipitation index from 1981 to 2013 with years of severe drought occurrence, based on probability one may predict possibility of drought early enough so that appropriate intervention strategies can be put in place.
**Figure 3:** MAM drought severity as measured by SPI for 1981-2013

**Figure 4:** Trend of overall food insecure population
Figure 4: OND drought severity as measured by SPI for years 1981 – 2013
Food insecurity

Food insecurity is an endemic problem for pastoralists in the ASALs. Livestock being the main source of livelihood, there are limited livelihood options. While some families manage with cash income or remittances from family members living in towns, many depend on social protection mechanisms such as relief food, cash transfers and other social safety nets from NGOs and the Government (Wayua and Kagunyu, 2015). Relief food is often grain based and requires wood fuel to cook. Firewood, the main source of fuel, is becoming increasingly scarce and hence expensive in ASAL regions [8]. There is seasonal availability of foods, with pastoralists experiencing low food availability and consequently high malnutrition rates during droughts.

Effects of Sedentarisation

Settling of pastoralist communities has been as a result of socio-economic, political, demographic, and environmental changes. For example, droughts have led to deaths of pastoralists’ livestock causing people to become destitute and settle around settlements to receive humanitarian assistance. The need for better education and health services has also caused nomadic pastoralists to settle around urban centres and along the roads; so is the need to integrate to the national economy. Sedentarisation offers new opportunities to pastoralists such as increased marketing benefits, for example for women who sell milk (Fratkin and Smith, 2005) and access to health services (Sheik-Mohamed and Velema, 1999). Several studies, however, report negative social and health consequences of pastoral sedentarisation, including shortage of livestock forage, poorer nutrition, lack of clean drinking water, and higher rates of certain infectious diseases despite better access of settled populations to formal education and health care (Fratkin et al, 1999).

Effect on livestock markets

Markets can exacerbate climate risks for pastoralists because livestock prices often decline during dry periods, a high degree of inter-market price variability and temporal volatility occur that can lead to lower producer prices and discourage trader and pastoralist market participation (Barret, 2001). Such problems of market inefficiency could be dealt with by investing more resources in roads, telecommunications, market infrastructure, and security in pastoral areas. Alternative methods of animal disease control should also be considered since quarantines have a disproportionately negative effect on poor pastoral producers compared to those for highlands consumers or ranchers.

Current Interventions to Address the Challenges

Several resilience interventions, which have significantly contributed to alleviating some of the challenges, are being implemented by the Government and NGOs in pastoralist areas of Kenya. These include projects on rangeland rehabilitation, water, and livestock market development, food security, livelihoods, disaster risk reduction, early warning among others. There is need for an integrated approach by all stakeholders implementing resilience interventions in the ASALs so as to effectively address the challenges.

Other efforts to address food insecurity have been done by the defunct Ministry of Northern Kenya and Other Arid Lands, Arid Lands Resources Management Project (ALRMP), and currently by the National Drought Management Authority (NDMA) and the various County Governments in the ASALs. Research on rangeland livestock production, food security and livelihoods is also being carried out by Government research organizations and international NGOs with the aim of boosting food security and consequently improve on livelihoods. However, implementing livestock interventions in ASALs has been constrained by several challenges including the following:

- Scarcity of pasture and forage
- High levels of land degradation
- The vastness of the areas making it a challenge to reach the whole population.
- Insecurity, which negatively affects pastoral production systems and service delivery
- Frequent livestock slaughter during drought periods instead saving the animals from starvation
- Poor infrastructure (poor or no roads, few inaccessible and poorly developed marketing facilities, limited telephone and internet connectivity).
• Low levels of literacy and education hence the communities’ low understanding of critical issues in health and nutrition. This, together with the high poverty levels, negatively affects people’s perceptions and uptake of interventions.

• Nomadic lifestyle. People migrate to access water and pasture for their livestock hence the services offered by the government and various agencies do not reach them at all times.

Conclusion

The pastoralists in Kenya’s ASALs experience several drought related challenges occasioned by high levels of chronic vulnerability, food insecurity, livestock mortalities and loss of livelihoods. The main drought related challenges include inadequate of pasture and forage, lack of market for livestock, food insecurity, limited access to water, sedentarisation leading to land degradation and high levels of insecurity

Efforts to address the challenges should focus at boosting the food security of the pastoralists and promoting pastoral livelihoods by establishing strategic livestock feed reserves across all the arid and semi-arid counties. Functional markets and phytosanitary standards be established at the accredited abattoirs. At the individual and household level, efforts should be focused on appropriate livestock husbandry techniques. At the community level, there should be an integrated approach by all stakeholders to address multiple household vulnerabilities which affect the population. At the national level interventions to boost food security should focus both on short term (relief) and long-term (resilience programmes), and be tailor made specifically for the pastoralists communities.

Further scientific research should be done on the drought impacts of the various interventions in pastoralist areas.

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ANIMAL GENETIC RESOURCES

Assessment of factors affecting conception rates following embryo transfer in recipient cows

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Abstract

Livestock sub-sector is the fastest growing in the world with demand for improved breeds and animal products outstripping supply. There are several ways of addressing the gap; one is through the use of Multiple Ovulation and Embryo Transfer (MOET) technology. Despite its introduction and usage for years, conception rates have not exceeded 50%, especially in developing countries. The objectives of this study were to evaluate the effect of physiological characteristics of recipients (body condition & lactation status), embryo stage of development and placement site in uterine horn on conception rate. Recipient cows (n=126) in three different lactation stages (mid, late and non-lactating) were synchronized for estrus. Conception rate data were analyzed using the LOGISTIC procedure of SAS with a stepwise model selection option. Odds ratio estimates and 95% confidence limits were given for each effect in the model. The residual Chi-square test provided evidence for model saturation or otherwise and the stepwise process was terminated when no additional effects met the 0.05 significance level for model. Results indicated that rate of conception may be influenced to a larger extent by body condition and lactation status of recipient cows as well as what side of the uterine horn the embryo is implanted. Odds ratio values indicated that careful selection of cows based on stage of lactation preferably >102 days can improve pregnancy rate by about 50% while one unit difference in body condition score marginally affects conception (by 5%). Placement of embryo in the right side horn of uterus can improve chances of conception by about 10%. The response of dry cows significantly (P<.05) differed from that of those in mid lactation but not the ones in late lactation. However, it may be instructive to take into account good corpus luteum size as routine practice (significant at P<.10 level). Observations from this study suggest that for an adequate response in breeding programme, cows must be suitably nourished and maintained in good body condition.

Introduction

One of the greatest challenges facing the world today is to preserve its natural resources while at the same time producing sufficient food to satisfy the demands of growing human population. World population is expected to grow to about 8 billion in the year 2020 (Cunningham, 1990) and by 2050 models predict the world population to reach 9.5 billion and in turn a 70% increase in world food production will be required to feed the populace (Keyzer et al. 2005). At the same time, alarming symptoms of the deterioration of resource base are being observed worldwide through land degradation caused by human activities, water scarcity and pollution because of the pathogen and industrial pollutants, global warming and diminishing biodiversity.

To improve food security, it is essential to double food production especially livestock production in Kenya. This is due to increasing demand for meat, milk and other related products. Livestock sub-sector is the fastest growing in the world with increasing trends at 114% in demand of meat and 133% for milk (Okeyo et al., 2009). The demand is clearly more than the current supply. To improve on food security it is essential to double livestock production in the developing world by 2020. Doubling it through traditional breeding
technique increases pressure on natural resources such as water, land and negatively impacts on biodiversity. To end this problem, development of reproductive techniques such as estrus synchronization, artificial insemination (AI) and embryo transfer are directed to solve or minimize the effects of these limiting factors as well as to make possible the application of more intensive systems of production and to facilitate the genetic improvement of the productive characteristics of the herd.

Of all the biotechnologies in use, AI is recognized as the best biotechnological technique for increasing reproductive capacity and has received widespread application in farm animals (Landiver et al., 1985; Mukasa-Mugerewa 1989). However, Using AI benefits the bull more than the female cow. Like AI has done to the bull Multiple Ovulation and Embryo Transfer (MOET) can do the same on the female side. Since traditional technique is slow in achieving goals, Multiple Ovulation and Embryo Transfer (MOET) is clearly one of the most efficient ways to accomplish this. To date, the most efficient way to maximize production from genetically superior cows is through the use of advanced reproductive techniques, specifically Embryo Transfer (ET). It is possible to obtain offspring from genetically valuable cows that have become infertile due to injury, disease, or age by means of superovulation and embryo transfer (Elsden et al., 1979). Application of MOET hastens the genetic improvement by virtue of its capacity to reduce the generation interval. Technology of MOET refers to the process which involves super-ovulation of the animals to release multiple eggs at a single estrus, insemination, flushing of embryos and transfer of the embryos from the donors to recipients whose estrus cycle has been synchronized with that of donors.

Material and method

The study was carried out using animals at the Agricultural Development Corporation (ADC) Farm, Namandala Complex. The ADC Namandala farm is situated 10km from Kitale town on the Kitale–Mt Elgon road at an altitude of 1800-1900 m above sea level. Temperatures range from 10°C to 27°C with an annual bimodal rainfall of 1000 to 1200 mm per year occurring in April to August and October to November with the peak in May to June. The experiment was conducted on the farm for twelve months focusing on 126 recipient cows and 45 donor cows selected on their phenotypic characteristics from a herd of 320 and 540, respectively. The experiment involved the transfer of fresh embryos to recipients and was conducted on three phases running between September 2013 and October 2014. In phase 1 recipients (n=42) used in September 2013 were in mid lactation ranging from 90 to 101d postpartum. Phase 2 recipients (n=42) used in April 2014 were in late lactation ranging from 102 to 300d postpartum. Phase 3 the last group of recipients (n=42) were used in October 2014 were non-lactating. The average age of all the animals was 5 years and ranged from 2 to 10 years of age.

The procedure for synchronization is given in Table 1

Table 5: Synchronization protocol

<table>
<thead>
<tr>
<th>Day</th>
<th>Time</th>
<th>Recipient program</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AM</td>
<td>Inject 20ml Mult V</td>
</tr>
<tr>
<td>7</td>
<td>AM</td>
<td>Insert CIDR+2ml ciderol</td>
</tr>
<tr>
<td>12</td>
<td>PM</td>
<td>Inject estrumate</td>
</tr>
<tr>
<td>14</td>
<td>AM</td>
<td>Inject estrumate</td>
</tr>
<tr>
<td>15</td>
<td>AM</td>
<td>Remove CIDR</td>
</tr>
<tr>
<td>16</td>
<td>AM</td>
<td>Observe heat</td>
</tr>
<tr>
<td>21</td>
<td>AM</td>
<td>Transfer</td>
</tr>
</tbody>
</table>
Data collection

The experiment involved synchronization of 126 embryo recipient cows. All animals in the herd were assigned a Body Condition Score (BCS) ranging from 1(lean) to 5(fat), which was based on visual and tactile evaluation of anatomical parts (tail, lumbar regions, vertebral column and the head) as established by Wildman et al.(1982). Only animals in BCS 3, 3.5 and 4 were selected for the study.

The selected recipients underwent synchronization program as described earlier. Day 24 prior to the transfers the recipients were palpated for the presence of CL. The ovaries of recipients were palpated rectally to determine which ovary reacted (ovulated), the size of the CL was also categorized as Good or Poor. The embryos transferred at all the three phases were collected from a total of 45 donor cows. Three deposit sites were identified on the uterine horn (Upper, Mid and Lower) where the embryos would be deposited as shown on Figure 1.

Data collected were stored in 2 different databases.

- Data base 1 contained information regarding transfers: Lactation stage (mid, late and non-lactating); Body Condition Score (3, 3.5 and 4); Days after estrus (7 and 8) and Size of the Corpus Luteum (Good or Poor)
- Data base 2 contained records on embryo stages (Morula, Early blastocyst, Compact Blastocyst, and Expanded blastocyst) and deposit sites (Lower, Mid and Upper third of the uterine horn and right or left uterine horn)
Data Analysis

In each database the variables were tested looking for significant relations. Conception rates following embryo transfer were analyzed as a linear logistic regression model using the LOGISTIC procedure of SAS program (SAS, 2006). Descriptive statistics looked at the Means and Proportion. The response variables conception and non-conception that was denoted by 1 and 0 respectively.

Logit regression model:

\[ Y = \ln \left( \frac{P}{1-P} \right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + e \]

Where:

- \(Y\) = Conception status: 1= conceived 0= not conceived
- \(P\) = Success odds ratio (probability of a cow conceiving)
- \(X_1\) = Body condition score in three classes 3, 3.5, and 4
- \(X_2\) = Lactation stage: mid lactation= 1, late lactation= 2, not lactation= 3
- \(X_3\) = Days after estrus: 7 days= 0, 8 days= 1
- \(X_4\) = Size of corpus luteum: 1= good, 0 = poor
- \(X_5\) = Embryo stage: morula= 1, early blastocyst= 2, compact blastocyst= 3
- \(X_6\) = Deposit site: lower= 1 mid = 2 upper= 3
- \(X_7\) = Uterine horn: left= 0, right= 1
- \(e\) = error term

Results

A total of 126 cows underwent synchronization. Eighty-three were detected on heat (synchronization rate= 65.87%) and received an embryo each. Conception of recipients were analyzed from the transfer of eighty-three fresh (n = 83) bovine embryos which were transferred to recipients in three phases. After 90 days following the embryo transfers pregnancy diagnosis was performed by trans-rectal palpation. Thirty-six recipients conceived out of eighty-three transfers.

Observed frequencies and success proportions for the three predictor effects are shown in Table 2

Table 2: Effect of Body Condition Score, Lactation Stage and Uterine horn on conception rate

<table>
<thead>
<tr>
<th>Conception Y</th>
<th>Body condition X_1</th>
<th>Lactation stage X_2</th>
<th>Uterine horn X_7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not conceived</td>
<td>0</td>
<td>25 12 10</td>
<td>17 16 14</td>
</tr>
<tr>
<td>Conceived</td>
<td>1</td>
<td>3 14 19</td>
<td>7 12 17</td>
</tr>
<tr>
<td>No. of cows</td>
<td>N</td>
<td>28 26 29</td>
<td>24 28 31</td>
</tr>
<tr>
<td>Conceived</td>
<td>Ratio</td>
<td>0.11 0.54 0.66</td>
<td>0.29 0.43 0.55</td>
</tr>
</tbody>
</table>

The table below shows parameter estimates, significance levels, odds ratios and their 95% confidence intervals for significant factors of the fitted model.
Table 3: Factor that had significance on conception rate

<table>
<thead>
<tr>
<th>Factor</th>
<th>Parameter Estimate</th>
<th>SE</th>
<th>Pr&gt;Chi-Sq</th>
<th>Odds ratio</th>
<th>95% confidence Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>14.4669</td>
<td>3.5100</td>
<td>&lt;.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BCS</td>
<td>-2.8970</td>
<td>0.8003</td>
<td>.0003</td>
<td>.055</td>
<td>0.011, 0.265</td>
</tr>
<tr>
<td>LS</td>
<td>-1.1148</td>
<td>0.4007</td>
<td>.0054</td>
<td>.528</td>
<td>0.150, 0.719</td>
</tr>
<tr>
<td>UH</td>
<td>-2.1498</td>
<td>0.7318</td>
<td>.0033</td>
<td>.117</td>
<td>0.028, 0.489</td>
</tr>
</tbody>
</table>

(*BCS-Body Condition Score, †LS-Lactation Stage, ‡UH-Uterine Horn)

Results indicate that in the absence of interaction among predictor effects (not considered), rate of pregnancy may be influenced to a larger extent by body condition and lactation status of recipient cows as well as what side of the uterine horn the embryo is implanted.

Odds ratio values indicate that careful selection of cows based on stage of lactation can improve pregnancy rate by about 50% while one unit difference in body condition score marginally affects conception rate (by 5%). Placement of the embryo in the uterine horn on the right side of the animal can improve chances of conception by about 10%.

Table 4: Contrasts of responses obtained at different levels of the explanatory variables:

<table>
<thead>
<tr>
<th>Contrast</th>
<th>DF</th>
<th>Chi-square</th>
<th>Pr &gt; Chi²</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCS3 vs BCS3.5</td>
<td>1</td>
<td>9.497</td>
<td>0.002</td>
</tr>
<tr>
<td>BCS3 vs BCS4</td>
<td>1</td>
<td>12.450</td>
<td>0.000</td>
</tr>
<tr>
<td>BCS3.5 vs BCS4</td>
<td>1</td>
<td>0.463</td>
<td>0.496</td>
</tr>
<tr>
<td>LS1 vs LS2</td>
<td>1</td>
<td>2.972</td>
<td>0.085</td>
</tr>
<tr>
<td>LS1 vs LS3</td>
<td>1</td>
<td>8.302</td>
<td>0.004</td>
</tr>
<tr>
<td>LS2 vs LS3</td>
<td>1</td>
<td>1.969</td>
<td>0.161</td>
</tr>
<tr>
<td>UH0 vs UH1</td>
<td>1</td>
<td>8.212</td>
<td>0.004</td>
</tr>
</tbody>
</table>

(BCS-Body Condition Score, LS-Lactation Stage, UH-Uterine Horn)

Generally, no significant difference (P>.05) was observed in the response of cows in body condition score 3.5 and 4, the difference in score probably being too close to separate objectively. The response of dry cows significantly (P<.05) differed from that of those in mid lactation but not the ones in late lactation.

Discussions

Effect of Body Condition Score

From this study results indicate that cows in body condition score 4 that are not lactating are predicted to have the highest chances of conception (up to 83%) while body condition score 3 will be very poor 22% at most. This is in agreement with studies done by (Rhind et al., 1989) who reported that BCS directly affects hypothalamic activity and GnRH, secretion. (Xu et al., 1989) also reported that increase in ovulation was associated with high BCS. In this study results show that a one unit difference in BCS, marginally affect conception by 5%. This is in agreement with (Stevenson et al., 2001) who reported that conception rate increased by 10% for every unit increased in BCS.

Effect of Lactation Stage

In this study, results show that response of dry cows significantly (P<.05) differed from that of those in mid lactation but not the ones in late lactation. It would therefore be logical to use non lactating recipient cows in body condition score ≥3.5 for better results. This is in agreement with (Sartori et al., 2002) whose study showed that in dairy cattle, the partition of nutrients toward milk synthesis affects reproduction partially
because of reduced ovulation. Previous studies by (Snijders et al., 1999; Snijders et al., 2001; Lopez et al., 2004) also reported that milk production has been associated with poor reproduction performance.

**Effect of Embryo Stage on Conception**

Results from a review by (Hasler, 2001) showed that morulla and early blastocyst had more conceptions compared to the compact blastocyst. In this study, out of the 36 conceptions that were achieved sixteen were morulae (44%); fourteen were from early blastocyst stage (39%) and six were compact blastocyst (17%). Though there was no significance, the morulae and the early blastocysts gave higher conceptions than the compact blastocysts.

**Effect of Deposit Site**

The right uterine horn had 57 reactions while the left horn had 26 reactions (67.67% and 31.33%), respectively. The significantly higher reactions (ovulation) of right uterine horn is in agreement with data from many authors (Morrow et al., 1968; Pierson and Ginter, 1987; Lopez-Gatius and Camon-Urgel, 1990). They confirmed that the right ovary was more active than the left one due to a physiological phenomenon in cycling cows. Several studies on ovarian activity in Bovine by (Casida et al., 1948; Reece and Turner, 1954; Rajakoski, 1960; Morrow et al., 1968; Pierson and Ginter, 1987) indicate that the right ovary to be more active than the left one. They also found out that ovaries on the right side are bigger and more active in cows which might be an explanation for this phenomenon.

**Conclusion and Recommendations**

Based on the analysis of the data collected in the entire experiment, the following conclusions were drawn:

1. The key influencing factors on conception were; Body Condition Score (BCS), lactation stage and Embryo deposit site.
2. Reproductive performance decreases, especially when animals are under severe Negative Energy Balance (NEB). Body Condition Score (BCS) directly affects ovulation and hence estrus. For an adequate response in breeding programme, cows must be suitably nourished and maintained in good body condition.

The results of these studies have raised a number of recommendations that need to be addressed. The areas where further investigation/research is needed include (but not limited to):

1. **Handling of the recipients:** Recipients used in this study were Borans which are generally temperamental. Stress and nervousness can cause infertility in cattle; however, these factors were not considered during the study. It is important to note that calm handling practices of recipients can improve conception rates as well. This can be induced by calming cattle just prior to transfer, using tranquilizers. However, further research on the same is necessary.
2. **Effect of hormone on conception:** Since transfers were done after the sixth day, meaning the cervix had already closed, chances of secreting oxytocin during the transplants are high hence may cause expulsion of the embryo. Further research needs to be done to confirm this.
3. **Economic factors:** The economic implication of the technology was not considered during the study. This is an area that needs further research.

**References**


Associations between intensification interventions and herd productivity in smallholder dairy farms in the Kenyan Highlands

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Abstract

Smallholder dairy farms intensify their milk production through genetics, ecological and socio-economic interventions to attain increased milk production for food and income security, but viability of the interventions may be an impediment. This study established the association between intensification interventions and herd productivity for a random sample of 140 farms benefitting from Kenya Market led Dairy Program (KMDP) in Kiambu and Meru Counties. Data obtained using cross sectional survey was processed in excel spreadsheet for descriptive statistics, Principle Component Analysis (PCA) and regression modelling to derive optimal predictive models for describing association of intensification intervention and productivity indicators. All the indicators showed large variations between farms in intensification interventions and herd productivity. From the indicators, PCA extracted two principle components (PC) explaining 99.6% of the total variance, which showed positive associations between intensification interventions and milk yield and margin per litre of milk. Milk yield was optimally explained by three socio economic indicators (concentrate use, milk sales and credit uptake) and one genetic technology (insemination costs) while margin was optimally explained by two socioeconomic indicators (concentrate use and milk sales) and one genetic technology (insemination costs). Indicators of ecological intervention had insignificant associations with herd productivity. Sensitivity analysis with the optimal predictive model showed that a ten percent increase in concentrate fed would increase milk yield by 1.6% but reduce the margins earned by 2.50% per liter of milk. Spending more on insemination, however, would marginally reduce yield and margins while ten percent more milk sales would increase margins by 11%. Results do imply that optimal use of concentrates is necessary to enable farmers attain rewarding returns and assure economic sustainability of dairy farming.

Key words: Margin, Milk yield, Principle Component Analysis, Regression analysis

Introduction

Dairy farmers intensify their production to attain more output per unit input (The Montpellier Panel 2013). In dairy farms, indicators of output are productivity measures represented by milk yield resulting from improved high yielding livestock breeds, better feeding and nutrition and practicing best animal husbandry practices. Muia et al. (2011) indicated that milk production per hectare tended to increase with increasing level of intensification and attributed this to access to extension services which aid in knowledge provision on better dairy husbandry management and practices. However, (Kibiego et al., 2015a) observed that as milk yield increases, gross margin and profit per litre of milk may decrease with increase in the level of intensification within smallholder dairy farms, attributable to increase in production costs involving feeds and labour costs. Kibiego et al. (2015b) further observed farmers need extension services and finances to improve on feed production and utilization technologies essential for increasing profitability. This is partly achieved through cooperative movements where farmers are able to access supplementary feeding through provision of feeds on credit arrangements (Bebe 2008). The objective of this study was to establish relationships between herd productivity indicators and intensification interventions within smallholder dairy farms to inform management intervention sustainable dairy farming.
Materials and methods

Study area

The study was undertaken in Kiambu and Meru Counties on smallholder dairy farms benefitting from the Kenya Market Led Dairy Program (KMDP) interventions being beneficiaries of intensification interventions. The farms represent the leading milk sheds in Kenya with a large population of smallholders intensifying their dairy production, favorable climatic conditions for dairy production, the high participation in dairy farmer cooperatives and small land holdings on which dairy is integrated with crops.

Data collection

Data collection was through observations and farm household interviews using a pre-tested structured questionnaire designed to capture individual animal and farm level data on indicator variables of genetics, ecological, socioeconomic interventions and herd productivity. The indicators were either measured directly in scale variable units or computed from the raw collected data. The computed indicator variables included concentrates, Napier, crop residues, legumes and off farm sourced feeds per Tropical Livestock Units (TLU) on the farm. The TLU was computed from herd composition on the basis of 1 for bull, 0.7 for cow, 0.5 for heifer and 0.2 for calves (Bebe, 2004). Production costs and gross margin per litre of milk was computed from revenues and input costs.

Data analysis

The analysis aimed at detecting the association between intensification interventions and herd productivity indicators. The analysis involved processing indicator variables on each sample farm in excel spreadsheet to generate descriptive statistics for Principle Component Analysis (PCA) using Statistical Package for Social Sciences (SPSS) version 20 (SPSS, 2011) and multiple linear regression modelling using the regression procedures of Statistical Analysis System (SAS, 2009) version 9.1. Data analysis proceeded in two stages involving PCA to reduce dimensionality in the data set and to select indicator variables for regression analysis. The goodness of fit of PCA was assessed on basis of Varimax rotation with Kaiser-Meyer-Olkin Normalization procedure (KMO). The varimax rotation aided in extracting fewer PCs with highly correlated variables that maximize sum of variances to simplify interpretation of the extracted PCs. Hair et al. (2006) and Che et al. (2013) explains application of the KMO as a measure of sampling adequacy which is satisfied when KMO value is at ≥ 0.5 and is significant (p<0.05). In addition, Bartlett’s test of sphericity was computed to check that the correlation matrix is not an identity matrix for which a p value <0.05 is indicative. A factor loading of ±0.3 was set prior and a rule of thumb applied in which an extracted PC has to explain at least 100/PC% of the variance to be selected for the next stage of regression modelling (Afifi and Clark, 1984; Rougoor et al., 2000). For instance, where PCA extracts five PC’s, only those variables within PC accounting for at least 20% (100/5=20%) are selected for subsequent linear regression model.

The second stage of data analysis involved fitting selected indicator variables from the PCA in a multiple regression model to determine optimal predictive model that explains association of herd productivity with the three groups of intensification interventions.

The multiple linear regression model fitted was in the form:

\[ Y_{ij} = a + b_1(x_1) + b_2(x_2) + b_3(x_3) + \ldots + b_n(x_n) + e_{ij} \]

Where \( a \) is the intercept, \( b_1, b_2, b_3 \ldots b_n \) are the coefficients for variable \( x_1, x_2, x_3 \ldots x_n \) respectively and \( e_{ij} \) is the random error.

The model goodness of fit was judged on the criteria of smallest AIC or BIC and SSE and largest adjusted \( R^2 \) to obtain an optimal predictive model that defines the association between intensification interventions and herd productivity.
Results

Table 1 presents the descriptive statistics for herd productivity indicators from sampled smallholder dairy farmers.

Table 1: Descriptive statistics for indicator variables of herd productivity in sampled dairy farms (n=140)

<table>
<thead>
<tr>
<th>Herd productivity</th>
<th>Units</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Cost</td>
<td>KES/ Kg of milk</td>
<td>20.4</td>
<td>5.3</td>
</tr>
<tr>
<td>Milk yield</td>
<td>Kg/cow/month</td>
<td>342.4</td>
<td>130.3</td>
</tr>
<tr>
<td>Calving Interval</td>
<td>Months</td>
<td>17.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Age at First Calving</td>
<td>Months</td>
<td>30.1</td>
<td>3.2</td>
</tr>
<tr>
<td>Margin/litre</td>
<td>KES/litre of milk</td>
<td>4.2</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Source: Estimated from survey data collected in the Kenyan Highlands

In Table 2, the PCA fitted for indicators defining intensification interventions and herd productivity was satisfactory in sampling adequacy (KMO=0.616) and the correlation matrix was not an identity matrix (Bartlett’s test Chi square =1457.48, p=0.000). Two PCs were extracted that explained 99.63% of the total variance and applying the rule of thumb (100/2PCs=50%), only variables loading on PC 1 were selected for subsequent linear regression model. This PC 1 explained 90.06% of the total variance and the variables loading highly on it are three socio economic indicators (credit uptake, milk sales, and concentrate use), one ecological indicator (manure recycling) and one indicator of genetics (insemination cost) interventions and all have positive associations with milk yield and margins per litre of milk. Two regression models were subsequently fitted to explain milk yield and margin per litre with the indicators of socioeconomic, ecological and genetics interventions in intensification of dairy production.

Table 2: Retained variables for herd productivity and intensification interventions from PCA analysis

<table>
<thead>
<tr>
<th>Indicator variables</th>
<th>Principle component 1</th>
<th>Principle component 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credit uptake</td>
<td>0.944</td>
<td>0.767</td>
</tr>
<tr>
<td>Replacement cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk sales</td>
<td>0.551</td>
<td></td>
</tr>
<tr>
<td>Insemination cost</td>
<td>0.399</td>
<td></td>
</tr>
<tr>
<td>Concentrates use</td>
<td>0.382</td>
<td></td>
</tr>
<tr>
<td>Milk yield</td>
<td>0.342</td>
<td></td>
</tr>
<tr>
<td>Manure recycling</td>
<td>0.340</td>
<td></td>
</tr>
<tr>
<td>Margin per litre of milk</td>
<td>0.331</td>
<td></td>
</tr>
</tbody>
</table>

Total variance explained (%): 90.063 9.566

Rotation method: Varimax with Kaiser-Meyer-Olkin Normalisation. Sampling adequacy (KMO=0.616). Bartlett’s test of sphericity (Chi square =1457.477, Sig=0.000).

The retained variables submitted to regression model (Table 3) for milk yield explained 57.5% of the variance, of which socioeconomics accounted for most (50.7%) and genetics the least (6.7%) while ecological intervention had no contribution. In contrast, the explanatory variables for margins per litre of milk explained 45.8% of which socioeconomics interventions (concentrate use and milk sales) accounted for the most (39.7%), much higher than 3.7% accounted for by genetic intervention (insemination costs) or the 2.4% accounted for by ecological intervention (manure recycling).
Table 3: Variance contribution (%) by ecological, genetics and socioeconomic indicators to herd productivity

<table>
<thead>
<tr>
<th>Intensification interventions</th>
<th>Milk yield</th>
<th>Margin per litre of milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure</td>
<td></td>
<td>2.4</td>
</tr>
<tr>
<td>Insemination costs</td>
<td>6.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Concentrate use</td>
<td>7.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Milk sale</td>
<td>41.3</td>
<td>36.2</td>
</tr>
<tr>
<td>Credit uptake</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>57.5</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 4 presents the results of optimal predictive models for milk yield and margins per litre of milk, selected out of 15 models evaluated on the basis of smallest AIC, BIC, and SSE values and largest adjusted $R^2$.

Table 4: Optimal model selected for predicting margin per litre of milk and milk yield

<table>
<thead>
<tr>
<th>Model</th>
<th>Variables in the model</th>
<th>Adj $R^2$</th>
<th>AIC</th>
<th>BIC</th>
<th>C(p)</th>
<th>SSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield</td>
<td>Concentrates, Milk sales, Credit uptake, Insemination costs</td>
<td>0.58</td>
<td>318.03</td>
<td>320.40</td>
<td>5.00</td>
<td>1263.75</td>
</tr>
<tr>
<td>Margin per litre of milk</td>
<td>Concentrates, Insemination cost, Milk sales, Manure recycling</td>
<td>0.46</td>
<td>498.71</td>
<td>501.15</td>
<td>4.06</td>
<td>4593.56</td>
</tr>
</tbody>
</table>

The predictive models derived for estimating the margin per litre of milk (G) and milk yields (M) respectively were:

\[
M = 6.38007 + 0.00061571(C) + 0.23152(S) - 0.00001009(L) - 0.00051878(I)
\]

\[
G = 3.68904 + 0.51669(S) - 0.00078502(C) - 0.00132(I)
\]

Where $M$ = milk yield in Kg per cow, $C$ = concentrates used in Kg dry matter per tropical livestock unit, $S$ = milk sales in Kg per herd, $L$ = credit uptake in Kenyan Shillings per year, $I$ = insemination costs in Kenya shillings per animal and $G$ = margins per litre of milk in Kenyan Shillings.

With the regression equation, sensitivity analysis for management interventions on milk yield and margins per litre of milk was performed and results are presented in Table 5. Milk yield was optimally explained by three socio economic indicators (concentrate use, milk sales and credit uptake) and one genetic technology (insemination costs) while margins was optimally explained by two socioeconomic indicators (concentrate use and milk sales) and one genetic technology (insemination costs). Indicators of ecological intervention had insignificant associations with herd productivity. Sensitivity analysis with the optimal predictive model showed that a ten percent increase in concentrate fed would increase milk yield by 1.6% but reduce the margins earned by 2.50% per liter of milk. Spending more on insemination, argins by 11%.

Table 5: Sensitivity Analysis of intensification interventions on productivity changes

<table>
<thead>
<tr>
<th>Intensification intervention</th>
<th>level</th>
<th>Milk yield Kg</th>
<th>% change</th>
<th>Margins on milk (KES/L)</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td></td>
<td>12.9</td>
<td></td>
<td>9.91</td>
<td></td>
</tr>
<tr>
<td>Concentrate use</td>
<td>+10%</td>
<td>13.1</td>
<td>1.56%</td>
<td>9.65</td>
<td>-2.50%</td>
</tr>
<tr>
<td>Insemination costs</td>
<td>+10%</td>
<td>12.1</td>
<td>-0.63%</td>
<td>9.70</td>
<td>-2.08%</td>
</tr>
<tr>
<td>Milk sales</td>
<td>+10%</td>
<td>-</td>
<td></td>
<td>11.0</td>
<td>+11.00%</td>
</tr>
</tbody>
</table>
Discussion

Large variations were observed in descriptive statistics for indicators of herd productivity and intensification interventions. This depicts differences in the level and adoption of interventions. Higher production costs of up to KES 20.40 per Kg of milk indicates that these farmers are spending more on inputs used within dairy farms to achieve maximum output (production) levels. This production costs differs from previous estimates of KES 32.10 per liter of milk (Kibiego et al., 2015a) but in agreement with KES 18.10 per litre of milk estimated in other studies (Mburu et al., 2007). With increased input use in the intensification process means stepping up production costs which erodes profitability despite increased milk productivity. Increased milk yield was attained with improved input – concentrates. Despite some farmers having negative gross margins, revenues from milk sales exceeded production costs with returns of up to KES 4.2 per Kg of milk realized in the study, in contrast to (Kibiego et al., 2015b) findings of returns of KES 8.25 per Kg of milk but agrees with (Mburu et al., 2007) estimate of KES 3.45 per Kg of milk in a zero-grazing system.

Margin per litre of milk was best explained by concentrate use, insemination costs and milk sales depicting contribution of genetics and supportive socioeconomic interventions to intensification. In this, the two indicator variables representing socioeconomic intervention outlines a higher contribution towards margin per litre of milk as compared to genetic and ecological intervention to intensification. Milk sales positively contributed to margins depicting increase in margins with increases in milk sales. In both margin and milk yield, the study realized insignificant contribution of ecological intervention to intensification. This therefore means that when designing feeding interventions to maximize on milk yields and margins, inclusion of supplements should not be inflating the production costs. Alternatively, provision of cheap sources of feed with high nutritive values should be encouraged so as to meet the animal requirements level (Mburu et al., 2007), as well as ensuring the smallholder dairy farm is economically viable.

Conclusion and recommendations

Concentrates use is important for increasing milk production, but their price will be prohibitive to their increased use because of reduced margins. Further research should aim at addressing the observed variations within these smallholder dairy farms.

Acknowledgments

The authors are grateful to extension officers and farmers who supported data collection for this study.

References


Genetic and non-genetic factors affecting milk yield in dairy cattle under low-input production systems in Senegal

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3 International Livestock Research Institute (ILRI), Kenya

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Abstract

Milk production in Senegal is dominated by traditional extensive system. Improved intensive system is also practiced. Indigenous breeds are kept with low milk production potential. Cross-breeding traditional breeds with newly introduced breeds have become common in some regions. This poses problems with climate adaptation with imported breeds and crossbred animals. The study was carried out in Thies and Diourbal regions in Senegal under the Senegal Dairy Genetics Project. Data related to the household’s dairy enterprise, including animal performance and economic data, was collected between July 2013 and April 2015 via a baseline survey and 13 subsequent visits to each household. The data was analysed using General Linear Model (GLM) in R. The result showed that breed group, ethnicity, cooperative membership, livelihood source and housing mode during the rainy season significantly affected milk yield (p<0.05). Members of the ethnic group Wolof being newcomers in dairy production; tend to adopt modern dairy cattle rearing practices and therefore produce and sell more milk. Members of the ethnic group – Fula - are traditional pastoralists who stick to their cultural beliefs of keeping cattle, as a result their animals produce less milk. The organization of farmers into cooperatives secures supply of milk because cooperatives provide information on dairy management activities to members which translate into higher milk yield. The current study was able to generate genetic and non-genetic factors affecting milk yield in Senegal. This information can help cattle farmers in low input conditions to make decision on cattle breed selection based on the prevailing non-genetic factors affecting milk productivity. This will lead to improved milk production and marketing resulting to improved livelihoods.

Key words: Senegal, milk yield, genetic, non-genetic, dairy cattle

Introduction

In developing countries, livestock farming is one of the fastest growing agricultural subsectors. This growth is driven by increasing human population and incomes which have resulted in high demand for livestock products. Urbanisation has led to new eating habits consuming a higher amount of proteins such as milk (Delgado, 2003). Observed increase in future demand for livestock products provides special opportunities for improving livelihoods through improved food and nutritional security.

Most of smallholder and pastoral farmers in developing countries keep livestock for multiple reasons, including as a store of wealth, for income, to provide draught power, and to provide organic fertilizer for crop production (Herrero et al., 2013; Smith et al., 2013). However, productivity of livestock in such systems is often low, for reason such as low use of inputs, and the harsh environmental conditions under which the animals must perform, amongst others.

In Senegal, milk production is dominated by traditional extensive system. Pastoral and agro pastoral system account for 38% and 61% of national milk production respectively. Intensive dairy production, which accounts for 1% of national milk production, is mainly concentrated in peri-urban areas, such as those around of Dakar and Thies. In pastoral and agro pastoral systems, mainly indigenous breeds are kept with low milk production potential of between one and three litres per day with large variation between the dry and wet seasons (Diao, 2003). To improve milk production in Senegal, cross-breeding traditional breeds
such as the Zebu Gobra with newly introduced breeds such as Jersey, Holstein Friesian, and Montbeliard, amongst others, has become common in some regions (Gning, 2004). However, pure exotic breeds and crossbreed have problems with adapting to local environment. They also require higher inputs in terms of feeds and health care (Hansen 2004). This results in cows producing less milk than their genetic potential if environmental conditions and inputs were optimal.

Milk production is affected by genetic and non-genetic factors. Genetic factors include both across breed and within breed differences. The non-genetic factors are those that are not part of the genetic makeup of the animal. A number of non-genetic factors are known to influence milk yield significantly. These include: management practice such as level of feeding, watering, health-care, shade provision etc. parity and age within parity (Amimo et al., 2007; Bajwa et al., 2004). Additionally, Agro-ecological zones are a source of variation on total milk yield (Nyamushamba et al., 2013). The low milk yield recorded in the tropics is often mainly a result of scarcity of livestock feeds and lack of proper health care (Usman et al., 2013).

Senegal Genetic Project is a project in peri-urban dairy systems in Senegal, led by the International Livestock Research Institute (ILRI) (Senegal dairy genetics). One of the project objectives is to determine the most appropriate dairy breeds/crossbreed types for peri-urban dairy production systems. This objective can be achieved if the factors affecting milk yield in peri-urban dairy production systems can be determined.

In this work we evaluate the genetic and non-genetic factors influencing milk yield in low-input dairy cattle production systems in Senegal. This was performed as part of a larger project termed ‘Senegal Dairy Genetics’ which aimed to compare the performance, including cost benefit of keeping different breeds or cross-breeds of dairy cattle under different management levels (Marshall et al., 2016).

Materials and Method

Study site

The study was carried out in two regions, namely Thies and Diourbal in Senegal. The regions were selected because they have a mixture of indigenous, exotic and cross-bred dairy cattle. The regions have two seasons dry (November to May) and wet (June to October). The average annual temperature ranges from 25.7 to 27.9°C and average annual rainfall of 503 mm to 539 mm (Fall et al., 2006).

Data collection

Data related to household’s dairy enterprise, including animal performance and economic data, was collected between July 2013 and April 2015 via a baseline survey and 13 subsequent visits to each household. The data was maintained in a Structured Query Language (SQL) database hosted by International Livestock Research Institute (ILRI). In total more than 220 households and about 3500 cattle’s were involved in the project.

Milk yield

The response variable was individual animal milk yield at 305 days in milk. Individual animal milk yield was estimated using the test day’s milk yield record by Interpolation Standard Lactation Curves (ISLC) Wilmink, 1987 function (ICAR Recording Guidelines 2014 ). Only animals with 5 or more test-day milk records were considered. The data set was explored further and only cows with an estimated daily milk yield at the start of lactation (DMY0) of less than 20 litres, and less than 2100 litres for the 305 day lactation, were maintained in the data set, resulting in 144 cows in 86 households.

Breed groups

Each animal was assigned to a breed group either based on genomic information or, in cases where this was not available, by farmer-given breed type (Table 1).
Table 6: Breed-group of cattle

<table>
<thead>
<tr>
<th>Breed group</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indigenous Zebu (IZ)</td>
<td>Zebu Gobra; Zebu Maure</td>
</tr>
<tr>
<td>Indigenous Zebu by Guzerat (IZG)</td>
<td>Indigenous Zebu cross with Guzerat; typically 25% to 50% Guzerat</td>
</tr>
<tr>
<td>Indigenous Zebu by Bos Taurus (IZB)</td>
<td>Indigenous Zebu cross with Bos Taurus; mainly Montbeliarde and Holstein-Friesian; typically 25% and 50% Bos Taurus</td>
</tr>
<tr>
<td>High Bos Taurus (HB)</td>
<td>Indigenous Zebu cross with Bos Taurus, mainly Montebeliarde and Holstein-Friesian; typically 75% to 100% Bos Taurus</td>
</tr>
</tbody>
</table>

1 Animals of other breed groups apart from the mentioned ones or without any breed information were classified as ‘others’

Data analysis

The selection of variables to test for influence on milk yield was based on existing literature on factors that affect milk yield in tropical countries. Simple regression was done to all continuous variables, while ANOVA was done on categorical explanatory variables separately. Variables that were not significant at a p-value of >0.2, >20% missing data and those that had too low number of observations for some of the classes were excluded from the data set for analysis. Finally, a total of 16 variables were left to be subjected to further analyses, where 3 were continuous (quantitative) and 13 were discrete (qualitative) variables. Summary statistics of 16 variables are given as mean, standard deviation for continuous variables and categories for discreet variables are presented in Table 2.

Covariance analysis was done using General Linear Model (GLM) in R with discrete (qualitative) explanatory variables as fixed effects and continuous (quantitative) explanatory variables as co-variables. Statistical significant level was assessed at (P<0.05).
Table 2: Descriptive statistic summary of explanatory variables and the number of observations per variable

<table>
<thead>
<tr>
<th>Variable name (units)</th>
<th>No of observation</th>
<th>Mean±std.</th>
<th>Number of observations per level for discrete variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCPC (CFA)</td>
<td>144</td>
<td>631.5±2206.4</td>
<td></td>
</tr>
<tr>
<td>THM (Number)</td>
<td>83</td>
<td>19.2±10.9</td>
<td></td>
</tr>
<tr>
<td>Herd tlu</td>
<td>85</td>
<td>16.0±13.0</td>
<td></td>
</tr>
<tr>
<td>Breed group</td>
<td>144</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BCS_wet</td>
<td>144</td>
<td></td>
<td></td>
</tr>
<tr>
<td>co_operative</td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education level</td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor type</td>
<td>78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site</td>
<td>86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Livelihood source</td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information provider</td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Record keeping</td>
<td>85</td>
<td></td>
<td>mental=44, No records=27, written and mental=14</td>
</tr>
<tr>
<td>PRD</td>
<td>85</td>
<td></td>
<td>Income=48, savings/insurance=13, others=24</td>
</tr>
<tr>
<td>Housing mode</td>
<td>84</td>
<td></td>
<td>IZ= 61 ,IZG= 20 IZB= 33 and HB =7 and OT</td>
</tr>
<tr>
<td>Housingmode</td>
<td>84</td>
<td></td>
<td>(others) = all other types of breeds beside the</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>mentioned ones 23</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>thin=67, good=42fat=35***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Yes=35 , No=50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coranic=42, informal education=13, primary and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>above=30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fula(peul)=20, Wolof= 54, others=11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Household and hired male=13, household male=20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>and hired male=45</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Diourbel=33, Thies=53</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>crop production=27, dairy production=20, own</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>business=32, others=6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Government extension +Vet=11, no-one=24,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>veterinary or animal health=50</td>
</tr>
</tbody>
</table>

*herd_tlu was calculated using the guide in gender, livestock and livelihood indicators(Njuki et al., 2011)

**The scale of body condition score was as per Note d’état corporal des zébus soudaniens (Vall & Bayala, 2004)

*** Dry and wet period refers to the third and the ninth visit by the enumerator to each household respectively

IZ= Indigenous Zebu, IZG= Indigenous Zebu by Guzaret, IZB= Indigenous Zebu by Bos Taurus, HB= High Bos Taurus, OT= Others, HCPC= health cost per cow, THM = Total Household Member, BCS = Body Condition Score, PRD= Primary Reason for Dairy

To estimate the effect of the factors affecting milk yield, the following model was assumed

\[ Y_{ijklmnopqrstuvwxyz} = \beta_0 + BGi + LS_j + IP_k + E_l + HMR_m + CM_n + BCSW_o + ED_p + LT_q + SR_r + RK_s + PRD_t + HMD_u + \beta_1HCPC_v + \beta_2THM_w + \beta_3HTLU_x + \epsilon_{ijklmnopqrstuvwxyz} \]

Where (Table 3)
Table 3: Explanation of the model including the variable, effect of the factor and the categories of discreet variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Effect</th>
<th>Categories of discreet variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y_{ijklmnopqrstuvwxyz}$</td>
<td>individual milk yield at 305 days in milk on the $y^{th}$ animal</td>
<td></td>
</tr>
<tr>
<td>$\beta_0$</td>
<td>mean</td>
<td></td>
</tr>
<tr>
<td>$BG_i$</td>
<td>Fixed effect of the $i^{th}$ breed group</td>
<td>$I = 1...5$ ($1 = IZ, 2 = IZG, 3=IZB, 4=HB, 5=OT$)</td>
</tr>
<tr>
<td>$LS_j$</td>
<td>Fixed effect of the $j^{th}$ livelihood source</td>
<td>$J = 1...4$ ($1 = Crop Production, 2= Dairy cattle, 3=others, 4= own business$)</td>
</tr>
<tr>
<td>$IP_k$</td>
<td>Fixed effect of the $k^{th}$ information provider</td>
<td>$k = 1...4$ ($1 = Government Extension and Veterinary, 2= no one, 3= veterinary or animal worker$)</td>
</tr>
<tr>
<td>$E_l$</td>
<td>Fixed effect of the $l^{th}$ ethnicity</td>
<td>$l = 1...3$ ($1 = Fula, 2 = Other, 3= Wolof$)</td>
</tr>
<tr>
<td>$HMR_m$</td>
<td>Fixed effect of the $m^{th}$ housing mode rainy season</td>
<td>$m = 1...2$ ($1=fenced with no roof, 2= tethered in an open space$)</td>
</tr>
<tr>
<td>$CM_n$</td>
<td>Fixed effect of the $n^{th}$ cooperative member</td>
<td>$n = 1...2$ ($1= Government Extension and Veterinary, 2= no one, 3= veterinary or animal worker$)</td>
</tr>
<tr>
<td>$BCSW_w$</td>
<td>Fixed effect of the $w^{th}$ body condition score wet</td>
<td>$w = 1...3$ ($1=thin, 2=good, 3 =fat$)</td>
</tr>
<tr>
<td>$ED_p$</td>
<td>Fixed effect of the $p^{th}$ education level</td>
<td>$p = 1...3$ ($1=Coranic, 2= informal education, 3= primary and above$)</td>
</tr>
<tr>
<td>$LT_q$</td>
<td>Fixed effect of the $q^{th}$ labour type</td>
<td>$q = 1...3$ ($1= household and hired male, 2= household male, 3= hired male$)</td>
</tr>
<tr>
<td>$S_r$</td>
<td>fixed effect of the $r^{th}$ site</td>
<td>$r = 1...2$ ($1= Diourbel, 2= Theis$)</td>
</tr>
<tr>
<td>$RK_s$</td>
<td>fixed effect of the $s^{th}$ record keeping</td>
<td>$s = 1...3$ ($1 = mental, 2= no records, 3= written +mental$)</td>
</tr>
<tr>
<td>$PRD_t$</td>
<td>fixed effect of the $t^{th}$ primary reason for dairy</td>
<td>$t = 1...3$ ($1= income, 2= savings/insurance, 3= others$)</td>
</tr>
<tr>
<td>$HMD_u$</td>
<td>fixed effect of the $u^{th}$ housing mode dry</td>
<td>$u = 1...3$ ($1= permanently fenced area with no roof, 2= structure with roof, 3= tethered in an open space$)</td>
</tr>
<tr>
<td>$\beta_1HCPC_v$</td>
<td>health cost per cow</td>
<td></td>
</tr>
<tr>
<td>$\beta_2THM_w$</td>
<td>total household members</td>
<td></td>
</tr>
<tr>
<td>$\beta_3HTLU_s$</td>
<td>Herd TLU</td>
<td></td>
</tr>
</tbody>
</table>

IZ= Indigenous Zebu, IZG= Indigenous Zebu by Guzaret, IZB= Indigenous Zebu by Bos Taurus, HB= High Bos Taurus, OT= Others

Means for the significant variables (P<0.05) were separated using Tukey’s range test. However, variables that were significant but had less than two classes per variable were not subjected to means separation.
Results

Milk yield at 305 days

Milk yield by breed group showed that High Bos Taurus had an average milk yield of 1500 litres for 305 days (Figure 1). Indigenous Zebu by Bos Taurus had a mean milk yield of 1250 litres. Indigenous Zebu had the lowest mean milk yield. The overall average 305-days milk yield was 725.4 ±533.2 litres.

![Figure 1: Milk yield per breed group for 305 days](image)

IZ= Indigenous Zebu, IZG= Indigenous Zebu by Guzaret, IZB= Indigenous Zebu by Bos Taurus, HB= High Bos Taurus, OT= Others

Milk yield by Ethnicity

Milk yield by ethnicity showed Wolof produced the highest mean milk yield (885.6 litres) followed by Fula (470.3 litres) and “others” produced the least mean milk yield at 305 days (445.1 litres) (Figure 2).

![Figure 2: Mean milk yield by ethnicity for 305 days](image)

Analysis of Covariance

About 61% of variation in 305-days milk yields can be explained by the model (Table 3). The analysis of covariance for various factors affecting milk yield indicated that, body condition score during wet season, education level, total household members, site, herd TLU, information provider, record keeping and primary reason for keeping dairy were not statistically significant (P>0.05) (Table 3). Breed group, cooperative membership, ethnicity, labour type, livelihood source and housing mode during rainy season were statistically significant (P<0.05) (Table 4)
Table 4: Degrees of freedom (Df) and P-values from analysis of variance for various factors affecting milk yield

<table>
<thead>
<tr>
<th>Factors</th>
<th>Df</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breed group</td>
<td>4</td>
<td>0.000***</td>
</tr>
<tr>
<td>Body condition score - wet</td>
<td>2</td>
<td>0.544</td>
</tr>
<tr>
<td>Health cost per cow</td>
<td>1</td>
<td>0.039</td>
</tr>
<tr>
<td>Cooperative</td>
<td>1</td>
<td>0.016*</td>
</tr>
<tr>
<td>Education level</td>
<td>2</td>
<td>0.082</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>2</td>
<td>0.000***</td>
</tr>
<tr>
<td>Total household members</td>
<td>1</td>
<td>0.263</td>
</tr>
<tr>
<td>Labour type</td>
<td>2</td>
<td>0.038*</td>
</tr>
<tr>
<td>Site</td>
<td>1</td>
<td>0.076</td>
</tr>
<tr>
<td>Herd tlu</td>
<td>1</td>
<td>0.842</td>
</tr>
<tr>
<td>Livelihood source</td>
<td>3</td>
<td>0.009**</td>
</tr>
<tr>
<td>Information provider</td>
<td>3</td>
<td>0.120</td>
</tr>
<tr>
<td>Record keeping</td>
<td>2</td>
<td>0.251</td>
</tr>
<tr>
<td>Primary reason dairy</td>
<td>2</td>
<td>0.522</td>
</tr>
<tr>
<td>Housing mode dry</td>
<td>2</td>
<td>0.760</td>
</tr>
<tr>
<td>Housing mode rainy</td>
<td>1</td>
<td>0.000***</td>
</tr>
</tbody>
</table>

Model summary df 93, Adjusted R2 - 0.6085 Signif.codes:0***, 0.001** and 0.01*

Means comparison for significant variables

Means for the significant variables (breed group, ethnicity and livelihood source) were separated using Tukey’s range test. There was significant difference between indigenous Zebu by Bos Taurus and Indigenous Zebu, Indigenous Zebu by Guzerat and high Bos Taurus (P<0.05) in 305 days mean milk yield. However there was no significant difference between Indigenous Zebu and Indigenous Zebu by Guzerat (P>0.05) and also between Indigenous Zebu by Bos Taurus and High Bos Taurus (Table 5).

Table 5: Milk yield means comparison for breed type

<table>
<thead>
<tr>
<th>Breed group</th>
<th>N</th>
<th>Means±Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indigenous Zebu</td>
<td>61</td>
<td>399.0±276.38^a</td>
</tr>
<tr>
<td>Indigenous Zebu by Guzerat</td>
<td>20</td>
<td>591.1±359.411^a</td>
</tr>
<tr>
<td>Indigenous Zebu by Bos Taurus</td>
<td>33</td>
<td>1171.4±457.36^b</td>
</tr>
<tr>
<td>High Bos Taurus</td>
<td>7</td>
<td>1316.7±434.55b</td>
</tr>
<tr>
<td>Others</td>
<td>23</td>
<td>888.1±650.6^c</td>
</tr>
</tbody>
</table>

N=Number of observations

^abc means in a column with one letter superscripts in common are not significantly different (P>0.05)

Milk yield mean comparison for the different ethnicity showed that Wolof and Fula were significantly different. Whereas, Fula and others ethnicity were not significantly different (P>0.05) (Table 5). Crop and cattle production as livelihood source were not significantly different on mean milk yield. However, those households with own business differed significantly with crop and cattle production as livelihood source in 305 days milk yields (Table 6).
Table 6: Milk yield means comparison for ethnicity

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>N</th>
<th>Means±Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wolof</td>
<td>90</td>
<td>885.6±570.35(^a)</td>
</tr>
<tr>
<td>Fula</td>
<td>34</td>
<td>470.3±352.50(^b)</td>
</tr>
<tr>
<td>Others</td>
<td>19</td>
<td>445.1±280.70(^b)</td>
</tr>
</tbody>
</table>

N=Number of observations
\(^ab\) means in a column with one letter superscripts in common are not significantly different (P. >0.05)

Table 7: Milk yield means comparison for livelihood source

<table>
<thead>
<tr>
<th>Livelihood source</th>
<th>N</th>
<th>Mean±Std.Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop production</td>
<td>45</td>
<td>503.4±441.68(^a)</td>
</tr>
<tr>
<td>Dairy production</td>
<td>34</td>
<td>609.4±472.77(^a)</td>
</tr>
<tr>
<td>Own bussiness</td>
<td>54</td>
<td>942.2±523.16(^b)</td>
</tr>
</tbody>
</table>

N=Number of observations
\(^ab\) means in a column with one letter superscripts in common are not significantly different (P. >0.05)

Discussion

In this study, the breed group had a positive effect on 305 days milk yield. High Bos Taurus and indigenous zebu by Bos taurus reported the highest milk yield at 305 days which was significantly the same. This is due to Bos Taurus are known genetically for high milk production, whereas, Indigenous Zebu by Bos Taurus had an effect of heterosis because in the crossbreds many genes are heterozygous that were homozygous in the parent breeds. The indigenous zebu and indigenous Zebu by Guzerat had 305 milk yields significantly the same. These are Bos indicus species which has low potential for milk production compared to Bos taurus under tropical conditions. The 305 days milk yield follows the trend of breed group averages reported by Marshall (Marshall et al., 2016). This confirms with other previously reports by several authors (Abraha et al., 2009; Tadesse & Dessie, 2003) in Ethiopia and (Ngongoni et al., 2006) in Zimbabwe under smallholder production system. The study shows that the genetic potential of the different genotypes plays a role in the 305 days milk yield.

Cooperative membership had a positive effect on milk yield. This is because organisation of farmers into cooperatives secures supply of milk throughout the seasons (Dieye et al., 2005). The cooperatives provide information on dairy cattle management activities to members which translate into higher milk yield.

Average milk yield (per lactation) produced was significantly influenced by ethnicity of the dairy keeping household. Wolof ethnicity had a significant and positive effect on milk yield. Their main primary reason for keeping dairy cattle was income. They took milk production practice as an income generating enterprise. Fula kept mostly Indigenous Zebu on both sites, which genetically have low potential for milk yield. Fula are traditional pastoralists who strongly associate cattle to their cultural tradition (marriage, pilgrimage and inheritance) and ethnic identity (Adriansen, 2006).

Housing mode during rainy season of under roof had positive effect on milk production. In additional, being in a roof provide shade, protects from the environmental harsh conditions. Households who own other business as primary livelihood source of income for one year had a significant different effect on milk yield to those who had crop and dairy as a source of livelihood. This is likely because income generated from off-farm activities can be used to cater for cattle feeds and health cost. The main provider of labour
throughout the periods in relation to dairy was hired male which was significant on milk yield. Herding the animals, feeding, watering and production of fodder were done by hired male.

**Conclusion**

The current study was able to generate genetic and non genetic factors affecting milk yield in Senegal. This information can help cattle farmers in low input conditions to make decision on cattle breed selection based on the prevailing non-genetic factors affecting milk productivity. This will lead to improved milk production and marketing resulting to improved livelihoods.

**Acknowledgements**

The study was carried out as part of research project ‘Senegal Dairy genetics. It was funded by the Finnish Ministry of Foreign Affairs under the Food Africa program, and the CGIAR Research Program on Livestock and Fish. The authors gratefully acknowledge participating farmers for availing their animals for study.

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Performance and Genotypes of Dairy Goats in Kenya: The Need to move beyond Donor Introductions

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Abstract

A study was conducted in the Central, Eastern and Nyanza cluster regions in Kenya where the Alpine, Toggenburg and Saanen dairy goat breeds respectively, were kept. The objective was to determine the breeds’ relative performance for use as a basis of their recommendation to farmers. Formal questionnaires were used to obtain information on farm sizes, dairy goat sources, reasons for keeping the dairy goats, goat milk production, amount of feed offered to the dairy goats and the constraints faced. Further information on the actual amounts of feed offered, milk production and live weights of the milking does was collected directly from the farms using hired recorders. Results indicated that the dairy goats were fed between six and 17 kg/goat day1 of forage. They had a low production average of 1.4 L milk/goat day1 with no cear cut breed differences. Toggenburg milking does were significantly (P < 0.05) heavier than the other breeds (48.3 vs 38.0 and 39.0 kg for the Alpine and Saanen dairy goats, respectively). The milk production and goat live weights were below their reported potential. It was concluded that farmers could keep any of the three breeds. It was recommended that efforts be made to generate data on the comparative potential performance from the three breeds and their upgrades based on research to guide on farmer choices. Sources of goat genetic material should be diversified to cater for the dwindling buck pool and low goat artificial insemination coverage.

Key words: Dairy goats, goat genotypes, goat milk, goat weights, Kenya

Introduction

Goats (Capra hircus) provide an important source of food through meat and milk, with goat milk being consumed by more people in the world than cow milk (Haenlein, 2004). It is estimated that there are about 28 million goats in Kenya (GoK, 2010), of which about 415,518 are the dairy type (MOALF, 2015). The dairy goat breeds include the Alpine, Toggenburg, Saanens and Anglo-Nubian while the indigenous breeds are mainly the Galla and the Small East African goat (SEAG). However, the term dairy goat is more frequently used to refer to the dairy goats and their crosses with the indigenous goats (CTA, 2007). The importance of the dairy goat enterprise in Kenya has increased due to its ability to earn income (Kinyanjui et al., 2008), through the sale of breeding stock and milk. The enterprise has further gained significance in the highlands due to decreasing farm holdings making it difficult to keep dairy cattle (Kinuthia, 1997).

Dairy goats have been in Kenya since the 1950s when they were first introduced by the British settler farmers (Shivairo et al., 2013). Subsequent introductions have been through the collaboration between the Government of Kenya (GoK) with donor agencies, or by non-Governmental organizations (NGOs), to upgrade the local goats. The agencies included the German Agricultural Team (GTZ/GIZ) in 1992-1999 (Kamau, 2016), Farm Africa NGO in 1996-98 (Ojango et al., 2010), and Heifer Project International-Kenya (HPIK) in 2005, among others. Different dairy goat breeds were introduced by the agencies in their respective areas of operation. The agencies also targeted different genotype upgrade levels. The increased interest on dairy goats in the country has led to increased enquiries to the Kenya Agricultural and Livestock Research Organization (KALRO), on which breeds are suitable for the various farmers’ localities. Milk production levels of 2.1 L (Ogola et al., 2010) and 3.0 L/goat.day (Mburu et al., 2014) have been reported for dairy goats in the country. There has been no study on the relative breed performance of the dairy goats in the different parts where they were introduced to guide on recommendation to farmers. Therefore, this study was conducted to determine the performance of the dairy goat breeds kept by farmers in three cluster...
regions in Kenya; Central, Eastern and Nyanza clusters, as a basis for recommendation and as a part of a wider project to determine the research priorities for dairy goats in Kenya.

Materials and Methods
The study area
The study was conducted in the Central, Eastern and Nyanza clusters in Kenya, in high to medium agricultural areas (Jaetzold et al., 2006a,b,c). Nine agro-ecological zones (AEZs) were covered; four in each of the upper (U) and lower (L) midland (M) zones, and one in the inner lowland (IL) zone. The Central cluster included farmers in Kirinyaga and Embu counties, where Alpine breed of dairy goats was introduced by the GTZ. The cluster area lies at an altitude of 1090-1880 m asl, longitude of 37°7’-37°41’ East, and latitude of 0°9’-0°47’ South (Jaetzold et al., 2006a,b). The mean annual rainfall and temperature ranges were 836-1800 mm and 16.7-23.4°C, respectively. The Eastern cluster included farmers in Meru and Kitui counties, where Toggenburg breed of dairy goats was introduced by the Farm Africa. The area has an altitude of 760-1800 m asl, longitude of 37°5’-39°0’ East, and latitude of 0°10’ North to 1°47’ South (Jaetzold et al., 2006b). The mean annual rainfall and temperature ranges for the area were 471-1079 mm and 19.2-25.8°C, respectively. The Nyanza cluster included farmers in Homa Bay and Migori counties, where Saanen breed of dairy goats was introduced by the HPIK NGO. The area has an altitude of 1135-1550 m asl, longitude of 34-35°East, and latitude of 0°20’-1°0’ South (Jaetzold et al., 2006c). The mean annual rainfall and temperature were 800-1800 mm and 20.4-22.7°C, respectively.

Data collection and analysis
Three regional clusters were selected in 2013 using stratified systematic sampling (Moser and Kalton, 1974), based on the predominant dairy goat breed kept. For each cluster, two counties were selected based on their history of having interventions on dairy goats. The respective dairy goats associations’ officials and the livestock extension staff assisted in identifying farmers keeping dairy goats. Data were collected from farmers, on farm sizes, goat numbers, dairy goat production systems, dairy goat management, and challenges faced using a formal questionnaire. Interviews were conducted by research and extension staff. A total of 205 questionnaires were successfully administered. Further data on the amount of feed offered, milk production, and live weights of the does were collected from 10 to 16 farmers per county for one month, using two recorders per county. The weights of milking does and feeds offered were estimated using weighing balances. The volume of milk produced was measured using graduated plastic one-litre jags. The study was conducted during the wet season.

Data were subjected to analysis of variance (ANOVA), using the General linear model (GLM) procedures of Statistical Analysis System (SAS, 2004). The model for Nested Design (Hicks, 1982) was used to analyze the data collected. Means were separated using the least significant difference (LSD) and Tukey’s multiple comparison test.

Results
Respondents
Majority of the farmers (74%) were over 45 years of age, had formal education (90%) and about 58% were women. Farmers owned an average of 1.6 hectares per household, mainly under the freehold tenure (82.4%) system. Farm sizes were largest in the Nyanza cluster (2.4 ha) and smallest in the Central cluster (0.9 ha).

Livestock kept
Farmers kept an average of five dairy goats per household, mainly under the zero grazing (82.5%) system. Farmers in the Nyanza cluster kept fewer (P < 0.05) dairy goats than in the other two clusters (4.0 vs 5.8 and 6.2 for the Central and Eastern clusters, respectively).
Sources of dairy goats

Majority of the farmers obtained dairy goats through grants by donors or purchasing (Table 1). Several agencies supported dairy goats in the Central cluster. The GTZ was the main donor and aimed to upgrade the local goats to 87.5% pure Alpine for dairy production, following the decreasing farm holdings for cattle dairying. In the Eastern cluster, the objective of the Farm Africa NGO was to avail nutritious milk and improve living standards of the resource poor farmers, especially women (Ojango et al., 2010a), using a 75% Toggenburg goats. Dairy goats in the Nyanza cluster were supported by several agencies but HPIK was the main NGO. HPIK aimed to support orphans and widows, and boosting their body immunity.

<table>
<thead>
<tr>
<th>Goat source</th>
<th>Frequency</th>
<th>Percentage of farmers</th>
<th>Percentage of farmers by cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provided by donor (through group)</td>
<td>106</td>
<td>53.8a</td>
<td>Central 17.2c</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Eastern 49.0b</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nyanza 95.3a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LSD 13.69</td>
</tr>
<tr>
<td>Bought by farmer</td>
<td>90</td>
<td>42.2b</td>
<td>Central 74.0b</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Eastern 47.9b</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nyanza 4.7c</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LSD 15.50</td>
</tr>
<tr>
<td>Provided by farmer group</td>
<td>5</td>
<td>2.6c</td>
<td>Central 4.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Eastern 3.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nyanza 0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LSD 7.60NS</td>
</tr>
<tr>
<td>Provided by donor and also bought</td>
<td>4</td>
<td>1.9c</td>
<td>Central 5.7a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Eastern 0.0b</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nyanza 0.0b</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LSD 5.62</td>
</tr>
</tbody>
</table>

LSD = least significant difference between means
Means bearing different superscript letters (a, b, c) within a row (or within a column for all clusters combined) are significantly different (P < 0.05)

The donated or purchased dairy goats had exotic blood already, or were local goats that farmers subsequently upgraded using pure bucks originally provided by the donors. The genotypes of the dairy goats kept were therefore the various upgrades (Table 2).

<table>
<thead>
<tr>
<th>Cluster (Breed)</th>
<th>No. of goats</th>
<th>Percentage of exotic blood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>Central (Alpine)</td>
<td>37</td>
<td>13.5</td>
</tr>
<tr>
<td>Eastern (Toggenburg)</td>
<td>92</td>
<td>9.8</td>
</tr>
<tr>
<td>Nyanza (Saanen)</td>
<td>38</td>
<td>92.1</td>
</tr>
<tr>
<td>Total</td>
<td>167</td>
<td>29.4</td>
</tr>
</tbody>
</table>

* Kitui county had three recorders and additional goats got recruited as the previous ones were dried off

Reasons for rearing dairy goats

Majority of the farmers kept dairy goats to get nutritious milk, but income generation to raise standards of living was also important (Table 3). Improving the health of orphaned children was an important reason unique to the Nyanza cluster. Sale of offspring ranked higher than sale of milk.

<table>
<thead>
<tr>
<th>Reason</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutritious milk for home consumption</td>
<td>146</td>
<td>80.8a</td>
</tr>
<tr>
<td>Raise standards of living</td>
<td>103</td>
<td>58.6b</td>
</tr>
<tr>
<td>Sale of offspring</td>
<td>99</td>
<td>53.3b</td>
</tr>
<tr>
<td>Sale of goat milk</td>
<td>91</td>
<td>48.3b</td>
</tr>
<tr>
<td>Support orphans and boost body immunity</td>
<td>46</td>
<td>27.1c</td>
</tr>
<tr>
<td>Consumes less hence easier to manage than cow</td>
<td>10</td>
<td>5.4d</td>
</tr>
<tr>
<td>Manure</td>
<td>5</td>
<td>2.3d</td>
</tr>
</tbody>
</table>

MSD = Tukey’s minimum significant difference between means
Means bearing different superscript letters (a, b, c, d) within a column are significantly different (P < 0.05)
Dairy goats feeding

Goats were offered between six and 17 kg of forage per goat per day, consisting of grasses and/or legumes. Farmers in the Eastern cluster fed more (P < 0.05) forage to their goats than those in the Central cluster. Concentrate supplementation was done occasionally by 83% of the farmers. Piped water was the commonest (34.2%) source of water, and farmers in the Central cluster enjoyed shorter (P < 0.05) distances to water source (0.1 km) than in the other two clusters (1.0 km).

Milk production and goat weights

About 62% of the farmers milked one or two dairy goats producing 1.4 L milk/goat day\(^{-1}\) (Table 4). The production level agreed well with the recorded data of 1.3 L/goat day\(^{-1}\). The milking does weighed 41.4 kg on average. However, the reported and recorded data did not agree on the cluster with the highest goat productivity for milk.

Table 4: Average daily milk production and weight of milking does by cluster and county, Kenya

<table>
<thead>
<tr>
<th>Cluster/county</th>
<th>Milk production (L/goat day(^{-1}))</th>
<th>Recorded doe weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reported (survey)</td>
<td>Recorded</td>
</tr>
<tr>
<td>Cluster (Breed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central (Alpine)</td>
<td>1.1(^b)</td>
<td>1.6(^a)</td>
</tr>
<tr>
<td>Eastern (Toggenburg)</td>
<td>1.2(^b)</td>
<td>1.3(^b)</td>
</tr>
<tr>
<td>Nyanza (Saanen)</td>
<td>2.1(^a)</td>
<td>1.2(^b)</td>
</tr>
<tr>
<td>LSD</td>
<td>0.33</td>
<td>0.12</td>
</tr>
<tr>
<td>County</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kirinyaga</td>
<td>1.2(^b)</td>
<td>2.1(^a)</td>
</tr>
<tr>
<td>Embu</td>
<td>1.1(^b)</td>
<td>1.2(^c)</td>
</tr>
<tr>
<td>Meru</td>
<td>1.2(^b)</td>
<td>1.2(^c)</td>
</tr>
<tr>
<td>Kitui</td>
<td>1.2(^b)</td>
<td>1.3(^c)</td>
</tr>
<tr>
<td>Homa Bay</td>
<td>2.4(^a)</td>
<td>1.7(^b)</td>
</tr>
<tr>
<td>Migori</td>
<td>1.6(^b)</td>
<td>0.6(^d)</td>
</tr>
<tr>
<td>LSD</td>
<td>0.46</td>
<td>0.16</td>
</tr>
</tbody>
</table>

LSD = least significant difference between means
Means bearing different superscript letters (a, b, c, d) within a column are significantly different (P < 0.05)

Goat survival rates

The number of the dairy goat age groups that died annually per household was 0.36, 0.12 and 0.46 for kids, weaners and adults, respectively. Weaners had higher (P < 0.05) survival rates than kids and adults. The number of deaths for the various age groups was not significantly (P > 0.05) different across the clusters.

Goat breeding

Dairy goats were bred through the natural buck service, with artificial insemination (AI) being used mainly in the Central cluster. A buck stayed in one station for an average of 19.5 months, and the buck rotation period was longer (P < 0.05) in Nyanza than in the other two clusters (29.4 vs 16.0 and 17.4 months in the Central and Eastern clusters, respectively).

Constraints to dairy goats production

The main constraints faced by dairy goat farmers included the inadequate feeds during the dry season (30.7%), disease prevalence (30.2%), unorganized goat milk markets (23.1%), irregular market for live goats (17.5%), and inadequate breeding bucks (10.4%).
Discussion

Both the breed and genotype of the dairy goats kept in the respective clusters were influenced by the main supporting donor. The exotic blood level with the highest percentage of milking goats in the Central and the second highest in the Eastern clusters (87.5 and 75%, respectively) was the upgrade level targeted by the respective donors. In the Nyanza cluster where the main objective was to provide the community with goat milk, pure Saanen dominated as it was the initial target genotype before the Galla breed was brought in for upgrading to improve survival rates. However, the dairy goats for all the breeds had lower average milk production (1.4 L/goat day\(^{-1}\)) than their potential, and milk production did not reflect differences in breed or genotype. All the three breeds have a reported potential of about 4 L day\(^{-1}\) (McDonald et al., 1988) and production levels achieved in Kenya include 3.0 L for the Alpine (Mburu et al., 2014), and 2.0 L for the Toggenburg (Ojango et al., 2010). The Saanen has been reported to produce 3.9 L (Livestock Kenya Com, 2014) in the tropics. The fact that the survey and recorded data did not agree on the breed with the highest production shows that comparison of the three breeds under the same level of management is necessary. Goat survival rates for the various classes were also similar across the clusters. The observed weights of mature does of 38.0, 43.8, and 39.0 kg respectively, were lower than the reported potentials of 60, 45-50, and 50-65 kg (Steel, 1996) for the Alpine, Toggenburg and Saanen goats, respectively. The Toggenburg breed, however, was superior contrary to the expectation, and almost achieved its potential. It was therefore difficult to recommend one breed over the other using the dairy goat performance results.

Several factors could have led to the lower dairy goat performance than their potential. The goats were offered forage on the basis of feed availability without regard to proportion of grass or legume, and not on nutrient requirements for milk production or body weight. Rations for dairy goats based on the available feed resources to achieve the potential production levels are needed. Some 38% of the farmers did not milk their goats. The sale of offspring ranked higher than the sale of milk, which agrees with the findings of a survey by RDCoE (2011) that dairy goats were mainly kept for milk production, but the sale of breeding stock was the main source of income in the enterprise. However, Ojango et al. (2010) reported that it was the best goats, which were the fast growing animals under one year, that were sold. The scarcity of breeding bucks could have led to the long buck rotation period especially in the Nyanza cluster (29 months), exposing goats to inbreeding. Marete et al. (2011) reported an increase in the population of Kenya Alpine that were inbred. Only farmers in the Central cluster had mainly benefited from AI service. There is need to seek ways to allow controlled buck importation, which is currently banned in Kenya following the outbreak of mad cow disease in Europe in 1990s (Marete et al., 2011). The problem of buck unavailability was exacerbated by the sale of the bucks with high growth rates. There is need to build the capacity of a Government institution or a breeder’s organization to preserve quality genetic material for access to farmers, and track breeding by farmers for records and maintain trust in such records, noting that the exotic blood level determined the price of the goats.

Conclusions

Information available on dairy goat production and survival rates did not favour any breed for recommendation to farmers over the others, hence farmers could keep any of the three. The farmers’ emphasis on raising dairy goats for sale of offspring may have influenced negatively the levels of milk production and goat live weights. Information on milk production and growth rates based on the upgrading exotic breed and the parental indigenous goats, taking into account the feeding and genotype by environment interaction, is needed as a guide to farmers on what to expect from their goats.

Recommendations and Way Forward

1. Characterization of performance of the various dairy goat upgrades emanating from Galla and SEAG under the same level of management to facilitate recommendation to farmers.
2. Accelerating the means of availing AI services and breeding bucks to farmers.
3. Monitoring the maintenance and improvement of the dairy goat germplasm already with the farmers.

Acknowledgement

The authors thank the Director General KALRO, for permission to conduct this work and providing funds through the East African Agricultural Productivity Project. The Centre Director, KALRO Naivasha is thanked for logistic and technical support. The officials of the Dairy Goat Association of Kenya, Meru Goat Breeders Association, Kitui-Mwingi Goat Breeders Association, and Nyanza Dairy Goats Farmers Association, together with Livestock extension officers in the various counties covered are thanked for facilitating access to farmers. Ms W. Gachina, Dr. M. Mudeheri and Mr. S. Mailu are highly appreciated for assisting in questionnaire administration in the field.

References


Effect of genotype, egg size, incubation weight loss and egg storage period on hatchability, chick-hatch weight and subsequent performance of chicken genotypes reared intensively

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Abstract

Although incubation egg weight loss has been long recognized, little is documented on its effect on the embryo to month old of chicks. It has been suggested that the loss occurs in two ways; molecular diffusion across the shell membrane and convection from the micro-climate in the incubator or storage area. This study investigated the effect of genotype, egg size, incubation egg weight loss and egg storage period on hatchability, chick-hatch weight and subsequent performance of chicken genotypes reared intensively at Non Ruminant Research Institute (NRI) – Naivasha. Incubation weight loss did not significantly affect all the measured parameters, whereas storage time was only significant (P< 0.05) for chick-hatch weight. Medium sized eggs lost more weight as compared to large eggs. There was significant variation in the genotypes with respect to hatchability, chick-hatch weight and month old chick weight. Increased hatchability was observed in scenarios where indigenous chicken was part of the parents of the incubated eggs, and the opposite observed for where indigenous chicken was not included as parents. This was however not the same in the case of chick-hatch weight where inclusion of indigenous chicken resulted in reduced weights. Storage time significantly (P < 0.05) affected chick-hatch weight. This was further confirmed by the negative correlation (-0.404) between incubation egg weight loss and hatchability. Further research is needed to determine the optimal storage period of eggs for incubation per genotype for better chick-hatch weight.

Key words: chick-hatch weight, egg storage period, genotypes, incubation weight loss

Introduction

Weight loss of eggs during natural/artificial incubation, together with mechanisms resulting in the same, has long been recognized and documented. Reasons for the loss are majorly due to molecular diffusion through the pores of the shell and convection from the incubation microclimate resulting into evaporation (Morgan et al., 1978; Tona et al., 2001; Mortola & Al Awam, 2010). The permeability of the egg shell membrane (leading to these loses), is important in ensuring the success of embryonic development, and results into a loss of about 15 % of the total weight in naturally incubated eggs (Portugal et al., 2010). Excess water loss from the eggs results in embryo dehydration and death whereas insufficient loss of the same, results in deformity at hatch or lower production performance (Peebles et al., 2014). Therefore, optimal losses are key to ensure embryo survival, ideal hatchability and chick weight at hatch (Tona et al., 2001; Caglayan et al., 2014).

Incubated eggs tend to absorb heat from their microclimate during the first half of incubation, since the embryo temperature is lower than the incubator’s. However, they must lose that heat during the second half of incubation since their metabolic rate and heat production increases (Leksrisompong et al., 2007). This is to avert the inherent risk of organ deformities, embryo mortality and post hatch growth challenges of chicks. Heat regulation, both by the egg in-vitro mechanisms and incubator environment are key in ensuring egg weight loss and in the long run, embryo survival and correlated production parameters. Additionally, having a predictable incubation egg weight loss may improve on hatchability and chick quality; and can be done by humidity adjustments in the incubator.
For logistical reasons and convenience, egg storage before incubation is a practise that is unavoidable in many production systems, despite its consequences to egg hatchability and chick quality (Bakst et al., 2016). Subsequent egg weight losses are recorded during storage due to in-vitro and in-vivo biotic and abiotic processes in the ambient environment. It is therefore important to determine the relationship between egg storage time and incubation egg weight losses as parameters of chick production.

The present study, therefore, aimed to determine the effect of incubation egg weight losses and storage time on hatchability, hatch weight and subsequent performance of five chicken genotypes reared in an intensive system.

Materials and methods

The research was conducted at the Non Ruminant Research Institute (NRI) – Naivasha, where eggs from five chicken genotypes were used. The genotypes included; (a) KALRO indigenous chicken (KIC) hens (spotted) by Rhode Island Red (RIR), (b) indigenous chickens (IC) (indigenous chickens are those obtained from within the country), (c) indigenous hens by KIC cocks, (d) indigenous hens by hybrid cocks (F1s from the KIC hens by RIR cocks) and (e) hybrid hens (F1s from KIC hens and RIR cocks) by RIR cocks. The birds were reared on deep litter system where water and feed were provided ad libitum. A total of 415 eggs were collected from the five genotypes for 10 consecutive days from 2nd to 11th March, 2012, and then stored at a temperature range of 13-16 °C and 70-75% relative humidity before incubation. The eggs collected from each genotype were classified into two size categories; medium (≤60 g) and large (>60 g). The storage duration was categorized into three groups; early (one to three days), mid (four to six days) and late (seven to ten days).

Trays defining all egg weights, storage period and different genotypes were randomly assigned in the setter and the hatchers to minimize possible environmental discrepancy caused by position in the incubator. Eggs were set in a 19,200-egg-capacity CD 19 single-stage setter (Pas Reform Integrated hatchery solutions) and operated at 37.5 ± 0.5 °C dry bulb temperature and 29.0 ± 0.5 °C wet bulb temperature. The hatcher was operated at 37.0 ± 0.5 °C dry bulb temperature and 31.0 ± 0.5 °C wet bulb temperature. Before the 18th day, eggs in the setter were automatically turned after every one hour.

At the 18th day of incubation, eggs were weighed and candled to determine incubation weight loss (IWL) and percentage fertility, respectively. The percentage incubation egg weight loss was calculated as the incubation weight loss per pre-setting egg weight. The percentage incubation weight loss was categorised into three classes; IWL1 (≤10%), IWL2 (>10-15%), IWL3 (>15%). The percentage fertility rate and hatchability were calculated using the formulas described by Sahin et al. (2009). Percentage fertility was calculated as the number of fertile eggs per total number of eggs set. Chicks were removed on the 21st day post incubation, counted, weighed and tagged individually. Hatchability of fertile egg was calculated as the number of chicks hatched per fertile or total eggs set. The second part of the study determined the effects on growth rate of the hatched chicks aged between day one and four weeks. Chicks were fed on commercial chick mash and water ad libitum alongside other standard management practices as described by Ondwasy et al. (2006).

Effect of incubation weight loss on hatchability, chick hatch-weight and performance of four weeks old chicks of different genotypes were analysed using the General Linear Model in R programme (R Core Team, 2012). The means were separated using Tukey’s multiple-range test procedures. A person correlations matrix to determine the relationship between the incubation weight loss and hatchability and between incubation weight loss and chick hatch-weight per genotype was performed. The Statistical model used was:

$$Y_{ijklm} = \mu + G_i + E_j + S_k + W_l + \varepsilon_{ijklm}$$

Where, $Y_{ijklm}$ is the overall observation (hatchability, chick hatch weight and month old weight), $\mu$ is the population mean, $G_i$ is the effect of genotypes (KIC hens by RIR, indigenous chickens, indigenous hens by KIC cocks, indigenous hens by hybrid cocks hybrid hens by RIR cocks), $E_j$ is the effect of egg weights...
Effects of incubation weight loss on the different parameters estimated was not significant \((P > 0.05)\) (Table 1), in contrast with other authors (Caglayan et al., 2014; Gradl et al., 2016) which is attributable to breed variation and agro-ecological differences. On the converse, egg size and genotypes differed significantly \((P < 0.05)\) for hatchability, chick-hatch weight and month old chicks weight (Table 1).

**Table 1:** Effect of genotypes, storage time, egg size and incubation weight loss on hatchability, chick hatch weight and month old chick weight

<table>
<thead>
<tr>
<th>Source</th>
<th>Df</th>
<th>Hatchability Mean Square</th>
<th>Chick hatch weight Mean Square</th>
<th>Month old chick weight Mean Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotypes</td>
<td>4</td>
<td>6201*</td>
<td>729.6*</td>
<td>23605*</td>
</tr>
<tr>
<td>Storage time</td>
<td>2</td>
<td>145*</td>
<td>18.8*</td>
<td>5688</td>
</tr>
<tr>
<td>Egg size</td>
<td>1</td>
<td>3672*</td>
<td>871.3*</td>
<td>5126</td>
</tr>
<tr>
<td>Incubation weight loss</td>
<td>2</td>
<td>11</td>
<td>10.8*</td>
<td>1371</td>
</tr>
</tbody>
</table>

\(^* (P < 0.05)\)

Chick-hatch weight was significantly affected by egg storage time, with eggs stored for a longer period having chicks with lower weights (43 g) compared to those stored for a shorter duration (45 g) (Table 2). This was a result of metabolic reactions in the egg and due to evaporation which reduced the available moisture in the egg (Wells et al., 2012). Storage time adversely contributes to incubation egg weight loss due to associated mechanisms earlier discussed. In addition, pre-incubation egg weight loss coupled with the extra loss during incubation reduces chick survival and hatch weight (Table 1), thereby further limiting the survival probability of chicks hatched (Tona et al., 2001). Energy needed for embryonic development is mostly derived from fat stored in the yolk, and for every unit of fat burned, an almost equal mass of water is generated. The more water lost from an egg, thereby implies that the needed fat for energy provision has been metabolized in part, thus limiting the amount available for the developing embryo.

The present study showed there was a high positive correlation between egg and chick-hatch weight across the genotypes (Table 2), the heavier the egg (large) the less the incubation weight loss across the genotypes. The IWL across the genotypes was between 10.5% and 15.6%. This is in agreement with other studies (Caglayan et al., 2014). Additionally, it was noted that cases where eggs had genetic contribution from indigenous chicken (IC), large eggs were rare, which was the converse to eggs without IC genetic contribution (Table ). This disparity in size could be attributed to genetic variations and inadequate selection associated with IC. The same scenario was observed for fertility and hatchability and the opposite in the case of chick hatch weight and month old chicks. On the other hand, incubation weight loss had a direct relationship to egg size, with larger eggs losing more weigh (10.5%-15.6%). Fertility was not affected by variations in breed, egg size and on incubation weight loss. It was observed to be similar in all instances and ranged from 83.4% to 94.9%. The value of 100% hatchability for indigenous hen by hybrid cock was ignored due the small sample size.

An increased hatchability was observed in eggs where indigenous chicken were part of the genotype (62.5% – 87.5%) with their absence resulting in a decrease in the same (54.2% – 60.6%) (Table 2). This situation is similar as was reported by Abraham and Yayneshet (2010) who found the Fayoumi and indigenous chicken to have better hatchability in comparison to Rhode Island Red and White leghorn in Ethiopia. Similarly, better hatchability of IC was reported by Alem (2014) in Ethiopia and Onasanya and Ikeobi (2013) in Nigeria. This was however reversed in relation to chick-hatch weight and month old chick weight.
in agreement with other authors (Abraham & Yayneshet, 2010; Ikeobi, 2013; Alem, 2014). These authors also noted that weight loss was greater in medium sized eggs than in large eggs, as was similarly observed in this study (Table 2). This was as a result of the difference in surface area to volume ratio.

**Table 2:** Mean and standard deviation of, chick-hatch weight, month old chicks’ weight, incubation egg loss weight, fertility and hatchability % per genotype and egg group

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Egg group</th>
<th>IWL %</th>
<th>Fertility %</th>
<th>Hatchability %</th>
<th>Chick hatch-weight (g) ± Std.D</th>
<th>Month old chick weight (g) ± Std.D</th>
</tr>
</thead>
<tbody>
<tr>
<td>KIC hens by RIR cocks</td>
<td>Medium</td>
<td>15.6</td>
<td>83.8</td>
<td>67.6</td>
<td>39.9±3.46</td>
<td>261.6±122.50</td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>14.4</td>
<td>83.4</td>
<td>55.8</td>
<td>44.7±3.25</td>
<td>188.8±159.07</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td><strong>14.6</strong></td>
<td><strong>99</strong></td>
<td><strong>60.6</strong></td>
<td><strong>43.8±3.74</strong></td>
<td><strong>201.6±155.41</strong></td>
</tr>
<tr>
<td>Hybrid hens by RIR cocks</td>
<td>Medium</td>
<td>11.9</td>
<td>87.5</td>
<td>62.5</td>
<td>39.5±3.43</td>
<td>193.9±122.31</td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>11.4</td>
<td>90.7</td>
<td>51.2</td>
<td>45.1±2.25</td>
<td>127.7±143.14</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td><strong>11.5</strong></td>
<td><strong>89.8</strong></td>
<td><strong>54.2</strong></td>
<td><strong>43.4±3.82</strong></td>
<td><strong>146.6±139.34</strong></td>
</tr>
<tr>
<td>Indigenous chickens</td>
<td>Medium</td>
<td>12.8</td>
<td>83.8</td>
<td>70.3</td>
<td>36.0±3.03</td>
<td>205.4±132.77</td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>11.0</td>
<td>100.0</td>
<td>100</td>
<td>44.2±1.07</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td><strong>12.7</strong></td>
<td><strong>92.5</strong></td>
<td><strong>72.5</strong></td>
<td><strong>36.8±3.85</strong></td>
<td><strong>205.4±132.77</strong></td>
</tr>
<tr>
<td>Indigenous hens by KIC cocks</td>
<td>Medium</td>
<td>11.7</td>
<td>87.8</td>
<td>66.7</td>
<td>37.7±2.00</td>
<td>222.4±148.70</td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>11.2</td>
<td>85.7</td>
<td>57.1</td>
<td>41.3±5.90</td>
<td>190.9±179.75</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td><strong>11.6</strong></td>
<td><strong>87.5</strong></td>
<td><strong>65.0</strong></td>
<td><strong>38.3±3.04</strong></td>
<td><strong>215.56±149.85</strong></td>
</tr>
<tr>
<td>Indigenous hens by hybrid cocks</td>
<td>Medium</td>
<td>11.6</td>
<td>94.9</td>
<td>87.2</td>
<td>34.2±3.0</td>
<td>233.4±96.87</td>
</tr>
<tr>
<td></td>
<td>Large</td>
<td>10.5</td>
<td>100.0</td>
<td>100</td>
<td>44.2</td>
<td>245</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td><strong>11.6</strong></td>
<td><strong>95.0</strong></td>
<td><strong>87.5</strong></td>
<td><strong>34.5±4.24</strong></td>
<td><strong>233.8±95.09</strong></td>
</tr>
</tbody>
</table>

IWL= Incubational weight loss

Multiple means comparison of different genotype showed that there was significant difference between the genotypes on hatchability, chick hatch weight and month old chick weight (Table 3).

**Table 8:** Multiple breed comparison on hatchability%, mean chick hatch-weight and month old chick weight

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Hatchability (%)</th>
<th>Chick hatch-weight (g) ± Std.D</th>
<th>Month old chick weight (g) ± Std.D</th>
</tr>
</thead>
<tbody>
<tr>
<td>KIC hens by RIR cocks</td>
<td>60.6a</td>
<td>43.8±3.74a</td>
<td>201.6±155.41b</td>
</tr>
<tr>
<td>Hybrid hens by RIR cocks</td>
<td>54.2c</td>
<td>43.4±3.82a</td>
<td>146.6±139.34b</td>
</tr>
<tr>
<td>Indigenous chickens</td>
<td>72.5b</td>
<td>36.8±3.85bc</td>
<td>205.4±132.77b</td>
</tr>
<tr>
<td>Indigenous hens by KIC cocks</td>
<td>65.0c</td>
<td>38.3±3.04b</td>
<td>215.56±149.85ab</td>
</tr>
<tr>
<td>Indigenous hens by hybrid cocks</td>
<td>87.5a</td>
<td>34.5±4.24c</td>
<td>233.8±95.09a</td>
</tr>
</tbody>
</table>

*abcd Means with different superscripts within column, differ significantly (P < 0.05)*

The relationship between incubation egg weight loss and egg hatchability showed a negative correlation (Table 10), implying that eggs that lost more water had a lower chance of hatching similar to observations with respect to storage time. It has been noted that energy depletion due to metabolism of required fat in the yolk is the primary factor associated with the reduced hatchability and subsequent chick survival. The normal scenario in most commercial hatcheries including the one used in this study is that, eggs laid by hens of different ages are incubated together under standard operating conditions. This is despite the fact that eggs from old hens differ in shell and albumen quality in comparison to younger hens. It is also known that eggs from old hens have a reduced hatchability due to embryo mortality, and this is attributed to the
increased incubational egg weight loss due to reduced shell quality. It is therefore important to note the relationship of age of hen to embryo mortality as a function of incubational egg weight loss.

**Table 9:** Multiple storage time comparison on mean chick hatch-weight

<table>
<thead>
<tr>
<th>Storage time</th>
<th>Chick hatch-weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td>45.7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mid</td>
<td>43.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Late</td>
<td>43.3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>ab</sup>Means with different superscripts within column, differ significantly (P < 0.05)

**Table 10:** Correlations matrix between hatchability, chick hatch-weight, month old weight, and incubation weight loss

<table>
<thead>
<tr>
<th></th>
<th>Hatchability %</th>
<th>Chick hatch-weight</th>
<th>Month old weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incubational weight loss</td>
<td>Pearson Correlation</td>
<td>-.404**</td>
<td>.336**</td>
</tr>
<tr>
<td>Hatchability %</td>
<td>Pearson Correlation</td>
<td>N</td>
<td>377</td>
</tr>
<tr>
<td>Chick hatch-weight</td>
<td>Pearson Correlation</td>
<td>N</td>
<td>357</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>228</td>
<td></td>
</tr>
</tbody>
</table>

**correlation is significant at the <0.05 level (2-tailed).**

**Conclusion**

The current study showed that genotypes plays a significant role in egg hatchability, chick hatch-weight and month old chicks weight. Additionally, the study revealed that incubation egg weight loss of between 10.5% and 15.6% does not affect hatchability, chick-hatch weight and month old chick weight. Further research is needed to determine the optimal storage time of eggs for incubation per genotype for better chick-hatch weight.

**Acknowledgment**

The study was carried out with the support from the Arid and Semi-Arid Lands - Agricultural Productivity Research Programme (ASAL-APRP) project.

**References**


Comparison of milk component levels, processability and mozzarella cheese acceptability from Toggenburg and their crosses in Kenya

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Abstract
Comparison of milk component levels, coagulation rate, cheese yield and sensory attributes of mozzarella cheese from Toggenburg and its cross breed with Galla goat was studied though lactation period of 120 days. The component levels of fat, protein, ash and totals solids from the two genotypes were found to be significantly different at α = 0.05. Toggenburg genotype had percent levels of 3.32, 2.85, 0.92 and 10.44 while cross breed had 3.87, 3.51, 0.82 and 11.68 for fat, protein, ash and total solids respectively. Cheese yield differed significantly at 18.66% for Toggenburg compared to 15.23% for cross breed. The correlations (r) between milk component and cheese yield were as follows: cross breed: r = 0.28, 0.42 and 0.65; Toggenburg: r = 0.38, 0.63 and 0.64 for protein, fat and totals solids respectively. A very weak correlation was observed between the fat and protein components of milk from the cross breed and the yield of the mozzarella cheese; Milk coagulation rate showed significant differences at 7.45 minutes for Toggenburg and 8.29 minutes for the crossbreed genotype. Mozzarella cheese from both genotypes also differed significantly in overall acceptability and scores for flavor, texture, finish and colour. Means acceptability for Toggenburg cheese was 3.80 while cross scored 3.63 on a 5-point hedonic scale. Except milk protein, cheese protein content and coagulation rate, all other components and sensory attributes were significantly influenced by the stage of lactation for both genotypes.

Keywords: Milk, Toggenburg, Goats, Crossbred, Genotype

Introduction
In Kenya, dairy goat farming has grown significantly through community based dairy goat improvement projects implemented by Farm-Africa in Meru, Kitui and Mwingi) and Heifer Project International in Kwale, Homabay, Nyakach, Rongo, Siaya, Suba and Bomet districts (Ogola et al., 2010). Through these projects pure Toggenburg among other dairy goats breeds have been crossed with indigenous goats mainly the Small East African goat and the Galla goat. Such crossbreeding programmes have been aimed at improving milk productivity and growth rate while retaining the beneficial characteristics of the indigenous genotype suitable for tropical climatic conditions. Studies by Ojango et al. (2010) indicate that milk yield has increased from 250 ml by the indigenous goats to 2-3 litres from three-quarter crosses. The herd size of dairy goats in Kenya has also grown significantly and is estimated to be over 200,000 with an annual milk production of 43.8 million litres contributing approximately 1% of the total milk production in the country (MOLD, 2010). Goats’ milk contains bioactive components such as medium chain fatty acids and serum proteins which confer health benefits besides nutrition (Haenelein, 2004). These health benefits have been used in Kenya to promote consumption of goats’ milk as disease mitigation/intervention measure focusing on child malnutrition and supporting families affected by HIV and AIDS (Ogola et al., 2010). For the country to fully exploit the dairy goat industry for economic growth, there has been need to expand the market access for goat milk through value addition and processing for the local niche market. Studies in Kenya by Ogola et al., (2010) have shown limited levels of goat milk value addition with most of the milk being marketed raw. Huge opportunities exist to innovate new products with the marketing strategy focusing on the use of technical information about goat milk which is its unique selling point.

Among the value addition products is the processing of milk into cheese. Kenyan market for cheese though small is still growing. Annually about 10 million litres of milk in Kenya is converted into cheese with goat cheese being limited and insignificant (Lati, 2007). Production of specialty goat cheese such as mozzarella would enhance market outlet for the pizza (in which it is an essential ingredient), prolong the shelf life of the milk and provide nutrients for the consumers interested in self-health maintenance. The quality of the milk is closely related to its physico-chemical and biological composition upon which its technological capacities are based (Sory et al., 2005). Previous studies in the country on dairy goats breeds have focused
more on milk yields with little information provided on the influence of the cross breeding programmes on the component levels and technological capability of the milk. This study was intended to compare consumer acceptability of Mozzarella cheese and the technological capability of milk from Toggenburg and its crosses in Kenya.

Materials and Methods

A total of ten does were used, five Toggenburg and five cross breed (\(\frac{3}{4}\) Toggenburg x \(\frac{1}{4}\) Galla Goats). The experimental does were selected from a flock maintained at the Naivasha Sheep and Goat Station. The does were balanced for parity and placed under similar management system during the entire experimental period. The does were milked once a day in the morning on each recorded day. The samples were assayed for proximate composition of Fat, Protein, Ash and Total Solids following official methods (AOAC 2000). Two batches of Mozzarella cheese consisting of milk from each breed was prepared fortnightly up to the 16th week of lactation following the procedure by Koskowiski (1997). The milk clotting activity was determined following modified procedure by Arima et al. (1970). Weight of the cheese and proximate composition was determined the second day after preparation. The cheese was analyzed for Moisture (%), Fat (%) and Protein (%) following official methods. Actual yields of the cheeses were expressed as kg of cheese per 100 kg of goat milk. Because no standard moisture content has been established for goat cheese varieties, the mean moisture content of experimental cheese made in this study was used to determine moisture adjusted cheese yield and hence the cheese yield formulae. Cheese yield efficiency was expressed as the percentage of the moisture-adjusted cheese yield to the predicted cheese yield using Van Slyke Formulae.

Descriptive sensory analysis for flavour, appearance, body and texture of mozzarella cheese was performed on the second day after processing by a panel of 5 cheese graders following procedure Murray et al (2001) was used. The panelists evaluated cheese samples using developed lexicons for intensities of flavor, body and texture, finish and colour/appearance. Maximum Scores of 45, 30, 15 and 10 points were assigned to the parameters respectively. To determine consumer acceptability, a group of 35 potential consumers were presented with the mozzarella cheese and asked to indicate their liking for the cheese product on a 5 point hedonic scale. The participants were varied in age (19 – 59 years), balanced in gender (Female 18 and Males 17) and having positive altitude (likeness) towards cheese.

Data analysis

The data was analyzed using Analysis of Variance (ANOVA) with the help of the computer Statistical Analytical Systems (SAS 2001) program. The significance of difference between the means was performed using Tukey’s Studentized Range Test. For all analysis, statistical significance was accepted at the \(P \leq 0.05\) level of probability.

Results

The results of analysis of milk and cheese from Toggenburg and the cross between Toggenburg and Galla are given in the tables below.

Table 1: Mean Values for Milk Fat, Protein, Ash and Total Solids according to Genotype and Lactation Stage.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Lactation Stage</th>
<th>Fat %</th>
<th>Protein %</th>
<th>Ash %</th>
<th>Total Solids %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossbreed</td>
<td>-</td>
<td>3.87 a</td>
<td>3.51 a</td>
<td>0.82 b</td>
<td>11.68 a</td>
</tr>
<tr>
<td>Toggenburg</td>
<td></td>
<td>3.32 b</td>
<td>2.85 b</td>
<td>0.93 a</td>
<td>10.44 b</td>
</tr>
<tr>
<td></td>
<td>Early Lactation</td>
<td>3.70 a</td>
<td>3.24 a</td>
<td>0.89 a</td>
<td>11.40 a</td>
</tr>
<tr>
<td></td>
<td>Mid Lactation</td>
<td>3.59 b</td>
<td>3.15 a</td>
<td>0.89 a</td>
<td>11.18 a</td>
</tr>
<tr>
<td></td>
<td>Late Lactation</td>
<td>3.50 b</td>
<td>3.16 a</td>
<td>0.86 b</td>
<td>10.59 b</td>
</tr>
</tbody>
</table>

*Means with the same letter are not significantly differently at \(\alpha = 0.05\).*
Table 2: Mean values for Cheese Yield, Cheese Moisture, Cheese Protein, Cheese Fat and Milk Coagulation Time.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Lactation Stage</th>
<th>Cheese Yield (%)</th>
<th>Cheese Moisture (%)</th>
<th>Cheese Protein (%)</th>
<th>Cheese Fat (%)</th>
<th>Coagulation Time (Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross Breed</td>
<td>Early Lactation</td>
<td>15.23 b</td>
<td>57.43 a</td>
<td>19.41 b</td>
<td>22.75 b</td>
<td>8.29 a</td>
</tr>
<tr>
<td>Toggenburg</td>
<td>Early Lactation</td>
<td>18.66 a</td>
<td>55.02 b</td>
<td>20.28 a</td>
<td>24.44 a</td>
<td>7.45 b</td>
</tr>
<tr>
<td></td>
<td>Mid Lactation</td>
<td>17.65 a</td>
<td>56.75 a</td>
<td>19.88 a</td>
<td>23.84 a</td>
<td>7.90 a</td>
</tr>
<tr>
<td></td>
<td>Late Lactation</td>
<td>16.98 a</td>
<td>56.34 a</td>
<td>19.83 a</td>
<td>23.60 ab</td>
<td>7.88 a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16.20 b</td>
<td>55.59 b</td>
<td>19.82 a</td>
<td>23.35 b</td>
<td>7.84 a</td>
</tr>
</tbody>
</table>

*Tukey Grouping* *Means with the same letter are not significantly differently at α = 0.05*

Table 3: Mean values for Scores of Acceptability, Flavour, Texture, Finish and Colour.

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Lactation Stage</th>
<th>Overall Acceptability</th>
<th>Flavour Score</th>
<th>Body &amp; Texture Score</th>
<th>Finish Score</th>
<th>Colour Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breed</td>
<td>Cross Breed</td>
<td>3.63 b</td>
<td>39.9 b</td>
<td>25.6 b</td>
<td>10.8 b</td>
<td>7.2 b</td>
</tr>
<tr>
<td></td>
<td>Toggenburg</td>
<td>3.80 a</td>
<td>40.7 a</td>
<td>26.1 a</td>
<td>11.0 a</td>
<td>7.3 a</td>
</tr>
<tr>
<td>Lactation Stage</td>
<td>Early Lactation</td>
<td>3.70 b</td>
<td>40.0 b</td>
<td>25.4 c</td>
<td>11.1 a</td>
<td>7.4 a</td>
</tr>
<tr>
<td></td>
<td>Mid Lactation</td>
<td>3.60 c</td>
<td>41.1 a</td>
<td>26.3 a</td>
<td>11.1 a</td>
<td>7.1 c</td>
</tr>
<tr>
<td></td>
<td>Late Lactation</td>
<td>3.85 a</td>
<td>39.9 b</td>
<td>25.8 b</td>
<td>10.6 b</td>
<td>7.3 a</td>
</tr>
</tbody>
</table>

*Tukey Grouping* *Means with the same letter are not significantly differently at α = 0.05*

Discussions

The component levels of butterfat, protein, ash and total solids from the two goat genotypes was found to be significantly different with cross breed having a higher butterfat, protein and total solids compared to that of pure breed. The ash content of Toggenburg was higher than that of the cross breed. Fat content for both genotypes exhibited significant difference between early and both mid and late lactation, however there was no significant difference between the mid and late lactation for both genotypes. Values of total solids and ash were significantly different between late lactation and both early and mid-lactation. Protein content was not significantly different across the lactation stages. The cross breed had superior composition of milk components except for ash content.

The values of fat, protein, ash and totals solids of Toggenburg were slightly different from that reported by Victor H. et al., (2010) of 3.12 +/- 0.27, 3.03 +/- 0.08, 0.96 +/- 0.01 and 10.52 +/- 0.32 respectively. The observed differences could had been occasioned by variations in nutrition as a result of geographical location. The cross breed with indigenous goats exhibited higher value for butterfat. This is expected as the indigenous African genotypes have been reported to have higher component levels for protein, fat and total solids (Adewumi et al., 2009, Zahraddeeneet al., 2007, Donkin et al., 1996).

Cheese yields from the Toggenburg were significantly higher than that from its cross breeds. The findings are in agreement with previous studies on the soft cheese from the same breed. Soryalet al., (2004) reported yield of Domiati soft cheese between 12 and 18% while Olizewki et al, (2002) found 16.5% as the mean yield value of the same.

Even though moisture content of soft cheese depends on the manufacturing technology, the mean moisture content of 57.43 and 55.02 for cross and pure breed respectively are in agreement with previous reports of between 48.7% and 57.1% (ALbenzioet al., 2006) and as high as 60% (Gou et al., 2004) for Cacioricotta.
and Domiati soft cheese respectively. Moisture contents of between 52.0% – 58.0% and fat content of 18% in mozzarella cheese has been found to be suitable for use as pizza topping (Koskowski, 1960).

Research on both commercial and laboratory scales have established relationships between milk components (fat and casein) or cheese composition (moisture, fat, protein) and yield for a variety of cheeses, such as Cheddar and Gouda (Lolkema 1993, Brito et al., 2002). Cheese yield from toggenburg was significantly higher than yield from cross breed genotype even though the later had higher values for milk protein and fat. It can be suggested that most of the fat and protein from cross breed may have been lost during the processing. Toggenburg breed exhibited a higher retention values for protein and fat which indicates that milk from this genotype has better cheese making characteristics.

Together with hygiene and milk composition, milk clotting properties are important technological parameters as they influence the later cheese making operations such as draining and ripening. Poor clotting properties can lead to yield losses in cheese making as well as poor cheese quality, requiring the adoption of technological modifications for particular type of milk.

The Toggenburg genotype exhibited better coagulation properties compared to cross breed. The cheese yield differed significantly between the late and both early and mid-lactation, however there was significantly no difference between yield in early and mid-lactation across the breeds. The study is in agreement with findings of Sapruet al., (1997) in Cheddar cheese, that the relative losses in fat and protein during cheese making are greater for cow milk produced at the end of lactation with respect to milk produced at the beginning of lactation, with consequent minor recovery of substances in the curd.

The correlation between Moisture Adjusted Cheese yield and milk components was determined. The average moisture content was calculated as 56.23 and used to determine moisture adjusted cheese yield since no work has been done on mean moisture content of goat mozzarella. The correlations between milk component and cheese yield (r) were as follows: Cross breed protein (r = 0.28), fat (r =0.42), total solids (r = 0.65); Toggenburg protein (r = 0.38), fat (r = 0.63), total solids (r = 0.64). There was a very weak correlation between the fat and protein components of milk from the cross breed and the yield of the mozzarella cheese. The weakness could be as a result of technological manipulation of cheese during the manufacture. Certain technological steps in mozzarella cheese making which include immersing curd in hot water at 70°C to enhance plasticity and facilitate stretching are likely to have an effect on retention of some of the milk component and hence yield.

Van Slyke formula though developed for prediction of cheddar cheese yield is the most widely used for cheese yield predictions. Different cheeses have been found to have different rates of component recovery as a result of different cheese making procedure and hence yield prediction formulae need to be adjusted for a particular cheese procedure. Comparing the yield efficiency between the moisture adjusted yield to the predicted yield using Van Slyke formulae a large variation was found from the yield of Toggenburg at 148% efficiency while cross breed had 96% yield efficiency. Such a huge variation indicates that the VanSlyke formulae may not be adequate to predict the yield of mozzarella cheese from goats’ milk. Various studies have shown huge differences in milk component recoveries during cheese making using sheep milk where Pirisi A.G., et al (2000) reported recoveries of 78 – 81.4% fat and 75.4 – 79.5% protein, Gonzalez J.M et al., (1991) recoveries of 65% fat and 65% protein while Economides et al., (1987) reported recoveries of 86.9% fat and 78.6% protein. The huge variation in recoveries from sheep milk may probably hold true for goat milk as there are more similarities between sheep and goat milk compared to that of cow and buffalo.

From the results a cheese prediction formula, \( Cy = 5.61 \times F + 1.85 \times P \) was proposed for predicting yield of mozzarella cheese based on the results from the two goat genotypes. Where \( Cy \) = yield of Mozzarella cheese, \( F \) and \( P \) are fat and protein contents in milk while 5.61 and 1.85 are retention coefficients for fat and protein.

There were significant differences in overall acceptability, flavor, texture, finish and colour scores. Cheese had mean scores of 3.80 and 3.63 on a 5 – point hedonic scale representing 76% and 72.6% acceptability respectively.
Even though these results show significant differences in sensory scores, acceptability of the mozzarella cheese produced from milk of both genotypes was found to be above average. Overall acceptability across the lactation stages was significantly different with mid and late lactation stages across the breeds showing the highest difference of 0.25 in mean acceptability scores. Even though cheese from mid lactation milk across the genotypes had the lowest score in terms of overall acceptability from consumer panel it exhibited very high scores from graders in terms of flavor, texture and finish. This may be due to lack of acquired taste for cheese by the majority of general consumer panelists.

**Conclusion and recommendations**

Goat breeds significantly influence milk composition. Though milk from cross breed with indigenous goats is richer in important components, slight modification of technological processes needs to be adopted to achieve the same cheese yield as pure toggenburg. To better understand the key limitations in achieving the same cheese yield from crossbred genotypes as from pure toggenburg, further studies on protein polymorphism need to be undertaken to compare levels of casein variants in milk of toggenburg and crossbreeds which have an effect on casein micelle organization, coagulation characteristics and cheese yield. Further studies are required to determine fatty acids profile and levels which have a direct influence on the overall acceptability of goat cheese. Studies need to be carried out to determine fat and protein recovery values for various cheeses from goat milk to predict cheese yield.

**References**


Biological Efficiency of Artificial Incubation and Brooding for Indigenous Chicken Production in Kilifi County, Kenya

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Abstract

The productivity of Indigenous chicken (IC) is low such that consistent supply of products has been lacking in the markets with farmers unable to keep up with regular demands from traders. Currently the production system depends on the birds to do all productive and reproductive functions. Relieving hens from incubation and brooding could release them to start the laying cycle early improving the number of clutches and eggs laid per year; while artificial brooding may also increase chick survival by reducing chicks’ exposure to predators and harmful weather. However, the impact of artificial incubation and brooding in IC production is scantly known. The study investigated the effectiveness of artificial incubation and brooding on the biological efficiency of the IC Production system. A Randomized Complete Block Design (RCBD) having factor 1: IC genetic lines (Normal feathers, frizzled feathers and naked neck) as blocking factor and factor 2: IC egg incubation and chick brooding strategy (three combinations of natural and artificial incubation along with natural and artificial brooding). The clutch sizes were similar and relatively higher for interaction of both ai*ab and ni*ab but a lower and significantly different clutch size for interaction between ni*nb at 15.95 eggs. All the clutch intervals were significantly different; the interactions had a clutch lag time of 40.88, 68.30 and 114.05 days respectively. All the interactions exhibited significantly diverse number of clutches/year ai*ab had the greatest number of clutches at 8.90, pursued by ni*ab with 5.36 and finally ni*nb which had 3.28 clutches. Adapting ai and ab is appropriate for IC

Key words: indigenous chicken, consistent supply, artificial incubation and brooding, clutch size, clutch interval, clutches per year

Introduction

Consistent supply of indigenous chicken products has been lacking in the poultry industry with farmers unable to keep up with the normal demands of traders. Production of IC presents commercial potential to contribute to improved rural livelihoods; however, low productivity is often cited as contributing to low commercial potential of the IC, in an inequitable comparison to industrial hybrid poultry (Safalaoh 2001). Besides low technology and innovation adoption (Wachira et al, 2011), laying rate, supply of IC day old chicks and survival of chicks to weaning is comparatively low and this would require adoption of appropriate modern innovation packages to improve yields (ASDS 2010).

The current form of IC production system does not favour improved productivity: it depends on the birds to carry out all productive and reproductive functions of egg laying, egg incubation and chick brooding until weaning for them to naturally start the cycle again (Muchadeyi et al 2005; Danda et al., 2010; Okeno et al; 2010, Daikwoet et al, 2011). Relieving hens from incubation and brooding could release them to start the laying cycle early hence improve on the number of clutches and eggs laid per year; while artificial brooding may also increase chick survival by reducing exposure of chicks to predators and harmful weather. However, the impact of artificial incubation and brooding in IC production is scantly known such that decision making to effectively invest in these technologies is not based on tangible evidence and facts. IC producers did not easily implement the extension technologies and innovation, to improve output and productivity; as offered by extension agents (Wachira et al, 2011).
Broadly to increase IC supply for protracted sustainable commercialization of the IC production system to improved food security and enhanced wealth creation of poultry value chain actors through adoption of appropriate egg incubation modes and chick brooding strategies. The investigation specifically aims to:

i) Examine the effect of breed lines on production performance.
ii) Assess the effect of egg incubation mode on production performance.
iii) Evaluate the effect of chicks brooding strategy on the production performance.
iv) Analyze the effect of a combination of egg incubation mode and chick brooding strategy on productive performance.

Materials and Methods

Site: The research was carried out at Pwani University Farm, Kilifi in Kilifi County, which is located 62 km to the north of Mombasa city: along the Mombasa – Malindi road and at latitude 20 S and longitude 400 E with an altitude of 16 m above sea level.

Indigenous Chicken Lines: Five months’ pullets from three genetic lines (Normal feathers, necked neck and frizzled feathers) with matching number of cockerels were sourced from local coastal low land ecotypes within Kilifi County.

Incubation mode and Brooding Strategy

Incubation

i. **Natural**: Natural incubation used broody hens to sit on the eggs in synchronized manner: early broody dams were delayed using dummy eggs, to allow all birds in a treatment to be ready for sitting in order to start incubation at the same time.

ii. **Artificial**: Artificial incubation used an electric forced air incubator with automated egg turning, temperature and humidity control. The incubator was sourced from Eco-Chick and had a hatching capacity of 528 eggs.

Brooding

i. **Natural**: where the chicks were left or given to the dams for care in which the broody hens provided the heat to keep them warm.

ii. **Artificial**: in which the brooder was made up of an external guard from circular bound three ply board cutting and kerosene lanterns, to provide light and the required heat for the artificial chick brooding.

Methodology

**Experimental Design**: The methodology involved a two (2) factor, 3X3 factorial Randomized Complete Block Design (RCBD) having factor 1: IC genetic lines (Normal, necked neck and frizzled feathers) that also was the blocking factor and with factor 2: IC egg incubation and chick brooding strategy (three combinations of natural and artificial incubation along with natural and artificial brooding).

**Experimental Model**
The model will be: \( Y_{ijk} = \mu + \alpha_i + \gamma_j + \beta_k + (\gamma \beta)_{jk} + E_{ijkl} \)

Where: \( Y_{ij} \) denotes the jth observation from the ith treatment group; \( \mu \) is the mean of the ith treatment population; \( \alpha_i \) is the effect of the breed (factor1), \( \gamma_j \) is the effect of the incubation mode, \( \beta_k \) is the effect of the brooding strategy (factor 2), \( (\gamma \beta)_{jk} \) is the interaction between \( \gamma_j \) and \( \beta_k \) and \( E_{ijkl} \) is the experimental error.
**Experimental Bird Management**

**Sample Size:** At total of 72 pullets were used, 24 of each IC line with a rooster in each cage of 8 pullets.

**Housing:** The house units were oriented east to west and made from locally available materials; with walls covered by ply wood up to one meter high, then wire mesh for the next meter of height. The floor was made of mud but had twenty-five (25) centimeters of deep litter; the treatments were in 2X2 m cubicles each with a laying box that had three compartments.

There were three (3) units one with five cubicles and two (2) had four cubicles. For each unit, the three cubicles housed the different IC lines (Breed): factor 1 in a random manner; and each one unit represented one of the combinations of IC egg incubation and brooding strategy: factor 2 (Natural or artificial incubation and natural or artificial brooding) as in 3.2.2 above. The fourth cubicle was used for chick brooding, while the fifth cubicle was used as inputs store.

**Biosecurity:** During arrival, the birds were vaccinated against NCD, treated using broad spectrum antibiotics, de-wormers and dusted to eliminate possible infections of disease, worms and external parasites.

**Feeding and Nutrition:** The adult birds were fed on a cafeteria feeding system; in which the birds were able to mix their own feed according to their needs. This is whereby the various types of feeds were offered separately as follows: Energy rich feeds, e.g. maize, millet, sorghum; Protein rich feeds, e.g. fish meal, beans, peas, oil cakes, maggots, termites; Mineral rich feeds, e.g. bone meal, burned eggshells; Vitamin rich foods, e.g. green vegetative plants leaf chopping. Feeder were divided into four compartments, enabling the poultry to choose the feed ingredient according to their physiological cravings and needs.

**Egg Handling:** When the birds started to lay eggs, the eggs were collected, marked and stored for each treatment until all the birds in a given treatment got ready to sit on their eggs. The eggs were stored in an air conditioned room at 15°C.

**Experiments**

I. **Experiment 1: Incubation**

**Incubators:** Artificial incubation used an electric forced air incubator with automated egg turning, temperature and humidity control.

**Broody Hens:** Natural incubation used broody hens to sit on the eggs in synchronized manner: early broody dams were delayed using dummy eggs, to allow all birds in a treatment time to be ready for incubation sitting.

**Egg Selection:** The eggs were selected for setting in the incubator or hen nest, by evaluating the physical conditions of the eggs. All the eggs were incubated except broken shelled, blood stained or dirty eggs which were discarded.

**Setting Eggs:** The birds were given a maximum of 10 eggs set, while the rest were set in the incubator for hatching.

II. **Experiment 2: Brooding**

After hatching, each batch and liters of chicks were brooded naturally or artificially as per treatment:

**Natural Brooding** is where the chicks were left or given to the dams for care in which the broody hens provide the heat to keep them warm.

**Artificial Brooding** is where the brooder was made up of an external guard from circular bound three ply board cutting and kerosene lanterns, to provide light and the required heat for the artificial chick brooding.
Brood Period: Artificially brood chicks were brooded up to six weeks at which they were weaned; the natural brooded chicks were left with the dams until they were naturally weaned and the dam started to lay eggs again.

Data Collected

a) Data Collection Process
The data was collected by one technical enumerator who was appropriately trained to accurately and precisely measure and record experimental parameters.

b) Data Points (Parameters)
The main parameters to be considered are as follows:

<table>
<thead>
<tr>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. Commencement of egg laying</td>
<td>i. Clutch interval/Clutch lag Time (Numbers</td>
</tr>
<tr>
<td>ii. Cessation of egg laying</td>
<td>of days) to next egg laying</td>
</tr>
<tr>
<td>iii. Number of eggs per clutch</td>
<td>ii. Number of clutches per year (Extrapolated</td>
</tr>
<tr>
<td></td>
<td>from i, above)</td>
</tr>
</tbody>
</table>

a) Data Analysis
General analysis
The data will be analyzed using General Linear Model (GLM) procedure in Statistical Analysis Software (SAS) for analysis of variance (ANOVA). The inference will be by orthogonal contrasts and mean separation by standard error of LS-means.

b) Planned Orthogonal Contrasts
i. Natural incubation and natural brooding versus natural incubation and artificial brooding.
ii. Natural incubation and natural brooding versus artificial incubation and artificial brooding.
iii. Natural incubation and artificial brooding versus artificial incubation and artificial brooding.

Results and Discussion
Effect of IC lines on clutch productivity: The number of eggs per clutch (clutch size) was assessed for the three IC lines (ff, nf, nn) as well as the lag time between clutches (clutch interval) and the number of clutches per year. The table below shows the clutch productivity depicting the number of eggs per clutch (clutch size), the lag time between two clutches (clutch interval) and the number of clutches per year (clutches/year).

Effect of IC lines on clutch size: The clutch size between ff and nf were similar but both significantly different from that of nn. The number of eggs per clutch from nn was highest at 17.5 eggs per clutch. The results imply that nn is the superior line for egg laying. The results imply that nn is the superior line for egg laying (Islam, 2006).

Effect of IC lines on clutch interval: The clutch interval for nf was longer, at 80.32 days and significantly different from ff and nn which had comparable clutch lag time. Accordingly, ff and nn came back to clutching faster than nf and are better lines for improved efficiency in egg productivity than nf; due to its genetic composition, which is adaptable to the ecology, together with a higher feed conversion for prolificacy (Islam and Nishibori, 2009; Magotheet al., 2010, Okenoet al., 2011).

Effect of IC lines on number of clutches: The mean number of times the IC lines came to clutch was equivalent for ff and nn however both were significantly varied from that of nf, which was fewer at 5.8 times relative to 6.20 times. Relatively ff and nn produced more clutches thus better IC lines for improved
egg clutching; similar findings by Islam and Nishibori, 2009; Magothe et al., 2010 and Okeno et al., 2011 attributed to their inherent alleles.

**Effect of interaction of incubation type and brooding regime:** The effect of three combinations of incubation mode and brooding regime (ai*ab, ni*ab and ni*nb) were analyzed on clutch size, clutch interval and number of clutches per year. The results in table 4 illustrate the findings.

**Effect of combination of incubation type and brooding regime on clutch size:** The clutch sizes were similar and relatively higher for interaction of both ai*ab and ni*ab but a lower and significantly different clutch size for interaction between ni*nb at 15.95 eggs. The hens produced large clutch sizes when ab is employed in interaction with ai and ni and that the technologies are appropriate to be adopted in combination.

**Effect of combination of incubation type and brooding regime on clutch interval:** All the clutch intervals were significantly different. The combination of ai*ab caused the hens to have the shortest clutch lag time followed by ni*ab, while the longest time was exhibited by the interaction between ni*nb. The interactions had a clutch lag time of 40.88, 68.30 and 114.05 days respectively.

**Effect of combination of incubation type and brooding regime on number of clutches:** All the interactions exhibited significantly different number of clutches. The combination of ai*ab had the greatest number of clutches at 8.90, pursued by ni*ab with 5.36 and finally ni*nb which had 3.28 clutches. The blending of ai*ab nearly tripled the clutching production while ni*ab gave 1.6 times more clutches per year than ni*nb, the normal practice.

**Conclusion and Recommendations**

At the minimum farmers are to embrace ab for improved IC productivity & supply. The IC production system is to adopt ai and ab for increased efficiency in IC supply as it improves production three-fold.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Clutch Productivity</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>CS (No)</td>
<td>CI (Days)</td>
<td>C/Y (No)</td>
</tr>
<tr>
<td>IC lines</td>
<td>ff</td>
<td>15.8a</td>
<td>76a</td>
</tr>
<tr>
<td></td>
<td>nf</td>
<td>15.7a</td>
<td>80b</td>
</tr>
<tr>
<td></td>
<td>nn</td>
<td>17.5b</td>
<td>76a</td>
</tr>
<tr>
<td>Incubation mode</td>
<td>ai</td>
<td>16.2a</td>
<td>63a</td>
</tr>
<tr>
<td></td>
<td>ni</td>
<td>16.4a</td>
<td>91b</td>
</tr>
<tr>
<td>Brooding strategy</td>
<td>ab</td>
<td>16.8a</td>
<td>54a</td>
</tr>
<tr>
<td></td>
<td>nb</td>
<td>15.9b</td>
<td>100b</td>
</tr>
<tr>
<td>Interaction</td>
<td>ai*ab</td>
<td>16.7a</td>
<td>41a</td>
</tr>
<tr>
<td></td>
<td>ni*ab</td>
<td>16.9a</td>
<td>68b</td>
</tr>
<tr>
<td></td>
<td>ni*nb</td>
<td>15.9b</td>
<td>114c</td>
</tr>
</tbody>
</table>

*For each objective, means in the same column with common superscript are not significantly (P<0.05) different*
References


SUSTAINABLE LIVESTOCK SYSTEMS

Black soldier fly larvae as feed: a literature review

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Abstract
Use of insect meal could alleviate and reduce cost of protein sources in animal feeds. This papers explores the use of Black Soldier fly larvae as such a source. Rearing methods, environmental impact and nutritive value of the meal are reviewed.

Introduction

Insect rearing could be one of the ways to enhance food and feed security (van Huis et al., 2013). They grow and reproduce easily, have high feed conversion efficiency (since they are cold blooded) and can be reared on bio-waste streams. One kg of insect biomass can be produced from on average 2 kg of feed biomass. Insects can feed on waste biomass and can transform this into high value food and feed resource. A desk study (Veldkamp et al., 2012) has demonstrated that it is technically feasible to produce insects on a large scale and to use them as alternative sustainable protein rich ingredient in pig and poultry diets, particularly if they are reared on substrates of bio-waste and organic side streams. This literature review presents the current status on the black soldier fly (BSF) with regard to its distribution, rearing, environmental impact, nutritional attributes of the black soldier fly larvae (BSFL) and BSFL meal and their use as a component in the diets of poultry and fish.

Description

Figure 1: Black soldier fly

The BSF (Hermetia illucens Linnaeus 1758) is a fly (Diptera) of the Stratiomyidae family. The adult fly is black, wasp-like and 15-20 mm long (Hardouin et al., 2003). The larvae can reach 27 mm in length, 6 mm in width and weigh up to 220 mg in their last larval stage. They have a dull, whitish colour (Diclaro et al., 2009). The larvae can feed quickly, from 25 to 500 mg of fresh matter per larva per day, and with minimal disturbance on a wide range of decaying organic materials, such as rotting fruits and vegetables, coffee bean pulp, distillers' grains, fish offal, corpses and particularly animal manure and human excreta (van Huis et al., 2013; Diener et al., 2011; Hardouin et al., 2003).
Distribution

*Hermetia illucens* is native from the tropical, subtropical and warm temperate zones of America. The development of international transportation since the 1940s resulted in its naturalization in many regions of the world (Leclercq, 1997). It is now widespread in tropical and warmer temperate regions between about 45°N and 40°S (Diener *et al.*, 2011).

Life Cycle

In ideal conditions, larvae become mature in 2 months, but the larval stage can last up to 4 months when not enough feed is available. At the end of the larval stage (pre-pupa), the larva empties its digestive tract and stops feeding and moving (Hardouin *et al.*, 2003). The pre-pupae then migrate in search of a dry and protected pupation site (Diener *et al.*, 2011). The duration of the pupal stage is about 14 days but can be extremely variable and last up to 5 months (Hardouin *et al.*, 2003). The females mate two days after emerging and oviposit into dry cracks and crevices adjacent to a feed source (Diener *et al.*, 2011). The adults do not feed and rely on the fats stored from the larval stage (Diclaro *et al.*, 2009).

Merits

Rearing *Hermetia illucens* has been proposed since the 1990s as an efficient way to dispose of organic wastes, by converting them into a protein-rich and fat-rich biomass suitable for various purposes, including animal feeding for all livestock species, biodiesel and chitin production (van Huis *et al.*, 2013; Diener *et al.*, 2011). According to the BSFarming blog, BSFL larvae will eat kilograms of scrap food a night in small composting units, eliminating kitchen food waste before it can even begin to rot. On average a household will produce a little under a kg of food waste per day. This food waste can be composted at home using BSFL faster than worms.

The BSF is an extremely resistant species capable of dealing with demanding environmental conditions, such as drought, feed shortage or oxygen deficiency (Diener *et al.*, 2011). One major advantage of *Hermetia illucens* over other insect species used for biomass production is that the adult does not feed and, therefore, does not require particular care. It is also not a potential carrier of disease. The larvae are sold for pets and fish bait, and they can be easily dried for longer storage (Leclercq, 1997; Veldkamp *et al.*, 2012). The duration of the life cycle ranges between several weeks to several months, depending on ambient temperature, and the quality and quantity of the diet (Veldkamp *et al.*, 2012). In aquaculture, using feeds based on BSFLarvae open additional marketing opportunities for farmers as some customers are opposed to the use of fishmeal in aquaculture feeds (Tiu, 2012).

Rearing

![A BSFL rearing facility](image)

**Figure 2:** A BSFL rearing facility
Several methods for rearing black soldier flies on substrates such as pig manure (Newton et al., 2005), poultry manure (Sheppard et al., 1994), and food wastes (Barry, 2004) have been designed. Rearing facilities use the migrating behaviour of the pre-pupae for self-collection. The larvae climb up a ramp out of a rimmed container to eventually end in a collecting vessel attached to the end of the ramp (Diener et al., 2011). Optimum conditions include a narrow range of temperature and humidity, as well as a range of suitable levels of texture, viscosity, and moisture content of the diet. Temperature should be maintained between 29 and 31°C, though wider ranges may be feasible. Relative humidity should range between 50 and 70%. Higher relative humidity makes the diet too wet. The diet should have enough structure for the larvae to grip on as they eat, and at the same time get an adequate oxygen supply (Barry, 2004).

Where temperatures are highly variable, it is necessary to maintain a year-round breeding adult colony in a greenhouse with access to full natural light. The greenhouse must be a minimum of 66 m$^3$ to allow for the aerial mating process (Barry, 2004). Ranges of optimal temperatures, for mating and ovipositing, of 24-40°C or 27.5-37.5°C have been reported (Sheppard et al., 2002). Wide ranges of relative humidity are tolerated. Reports these ranges to be 30-90% (Sheppard et al., 2002), or 50-90% (Barry, 2004). The greenhouse will need a container with a moist food waste medium to attract egg-laying female adults (Barry, 2004).

**Processes**

Black soldier fly larvae are used live, chopped or dried and ground. There have been attempts to create a defatted meal by cutting the larvae to enable the leakage of intracellular fat and then transferring the material to a tincture press (Kroeckel et al., 2012). A possible way to use the BSF raised on waste is shown here.

![Process Diagram](chart1.png)

**Chart 1:** Possible processing pathway for BSFL

**Environmental impact**

The BSF can be used commercially to solve a number of environmental problems associated with manure and other organic wastes. Adult flies are not attracted to human habitats or foods and not considered a nuisance (van Huis et al., 2013).
Biomass conversion

Dense populations of larvae can convert large volumes of organic waste into valuable biomass (van Huis et al., 2013). For instance, larvae can reduce the accumulation of manure from laying hens and pigs by 50% or more without extra facilities or added energy (Sheppard et al., 1994; Newton et al., 2005; Barry, 2004). In Costa Rica reduction values of 65-75% have been observed in field trials with household waste (Diener et al., 2011). In confined bovine facilities, the larvae were found to reduce available phosphorous by 61-70% and nitrogen by 30-50% (Newton et al., 2008).

Odour reduction

Black soldier fly larvae are voracious and process organic waste very quickly, restraining bacterial growth and thereby significantly reducing the production of bad odours. Moreover, the BSFL aerate and dry the manure, so reducing odours (van Huis et al., 2013).

Housefly control

Black soldier fly larvae are a competitor to housefly larvae (Musca domestica), as they make manure more liquid and thus less suitable for housefly larvae. Their presence is also believed to inhibit ovipositing by the housefly. For instance, they have been shown to reduce the housefly population of pig or poultry manure by 94-100%. As a result, they can help to control housefly populations in livestock farms and in households with poor sanitation, thereby improving the health status of animals and people since the housefly is a major vector of disease (Sheppard et al., 1994; Newton et al., 2005).

Low pathogenicity

Unlike other fly species, Hermetia illucens is not a disease vector: not only the eggs are never laid on decaying organic material, but, since the adult fly cannot eat due to its lack of functioning mouthparts, it does not come in contact with unsanitary waste materials. Additionally, the larvae modify the microflora of manure, potentially reducing harmful bacteria such as Escherichia coli 0157:H7 and Salmonella enterica (van Huis et al., 2013). It has been suggested that the larvae contain natural antibiotics (Newton et al., 2008).

Nutritional attributes

The dry matter content of fresh larvae is quite high, in the 35-45% range, which makes them easier and less costly to dehydrate than other fresh by-products (Newton et al., 2008). Black soldier fly larvae are a high-value feed source, rich in protein and fat. They contain about 40-44% protein on dry matter (DM) basis. The amount of fat is extremely variable and depends on the type of diet and on its fat content: reported values are 15-25% of DM for larvae fed on poultry manure (Arango Gutierrez et al., 2004), 28% of DM for larvae fed on swine manure (Newton et al., 2005), 35% of DM for larvae fed on cattle manure (Newton et al., 1977) and 42-49% of DM for larvae fed on oil rich food waste (Barry, 2004). Ash content is relatively high and highly variable, from 11 to 28% of DM. The larvae contain high levels of calcium and phosphorus, reported data showing levels of 5-8% and 0.6-1.5% of each mineral respectively (Newton et al., 1977; St-Hilaire et al., 2007; Arango Gutierrez et al., 2004; Yu et al., 2009). The amino acid profile shows that the larvae are rich in lysine, at 6-8% of the protein (Newton et al., 2008).

The fatty acid composition of the larvae depends on the fatty acid composition of the diet. The lipids of larvae fed cow manure contained 21% of lauric acid, 16% of palmitic acid, 32% of oleic acid and 0.2% of omega-3 fatty acids while those proportions were 43%, 11%, 12% and 3%, respectively, for larvae fed 50% fish offal and 50% cow manure. Total lipid content also increased from 21% to 30% of DM for larvae from the fish offal-cow manuresubstrate. Feeding BSFL with a diet made of wastes containing desirable omega-3 fatty acids is, therefore, a way to enrich the final biomass (St-Hilaire et al., 2007).
Feeding value

Poultry

As a component of a complete diet, BSFL meal has been found to support good growth in chicks. One study showed that chicks fed a diet containing dried BSFL as the protein supplement gained weight at a slower but non-significant rate of 96% compared to the growth rate of chicks fed soybean meal plus fat, but they consumed significantly less feed (93%) than those supplemented with soybean meal plus fat (Hale, 1973).

Fish

Pre-pupae BSFL could replace part or all of the fish meal in fish diets. However, the type of rearing substrate and the processing method affect the utilization of the larvae by fish. When chopped BSFL grown on hen manure were fed to blue tilapia (Oreochromis aureus) alone or in combination with commercial diets, there were no significant effects on performance, (measured as body weight and total length) compared to the commercial diets. Additionally, aroma and texture of tilapia fed larvae were acceptable to the consumer (Bondari et al., 1981). In a later experiment, feeding 100% dry larvae did not provide sufficient dry matter or protein intake for tilapia grown in tanks to allow a sufficient growth. Chopping of the larvae improved weight gain and efficiency of utilization (Bondari et al., 1987).

Conclusion

The foregoing review shows good potential for use of BSFL as partial replacement for protein supplements. However, there is need for economic comparison of BSFL to conventional locally available protein supplements before any recommendations can be made. Efforts to standardize the meal in line with other conventional feedstuffs becomes necessary for effective utilization at local and commercial level.

References


Perspectives on the potential of silvopastoral systems in Kenya

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Abstract

This paper describes documented research findings on resource sharing between trees and pastures in Arid and Semi-Arid areas of Kenya and attempts to reconcile the information with current knowledge of the interactions between trees and understorey vegetation by examining silvopastoral systems from the perspective of succession and utilization. This is a land-use practice involving the deliberate combination of trees and pastures on the same land management unit in some form of spatial arrangement or temporal sequence. The compatibility and spatial complementarity of trees and pastures offers an opportunity for an increase in productivity per unit area of land. Trees like Faidherbia albida, Calliandra calothyrsus, Leucaena leucocephala, and Melia volkensii have reverse phenology in which growth demands are made at a different time from that of other crops. The most preferred grass species for understorey establishment are Enteropogon macrostachyus and Eragrostis superba. Silvopastoral systems are becoming the technology of choice in Kenyan Arid and Semi-Arid areas. It has many benefits, such as enhanced biomass productivity, improvement of soil fertility, soil conservation, nutrient cycling, micro-climate improvement, carbon sequestration, and bio-drainage. It can also help reduce the seasonality of plants and therefore contribute to mitigate and adapt to the effects of climate change.

Key words: climate change, silvopastoral systems, technology, complementarity, productivity

Introduction

Land-use espousals that increase livelihood security and reduce vulnerability to climate and environmental change are necessary. Traditional resource management adaptations such as agro-forestry systems may potentially provide options for improvement in livelihoods through simultaneous production of food, fodder and firewood as well as mitigation of the impact of climate change.

Soil and pasture degradation is one of the major constraints in the tropics affecting 500 million ha (Lamb et al., 2005). It threatens ecosystem services and food security for people in developing countries (Herrero et al., 2010). Approximately 80–100% of the grasslands exhibit soil erosion, soil compaction, and low soil nutrient availability for livestock systems (Obalum et al., 2012). The major causes being overgrazing, poor soil conservation practices, inadequate soil fertilization and lack of proper management practices such as monoculture of Gramineae versus plant diversity.

Farmers in drylands have for centuries utilized a wide range of agroforestry practices, largely by preserving and managing a few scattered mature trees. Recent attempts to promote agroforestry through further tree planting in such environments have been made unfortunately without much success. There are quite a number of limitations, for example, alley cropping in the semi-arid tropics, where below-ground competition for water between trees and crops frequently outweigh the benefits of soil enrichment and microclimate improvements. Kenya Arid and Semi-Arid Land (ASAL) hosts about 70 percent of the national livestock population with an estimated value of Kshs 70 billion (MoALF, 2017). Agricultural activities seriously threaten natural resources; therefore, it is necessary to ensure that livestock production contributes to satisfy the demand for animal products in a sustainable manner.

As an alternative, Silvopastoral Systems (SpS) can be successfully implemented because they can provide several benefits such as animal comfort and productivity, litter supply, nutrient cycling, water infiltration, soil bulk density, soil fauna, and biodiversity (Sierra and Nygren, 2006).
The rationale for diversification of SpS is associated with complementarities in resource use, potentially involving the management and use of the natural resources (crops, animals, land and water) in which these sub-systems and their synergistic interactions have a significant positive and greater total effect than the sum of their individual effects (Edwards et al., 1988). The SpS are becoming the technology of choice to many farmers in the ASALs of Kenya because it can help reduce the seasonality of plants and animal production and therefore contribute to mitigate and adapt to the effects of climate change. Generally grasses utilize the topsoil water while tree roots have exclusive access to deeper water, creating a clear niche separation (Deans et al., 1995). Indeed in the present socio-economic context, the role of browse in SpSs to provide stability and productivity of livestock production, which is the major source of livelihood and income in arid and semi-arid African zones.

Materials and Methods

Literature review was done and information sourced from both primary and secondary sources; Government of Kenya reports, technical reports, research data and Scientific journal articles

Results and discussion

Tree-grass interactions in silvopastoral systems

Arid and semi-arid SpS cover about a third of inter-tropical Africa and sustain about 60% of the livestock population of the continent (Le Houérou, 1977). Trees can exploit resources that are unavailable to pastures, SpS can increase productivity per unit area of land through the efficient use of resources (Cannell et al., 1996); in other words trees and pastures have spatial complementarity which should be matched to appropriate niches within the farm. The ASALs of Kenya provide a perfect ecosystem in which silvopastoral systems can be practiced effectively.

Spatial complementarity of trees and pastures offers an opportunity for an increase in productivity per unit area of land. Trees of choice in this region are; Faidherbia albida, Calliandra calothyrsus, Leucaena leucocephala, T. trichandra, and meliavolkensii (Franzel et al., 2003) which have reverse phenology in which growth demands are made at a different time from that of the crops. The grass species planted as understorey are Enteropogonmacrostachyus and Eragrostissuperba. The farm-grown fodder increases milk production and can substitute for relatively expensive purchased dairy meal, thus increasing farmers’ income. Fodder shrubs also conserve the soil, supply fuelwood and provide bee forage for honey production. Rather than cash outlays, farmers only need small amounts of land and labour to plant them. Some farmers also earn money by selling seeds. In these systems trees and pastures are planted in variety of spatial patterns.

Rainfall captured through stem flow, especially by a woody canopy, can be stored deep in the soil close to the roots and be returned to the topsoil beneath the canopy by hydraulic lift for later use with associated benefit for understorey species. It has been found that the presence and abundance of trees within pastures changes according to the cattle production system (dairy, meat or dual purpose (Franzel et al., 2003). This combination of grasses and trees can ensure year-round supply of fodder for livestock.

Management approaches in silvopastoral systems

It is important to consider the different components in SpS and study them individually, paying particular attention to their cause-effect relationships. The other approach is to study the system in its totality in the long term and drawing conclusions based on the findings. Focus should be on plant and soil components.

When considering integration of trees on farmland where some plant species are already being grown, it is assumed that there will be little or no change at all in the type of herbaceous species. On the other hand, the compatibility and complementarity of the perennial grasses with woody species will be a critical
consideration. In addition to the genotype of the species, it should provide resource sharing capabilities, potential micro-site enrichment and environmental amelioration. Thus appropriate management in terms of weeding, pruning, lopping, pollarding and browsing have to be practiced in order to optimize the benefits of combined production system.

Well managed SpScan improve overall productivity and this is an economic boost for livestock keepers. In these systems, tree roots generally explore deeper soil depths and can contribute to relatively large amounts of sequestered Carbon compared with grass monocultures or forest systems. This agrees with other studies done on the importance of SpS e.g. pastures with high tree densities for the conservation of biodiversity (Preston and Leng, 2008). The use of leguminous-based pasture systems is also important because it can offset the use of nitrogen (N) fertilizers for sustaining pasture yields, thus contributing to a reduction in the emissions of nitrous oxide (N\(_2\)O). Feeding better-quality forages results in a reduction of methane (CH\(_4\)) during rumen fermentation. This paper documents the importance of SpSin the wake of climate change scenarios with a view to enhance livestock productivity and improve the livelihood of the livestock keepers

**Potential of Silvopastoral systems**

The SpS has great potential over vast areas of land. These systems thrive well in areas where soil fertility is low and is dependent mainly on soil organic matter fraction and where erosion hazards are high and such marginal lands cover a huge land mass of Kenya. It’s also possible in high rainfall areas of Kenya in smallholder systems. The potential of SpS is enormous in production of fodder, fuelwood, poles among others and in protecting the environment through soil conservation and windbreak.

**Conclusion**

Silvopastoral systems have enormous promise for addressing multiple issues facing livestock farmers in Kenya. If managed well it could enhance water capture and storage, soil and biomass and biological diversity while directly enhancing the livelihoods of cattle producers through improved livestock production and profitability. There is need for further research on the contribution of SpStowards greenhouse gas mitigation. Many success stories-cite them appear to be confined to small areas. Thus, emphasis needs to be placed on ways to replicate these on a larger scale to reach more households. Other issues involve identifying policies, institutional innovations and extension strategies that facilitate the spread of SpS as to increase economic benefits. Indeed, SpScan increase land productivity and allow conservation of forests and biotic diversity of both local and worldwide importance.

**Acknowledgement**

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Kenya Livestock Insurance Programme: Utilization of Satellite forage images for provision of Index Based Livestock Insurance in the ASALs

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Abstract

Kenya is a relatively unique economy in that it has about 30 percent of its citizens living in Arid and Semi-Arid Lands (ASALs) and livestock is the most important sector in terms of income and food. Livestock production and particularly extensive livestock grazing is the main livelihood in the ASALs which comprise about 80 percent of the country’s landmass. Pastoralists and agro-pastoralists use these dry lands to generate food and income for themselves by rearing livestock and also generate income as livestock traders and the national economy. Pastoralists in Kenya’s northern rangelands are particularly vulnerable to the impacts of recurrent droughts. This paper focuses on the use of innovative technology on satellite images, to generate an index that is used for livestock insurance as a way of hedging against the loss of the main asset of the pastoralist. The use of Normalized Vegetation Index (NDVI) is used to develop the insurance product that is used by the Kenya Livestock Insurance Programme (KLIP) for hedging the risk against livestock lose due to drought.

Introduction

In Kenya’s arid and semi-arid lands (ASALs), pastoralists are particularly vulnerable to the impacts of recurrent droughts and the effects of climate change. The increased frequency and intensity of droughts across the ASALs in recent years means that affected communities have less time to recover and rebuild their assets. The main asset for these pastoral communities is livestock. Catastrophic livestock loss, especially induced by drought, is the most pervasive hazard encountered by households on a widespread level. This is especially true for northern Kenya, where more than 3 million pastoralist households are regularly hit by increasingly severe droughts (Chantarat, S. et al. 2013.). At the same time, the qualities of the rangelands have deteriorated. Unfortunately, the bulk of the attention provided for these regions is usually in the form of short-term humanitarian rather than long-term sustainable development initiatives. Such trends have rendered pastoralists less resilient against future shocks. Consequently, food security and poverty indicators commonly identify the country’s pastoral populations as suffering lower standards of living than the rest of the population. Thus standing out as a major concern in the agenda on poverty reduction and sustainable development goals. For livelihoods that rely solely or partly on livestock, the risk – and especially the realization – of catastrophic livestock mortality losses has devastating effects, driving them into extreme poverty and making it difficult for them to escape once they fall destitute (Chantarat, S. et al., 2013).

Livestock risk management contributes to stabilization of pastoralists’ incomes and earnings. Further risk management leads to increased investment in agriculture through leveraged access to finance and increased pastoralists’ resilience through asset protection and restocking (Otieno, D.J., et al. 2006; Mude, A. 2014)

Notwithstanding the considerable risks pastoralists face, livestock are and will remain for the foreseeable future, the foundation for livelihoods in the region (McPeak, J. et al. 2011). Animal husbandry represents the most economically efficient use of rangelands and is thus a crucial element of any viable strategy to support the livelihoods of the more than four million pastoralists who live in the ASALs. (McPeak, J. et al. 2011). Consequently, livestock risk management today is about how herders can cope with increased
economic and environmental pressures without jeopardizing their key asset, livestock (McPeak, J. et al. 2011). The Kenya Livestock Insurance Programme has started activities to enhance the capacity of pastoral communities to minimize weather related risks through provision of satellite based index livestock insurance.

**Overview of the Kenya Livestock Insurance Programme (KLIP) for the ASAL**

Modeled after the ILRI piloted product in Marsabit, Kenya in 2010, KLIP uses the Normalized Differentiated Vegetation Index (NDVI) – satellite imagery of rangeland conditions – to construct an index of pasture conditions, and pays out to the insured based on predicted losses when the NDVI dips below a certain pre-determined threshold level (Chantarat, S. et al., 2010.). The Government of Kenya funded drought insurance programme for vulnerable pastoralist is being implemented in the Arid and Semi Arid Land (ASAL) Counties of Kenya. The ASAL counties that are being covered by the programme include Turkana, Wajir, Mandera, Marsabit, Isiolo, Tana River, West Pokot, Baringo, Samburu, Garissa, Narok, Kajiado, Laikipia and Lamu. The underwriting is sourced competitively and is currently being done by a pool of seven insurance companies lead by APA insurance.

KLIP is currently implemented through the State Department of Livestock, in the Ministry of Agriculture, Livestock and Fisheries, in collaboration with the County Governments in six counties (Turkana, Wajir, Mandera, Marsabit, Isiolo and Tana River). The World Bank Group, International Livestock Research Center (ILRI) and Financial Sector Deepening are providing technical assistance. Implementation will be scaled up to 8 other ASAL counties in the following year.

**KLIP Design and Implementation**

KLIP builds on the experience of the ILRI designed Index-Based Livestock Insurance (IBLI) product piloted in Marsabit in 2010. Like any insurance product, index-based insurance aims to compensate clients in the event of a loss. Unlike traditional insurance, which makes payouts based on case-by-case assessments of individual clients’ loss realizations, index-based insurance pays policy holders based on an external indicator that triggers payment to all insured clients within a geographically-defined space. For index insurance to work there must be a suitable indicator variable (the index) that is highly correlated with the insured event (Chantarat, S. et al. 2013.). An index insurance contract makes the agreed indemnity payment to insured beneficiaries whenever the data source indicates that the index reaches the “trigger point,” or insurance activation level using a data source that is promptly, reliably, inexpensively available and not manipulatable by either the insurer or the insured (Mude, A. et al, 2009.).

For KLIP an insurance contract based on forage availability to protect against specified levels of aggregate livestock losses is developed. The contract specifies its geographical reach, temporal (or seasonal) coverage, the trigger level, and the relevant premium and payment terms.

**Advantages of Index Based Insurance**

An index-based insurance product has significant advantages over traditional insurance. Traditional insurance requires that the insurer monitor the activities of their clients and verify the truth of their claims. For relatively small clients in infrastructure-deficient environments like the northern Kenyan ASALs, the costs of such monitoring are often prohibitive. With index based insurance products, all that is required is to monitor the index, thereby sharply reducing costs. Furthermore, by using an index based on variables that cannot be influenced by any policy holder’s behaviour, index-based insurance products overcome the key problems with traditional insurance contracts of an individual’s experience: that more (less) risk-prone individuals will self-select into (out of) the contract and that insured individuals have an incentive to take on added risk – phenomena known as “adverse selection” and “moral hazard,” respectively. These gains from index-based insurance come at the cost of “basis risk”, which refers to the imperfect correlation between an insuree’s potential loss experience and the behaviour of the underlying index of which the insurance product payout is based. Individuals can suffer losses specific to them but fail to receive a payout because the index does not trigger. On the other hand, lucky individuals may receive indemnity payments
that surpass the value of their losses. While this problem cannot be completely eliminated, the KLIP contract has been carefully designed to minimize basic risk and therefore to maximize its value to the insured population (Mude, A.2014).

**KLIP : Social Protection through Livestock Insurance**

In 2013 the Government made a commitment to fund a drought insurance programme for vulnerable pastoralists in the ASAL Counties. The State Department of Livestock in the Ministry of Agriculture, Livestock and Fisheries, was mandated to develop the programme. In partnership with ILRI, the World Bank Group and Financial Sector Depeening, the Kenya Livestock Insurance Programme (KLIP) was designed.

The KLIP aims to minimize risks emanating from drought-related disasters and build resilience of pastoralists for enhanced and sustainable food security. The main objective of this programme is to develop, and institutionalize a large-scale sustainable livestock insurance programme for the Arid and Semi-Arid Lands, under two main components thus:

1. **Component 1**: Macro-level social protection cover for the most vulnerable pastoralists in which GOK fully funds the premiums for drought insurance protection of selected beneficiaries for a fixed number of 5 Tropical Livestock Units (TLUs) per household and;

2. **Component 2**: Voluntary retail sales of the insurance cover to any pastoralists who is interested in purchasing the KLIP/IBLI product. This component is designed to develop a sustainable commercial insurance market for livestock insurance in the ASALs and builds on the previous experience of the IBLI program. In order to make index insurance more accessible and affordable to small-scale pastoralists the Government is considering providing partial premium subsidy support for this voluntary sales component.

KLIP component 1 is intended to complement the government’s other social protection programmes such as Hunger safety Net Programme, and to contribute to the National Drought Management Agency’s drought risk management programmes in the northern counties. The sum insured in both the subsidized and voluntary insurance covers is calculated on the basis of the cost of supplementary feeds required to maintain one TLU during the drought months of the year. Currently the value is Ksh. 14,000 per TLU. Consequently each pastoralist who is under the subsidized GOK cover for five TLUs, can receive a maximum payout of 5x14,000 (Kes,70,000) in the event that the policy triggers hundred percent. KLIP provides the asset protection cover over two seasons, the potential payouts are divided into the two seasons at the ration of short rains season 42% and the long rains season 58%.

Registration, targeting and selection of beneficiaries are done by the County Governments and the local community leaders. Every attempt is made to ensure that pastoralist are selected from communities throughout the respective Counties in the determined geographically-defined space called the “insurance unit area”. Broad selection criteria provided by the programme is that:

a. The beneficiary must be a pastoralist who owns a minimum of 5TLUs
b. They should not be beneficiaries of HSNP cash transfer programme and
c. They should be identified by the community as being venerable pastoralist.

After selection of the beneficiaries by the County Government, the national Government then pays 100% the premiums for 5 TLUs for each selected beneficiary to the contracted insurance company. If the trigger point is reached in any season, the agreed indemnity payment is made directly to insured beneficiaries through their accounts.

**KLIP Results and Progress**

KLIP component 1 was launched during the 2015 short rainy season of October-December in Turkana and Wajir Counties. A total of 5,012 (2502 and 2510) pastoralist respectively from Turkana and Wajir Counties were covered each for 5 TLUs. During the short rains of 2016 four additional Counties of Mandera,
Marsabit, Isiolo and Tana River were brought under the insurance cover with Tana River and Marsabit contributing 2500 pastoralist each, while Mandera and Isiolo each contributed 2000 pastoralist. Hence in this period a total of 14,012 pastoral households were covered by the insurance.

In the 2015 short rains, two insurance units in Wajir County triggered and payouts of over 3.5 million were made to 275 pastoralist households. In the just ended short rains of 2016, sixty two out of 70 insurance units in the six counties triggered with a severe drought. Nearly KSE 215 million will be paid to 12,064 pastoralists. The range in the payouts is KSE. 1,400 in the areas that were less affected, to KSE. 29,400 in the areas were the trigger reached the lowest percentile.

Partners

• The Government of Kenya through the State Department of Livestock provides government subsidy.
• The County Governments are expected to do the registration and selection of beneficiaries as well as participate in awareness creation and capacity building.
• The insurance underwriting is done by private insurance companies.
• Currently a consortium of insurance companies, (UAP insurance, CIC insurance, Jubilee Insurance, Amaco Insurance, Heritage Insurance, Kenya Orient), lead by APA insurance are doing the underwriting.
• Technical assistance partners include World Bank Group, International Livestock Research Institute and Financial Sector Deepening.

References


Effect of Black Soldier Fly Larvae Meal Inclusion in Layers Diets on Laying Performance of Improved Indigenous Chicken

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Abstract

Fifty five hens aged 30 weeks were offered five diets formulated to be iso-energetic and iso-nitrogenous but containing different levels of black soldier fly (BSF) meal at 0, 5, 10, 15 and 20% inclusion rates. Treatments were randomly allocated to the hens, with each diet having 11 replicates. The birds were housed in a battery cage system and offered feed at a rate of 200g per day. Measures of feed intake, egg weight, egg production and weekly weight gain were taken over the eight weeks experimental period. There was significance difference in feed intake among the treatments (p<0.05). Egg production was affected by the level of inclusion of BSF larvae, with 20% inclusion level having highest (82.9%) percentage lay and 0% inclusion level having the lowest (54.32%) laying percentage. There was significance (p<0.05) difference on the egg weight among the treatments with 15% inclusion level having the highest average weight (59.32g) and the control (conventional) (0% inclusion level) having the lowest (54.32g) average egg weight. The cost of producing an egg was lowest at 10% inclusion level. The findings are expected to inform in the formulation of indigenous chicken layer diets with the black soldier fly larvae as an alternative protein source.

Keywords: Hermetia illucens, Feed intake, Egg production, Egg weight, weight change.

Introduction

The Kenya poultry sector mainly comprises of indigenous and exotic chicken, with the indigenous chicken taking about 80% of the sector (KNBS, 2010). Poultry in Kenya are an important part of nutritional and food security of the populations especially the rural poor. The effectiveness of poultry production largely depends on feed availability, quality, and cost which can limit development of poultry production (Agritrade poultry brief, 2013). Since feeds constitute over 70% of the total cost of poultry production, alternative feed sources are important to contribute in lowering the cost of production. Insects have been proposed as a viable alternative feed resource... Insects are also part of the natural diet of free range chicken and have high nutritional value and are widely distributed. For instance, insects have been shown to contain essential amino acids such as lysine and methionine that are required by poultry for improved performance (Van Huis, 2013, our unpublished data). Makkar et al. (2014) reported that insects have a good palatability and can replace 25–100% of soybean meal or fishmeal depending on the animal type. Black Soldier Fly (BSF) larvae has been proposed as a potential insect that can be used in the feed industry. BSF larvae are easy to rear as they are scavengers and flourish on various kinds of putrefying organic matter producing feed matter that is rich in crude protein content (42-57% DM) and high in essential amino acids depending on the media of growth (Makkar et al., 2014). The aim of this study was therefore to determine the effect of BSF larvae inclusion in diets on the egg laying performance of KALRO improved indigenous chicken.
Materials and Methods

**Experimental site:** The study was conducted at the Poultry Research Unit of the Non-Ruminant Institute of Kenya Agricultural and Livestock Research Organization, Naivasha, Kenya.

**Experimental diets:** Five iso-nitrogenous diets were formulated to contain BSF larvae at different inclusion levels and consisted of the control diet with 0% BSF larvae and 5%, 10%, 15% and 20% BSF larvae inclusion levels (Table 1).

**Table 1:** Experimental diet composition

<table>
<thead>
<tr>
<th>Feed Ingredients</th>
<th>Control</th>
<th>BSF 1</th>
<th>BSF 2</th>
<th>BSF 3</th>
<th>BSF 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>49.1</td>
<td>46.95</td>
<td>46.08</td>
<td>45.2</td>
<td>46.82</td>
</tr>
<tr>
<td>Pollard</td>
<td>29.11</td>
<td>28.94</td>
<td>29.08</td>
<td>28.2</td>
<td>24.91</td>
</tr>
<tr>
<td>Bone Meal</td>
<td>0.39</td>
<td>2</td>
<td>0.38</td>
<td>0.45</td>
<td>0.01</td>
</tr>
<tr>
<td>Soya Bean Meal</td>
<td>7.83</td>
<td>8.53</td>
<td>4.96</td>
<td>3.6</td>
<td>0</td>
</tr>
<tr>
<td>Fish Meal</td>
<td>7.51</td>
<td>3.07</td>
<td>2.59</td>
<td>0.17</td>
<td>0</td>
</tr>
<tr>
<td>DCP</td>
<td>1.27</td>
<td>1.42</td>
<td>2.32</td>
<td>2.87</td>
<td>3.46</td>
</tr>
<tr>
<td>Calcium carbonate</td>
<td>4.44</td>
<td>2.81</td>
<td>4.06</td>
<td>3.89</td>
<td>4.18</td>
</tr>
<tr>
<td>Vitamin Premix</td>
<td>0.35</td>
<td>1.27</td>
<td>0.52</td>
<td>0.62</td>
<td>0.62</td>
</tr>
<tr>
<td>Insect meal</td>
<td>0</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Total diet</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

**Experimental birds, design and procedures:** Fifty five (55) KALRO improved indigenous chicken layers of the same age (30 weeks) were allocated randomly to the five treatment diets with each treatment having 11 birds. The birds were subjected to the recommended health bio-security procedures and management practices. The experiment was laid out in a completely randomized design. Initial weight of the birds at the start of the experiment was taken and the birds randomly placed in individual cages. The treatment diets were offered ad libitum to the birds. The hens were given a one week adaptation to the diets followed by an 8 weeks data difference of feed intake, egg production and weight and chicken live weight. Significant means were separated collection period.

**Data collection and analysis:** Data on daily feed intake, weight change and egg production and weight was collected. All the data was then subjected to a one way ANOVA to determine mean significance using LSD at P<0.05.

**Results and Discussion**

Table 2 presents the nutritional composition of the treatment diets. The dry matter (DM) content ranged between 89.2% and 90.1%, which was within the range recommended for layer diets. The crude protein content of the diets were similar ranging from 16.6% to 17.5% which was around the target protein content of 16% for laying hens. The fibre content and especially the acid detergent content was generally low which implies it did not limit the intake of the diets.
Table 2: Experimental Diet Nutritional Composition

<table>
<thead>
<tr>
<th>Diet</th>
<th>DM</th>
<th>ASH</th>
<th>EE</th>
<th>CP</th>
<th>NDF</th>
<th>ADF</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSFL 0%</td>
<td>89.6</td>
<td>7.9</td>
<td>3.5</td>
<td>16.7</td>
<td>38.3</td>
<td>11.2</td>
</tr>
<tr>
<td>BSFL 5%</td>
<td>90.1</td>
<td>8.6</td>
<td>5.5</td>
<td>17.5</td>
<td>55.2</td>
<td>15.0</td>
</tr>
<tr>
<td>BSFL 10%</td>
<td>89.6</td>
<td>11.5</td>
<td>7.6</td>
<td>17.0</td>
<td>45.3</td>
<td>9.4</td>
</tr>
<tr>
<td>BSFL 15%</td>
<td>89.6</td>
<td>9.8</td>
<td>6.8</td>
<td>16.6</td>
<td>51.3</td>
<td>3.9</td>
</tr>
<tr>
<td>BSFL 20%</td>
<td>89.2</td>
<td>9.7</td>
<td>6.4</td>
<td>16.7</td>
<td>53.3</td>
<td>13.5</td>
</tr>
</tbody>
</table>

The influence of the different diets on feed intake, egg production and weight and chicken weight change is shown in Table 4. The birds fed on 15% BSF larvae inclusion level had the lowest feed intake (P < 0.05). This was followed by the birds consuming 0% and 10% BSFL inclusion levels which were not significantly different (P>0.05). The birds fed on 5% and 20% BSF larvae inclusion levels had the highest (P<0.05) feed intake.

Table 3: Effect of BSF Larvae inclusion levels on feed intake and Egg production on KALRO Improved indigenous chicken.

<table>
<thead>
<tr>
<th>BSF Inclusion Level</th>
<th>BSFL 0%</th>
<th>BSFL 5%</th>
<th>BSFL 10%</th>
<th>BSFL 15%</th>
<th>BSFL 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Intake (g)</td>
<td>106.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>111.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>107.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>103.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>111.2&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Egg Weight (g)</td>
<td>54.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>56.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>58.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>59.3&lt;sup&gt;d&lt;/sup&gt;</td>
<td>57.8&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Egg Production (%)</td>
<td>51.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>68.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>77.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>72.1&lt;sup&gt;b, c&lt;/sup&gt;</td>
<td>82.9&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Weight change (Kg/bird/week)</td>
<td>-0.013&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.015&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-0.003&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.002&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.024&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

The diets were formulated to be iso-nitrogenous and iso-calorific. However the feed intake tended to increase with the inclusion of BSF larvae in the diets. It was observed that palatability of the diets was enhanced with the inclusion of the BSF larvae. Chicken are known to consume insects under free range systems. The inclusion of the BSF larvae in formulated diets for layers has shown that it enhances the intake of the overall diet. Other factors that affect voluntary feed intake in animals are breed, age, nutrient balance of the diet, ambient temperature and health.

Average egg production was lowest (P < 0.05) for birds offered 0% BSF larvae inclusion levels at 51.2% while birds offered 20% BSF larvae inclusion level had the highest (P<0.05) laying percentage (82.9%). The egg weights were significantly different (P < 0.05) among all BSF larvae inclusion levels with the highest weight being for the birds consuming 15% inclusion level.

The inclusion of BSF larvae increased laying performance of the birds. This may be due to the supply of the essential nutrients which are contained in the BSF larvae such as essential amino acids like lysine and methionine and essential fatty acids such as linolenic acid (Newton et al. 1977; Makkar et al., 2014).

Though there were significant differences in weight change of the birds between the treatment diets, the changes were very modest during the experimental period. However, the birds consuming diets containing 0% and 10% BSF larvae inclusion levels lost a little weight while all the others marginally gained weight during the experimental period (Table 3). The increased performance of the birds fed on diets with BSF inclusion without decrease in weight shows that the inclusion supplies additional nutrients which improves the efficiency of use nutrients in the birds (Newton et al. 1977).
Conclusion

The BSF larvae meal inclusion in layer diets has positive effect on egg production, egg weight and weight change of laying hens. Therefore, BSF larvae meal can be used as an alternative feed source to replace other sources especially the high quality and scarce protein sources such as fishmeal and soybean meal/cake.

Acknowledgement

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References


Effects of Black Soldier Fly Larvae Based Feed on the Growth of Nile Tilapia

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Abstract

Fishmeal is the most commonly used source of protein in fish feeds. However, this ingredient is increasingly becoming scarce and expensive. The need for alternative sources of protein to sustain the current growth in the aquaculture industry has become necessary. A study was therefore conducted to determine the growth of Nile tilapia fed on Black Soldier Fly (BSF – \textit{Hermetia illucens}) larvae as a protein substitute for fishmeal. Four diets were formulated to replace fishmeal with BSF larvae at 0\% (Conventional), 33\%, 67\% and 100\% levels. Nile tilapia of similar age and weight in 12 cages were fed the different feeds in a completely randomized design experiment. Results of the experiment showed that feed intake, weight gain and feed utilization were all affected by the BSF larvae inclusion level (p<0.05). Diet containing 33\% of fishmeal substitution had the best overall performance in terms of intake, weight gain and utilization while feed with 67\% fishmeal substitution with BSF larvae performed as good as diet with 100\% fishmeal. It is concluded that replacement of fish meal up to 67\% level with BSFL does not affect growth.

Introduction

Fish feeds account for about 40-60\% of the production costs in aquaculture with protein being the most expensive nutrient (Munguti \textit{et al.}, 2012). Fish require high proportion of protein in their diet because they metabolize protein as energy source (Aladetohun and Sogbeasan, 2013). Fishmeal has been the commonly used protein source in fish diets because it has a good amino acid profile, highly palatable and has high digestibility (Hardy, 2012). The shortage in the global fish meal production coupled with increased demand and competition with human and livestock has caused the prices of fish meal to increase thus affecting the economic viability of aquaculture industry (Watanabe, 1988). The sustainability of the aquaculture industry depends on establishment of suitable alternative feedstuffs which are economical to replace fish meal without being detrimental to growth performance of fish (Ogello \textit{et al.}, 2014).

The use of non-conventional feedstuffs such as animal and plant products as possible fish meal replacers has been studied by scientists with varying levels of success. Use of insects in the production of protein for use as feed ingredient in the animal industry has shown great potential. Black soldier fly larvae has been identified as the best alternative for fishmeal due to its mass rearing ease. This study aimed at substituting fish meal with black soldier fly larvae meal at various levels to determine their effects on growth performance of Nile tilapia reared on cages in earthen ponds.

Materials and methods

\textit{Experimental site}: The experiment was conducted at the Kenya Marine and Fisheries Research Institute (KMFRI), Sagana, which lies at the altitudes 1230 m above sea level, latitude 0° 39S and longitude 37°12 and 90 Km north of Nairobi city.
**Experimental diets and procedures:** Four iso-nitrogenous diets (ca. 30% CP) were formulated to substituting fish meal with BSF larvae at 0%, 33%, 67% and 100% levels as protein sources as shown in Table 1. Some 30 male fingerlings weighing 35g (+2g) were allocated to each of the twelve cages and the experimental diets were randomly distributed each having three replicates. The fish were acclimatized for two weeks using the conventional diet.

**Table 1:** Proportions of different ingredients used to make various diets

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Conventional</th>
<th>Diet 33%</th>
<th>Diet 67%</th>
<th>Diet 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize germ</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Wheat pollard</td>
<td>42.8</td>
<td>35.4</td>
<td>28.1</td>
<td>17.9</td>
</tr>
<tr>
<td>Fish meal</td>
<td>32.5</td>
<td>22.8</td>
<td>13.3</td>
<td>0</td>
</tr>
<tr>
<td>Black soldier fly</td>
<td>0</td>
<td>16.8</td>
<td>33.6</td>
<td>57.1</td>
</tr>
<tr>
<td>Total (Kgs)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>C.P (%)</td>
<td>29.4</td>
<td>28.2</td>
<td>29.0</td>
<td>26.8</td>
</tr>
</tbody>
</table>

After the two weeks of adaptation, the initial weight was taken and the feeding of experimental diets started. Fish were fed twice daily at 9a.m and 3p.m at rate of 3% of their body weight.

**Data collection and Analysis:** Data collection was done after every two weeks for a period of 12 weeks. Data collected included: feed offered, fish weight and mortalities. All data on growth performance parameters and economic analysis were subjected to analysis of variance (ANOVA) and significance of means were tested at P < 0.05.

**Results and Discussion**

Table 2 presents the proximate composition of the treatment diets. All the diets had a DM content of more than 93%. The crude protein content ranged between 26.8% DM and 29.4% DM, which is within the required protein content for tilapia fish. The fibre content was generally low thus did not limit the feed intake by the fish.

**Table 2:** Proximate composition (%) of the diets used in the experiment

<table>
<thead>
<tr>
<th>Diet</th>
<th>DM</th>
<th>CP</th>
<th>ADF</th>
<th>NDF</th>
<th>EE</th>
<th>ASH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>96.0</td>
<td>29.4</td>
<td>7.0</td>
<td>24.0</td>
<td>5.2</td>
<td>8.0</td>
</tr>
<tr>
<td>Diet 33%</td>
<td>93.0</td>
<td>28.2</td>
<td>9.5</td>
<td>28.0</td>
<td>10.2</td>
<td>26.5</td>
</tr>
<tr>
<td>Diet 67%</td>
<td>97.0</td>
<td>29.0</td>
<td>6.0</td>
<td>27.0</td>
<td>13.4</td>
<td>6.0</td>
</tr>
<tr>
<td>Diet 100%</td>
<td>98.0</td>
<td>26.8</td>
<td>6.5</td>
<td>27.0</td>
<td>14.4</td>
<td>5.0</td>
</tr>
</tbody>
</table>

The results of substitution of fishmeal with BSF larvae on the performance of fish are presented in Table 3. Fishmeal substitution level had significant (P<0.05) effect on feed intake, final body weight, daily weight gains of the fish. Feed with 33% fishmeal substitution had the highest weight gain. There was no significant difference between conventional feed and feed with 67% fishmeal substitution in terms of weight gain; however 100% fishmeal substitution recorded the lowest weight gain. At 33% fishmeal substitution, feed intake was significantly (P<0.05) higher than in conventional feed however the 67% and 100% fishmeal substitution had significantly lower consumption compared to conventional feed.
Table 3: Growth performance of fish fed Black soldier fly as a replacement for fishmeal

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Diet 1</th>
<th>Diet 2</th>
<th>Diet 3</th>
<th>Diet 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial body weight (g)</td>
<td>35.3</td>
<td>35.1</td>
<td>35.4</td>
<td>35.2</td>
</tr>
<tr>
<td>Final body weight (g)</td>
<td>108.5^b</td>
<td>138.6^c</td>
<td>104.9^ab</td>
<td>94.7^a</td>
</tr>
<tr>
<td>Weight gain (g)</td>
<td>73.2^a</td>
<td>103.5^b</td>
<td>69.5^a</td>
<td>59.5^c</td>
</tr>
<tr>
<td>Daily weight gain (g)</td>
<td>0.9^a</td>
<td>1.2^b</td>
<td>0.8^ac</td>
<td>0.7^c</td>
</tr>
<tr>
<td>Feed intake</td>
<td>195.9^a</td>
<td>214.7^b</td>
<td>180.3^c</td>
<td>173.4^c</td>
</tr>
</tbody>
</table>

^a means with different superscricion in a row are significantly different (p<0.05)

The trend in the weight gain is presented in Figure 1. There was a consistent effect on performance with increasing the level of BSF larvae meal.

![Figure 1](image-url)

**Figure 1:** Effect of fishmeal substitution with black soldier fly larvae meal on Nile Tilapia’s cumulative weight gain over a period of 112 days

Fishmeal has been reported to lead to excellent performance if fish diets due to its good amino acid profile, high digestibility and palatability which promote good growth (Hardy and Tacon, 2012). Combining two or more animal protein ingredients in fish diets have been observed to improve the growth performance of fish as compared to inclusion of a single protein source perhaps due to a desirable balance of essential amino acids achieved from combining proteins of animal origin (Phonekhampheng, 2008). The results of this study also found that when fishmeal was combined with BSF larvae, the performance was better. The fish that was consuming diet with 33% fishmeal substitution with BSF larvae had highest (P<0.05) weight gain. Rana et al. (2014) also reported highest growth performance when fishmeal was substituted in Nile tilapia fry diet with BSF larvae followed by 25% fishmeal substitution. In addition, Sealry et al. (2011) recommended 50% replacement of fishmeal with BSF larvae meal in practical diets of rainbow trout diets without significantly affecting fish growth. The performance differences of the fish fed on the different diets was consistent over time (Figure 1).

**Conclusion**

The BSF larvae meal can be used as a protein ingredient in replacement of fish meal in fish feeds. Replacing fishmeal with BSF larvae at 33% gave the best results. Combining protein sources seems to give better results than single source of proteins for the fish.
Acknowledgement

This research work was supported by “INSFEED- Insect feed for poultry and fish production in Kenya and Uganda” project (Cultivate Africa Grant No.: 107839-001) funded by the International Development Research Centre, Canada (IDRC) and the Australia Centre for International Agricultural Research (ACIAR). The first author was funded by the same project through Dissertation Research Internship Programme (DRIP) of icipe. We would like to thank the Kenya Marine and Fisheries Research Institute management and Staff who facilitated the implementation of the current research.

References


Effect of Black Soldier Fly Larvae inclusion in Broiler Diets on Broiler Chicken Growth Performance


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Abstract

Broiler chickens were fed on diets containing full fat black soldier fly (BSF) (Hermetia illucens) larvae in an experiment to determine their performance. The diets were formulated to be iso-nitrogenous and iso-caloric and the BSF was included to partially replace soybean meal and fishmeal. The larvae were ground and mixed at various inclusion levels with other ingredients to form the compounded experimental broiler feed diet. The diets included 0% (conventional diet with fishmeal/soybean meal included), 5%, 10% and 15% BSF larvae inclusion levels. Two hundred and eighty eight (n=288) day old COBB 500© broiler chicks were housed in Forty eight, 0.675m² metallic cages (6 birds/cage) and randomly fed to the four dietary treatments for 42 days. Each diet was fed to 6 birds replicated twelve times. Performance of broilers fed on BSF larvae diets was similar (p>0.05) to those fed conventional meal for daily feed intake, body weight gain and feed conversion ratio. The study demonstrates that BSF larvae meal can partially replace soybean meal and fishmeal in broiler chicken diets with no adverse effects on the performance of the broiler chicken.

Introduction

World population is likely to continue growing for the rest of the century, with at least a 3.5-fold increase within Africa (Gerland et al., 2014). At the current growth rates, Kenya is adding about one million people to its population annually (KNBS, 2009). The projected population increase and improved GDP suggests that demand for both cereal grains and animal protein will continue to increase. FAO projections forecast a massive increase in animal protein demand (Speedy, 2004) with poultry meat accounting for 40% of this global increase in meat consumption (Rosegrant, 2001).

Recent high demand and consequent high prices for soybean meal and animal protein such as fishmeal is pushing new research into development of alternative protein sources for poultry (Van Huis et al., 2013). The prospect of using insects in animal feeds has elicited global interest in the recent past. Sánchez et al., (2014) also reported insects to be a sustainable source of protein with appealing quantity and quality of proteins containing good nutritive properties.

Black soldier fly (BSF) like other insects has a tiny ecological foot print and therefore diminished Green House Gas (GHG) and ammonia emission (Oonincx et al., 2010). The BSF larvae can grow on a wide range of organic wastes. According to Tran et al. (2015), this attribute can be harnessed to convert waste into valuable biomass rich in protein (up to 44%) with a better or comparable amino acid profile to soybean meal.

Therefore the aim of this study was to determine the effect of including BSF larvae meal in broiler diets on broiler growth performance. The test diets were formulated to replace soybean and fishmeal as protein source ingredients.
Materials and Methods

**Experimental site:** The study was conducted at the Poultry Research Unit of the Non-Ruminant Institute of Kenya Agricultural and Livestock Research Organization, Naivasha, Kenya

**Experimental diets:**

Four dietary treatments were formulated to be iso-nitrogenous and iso-energetic and offered to 6 birds in 12 replicates per treatment. The control treatment (C) contained Fishmeal while the other treatment contained Black Soldier Fly (BSF) larvae meal at various inclusion levels to replace soybean meal and/or fishmeal including T1 (5% BSF larvae), T2 (10% BSF larvae) and T3 (15% BSF larvae). Table 1 shows the percentages of these protein ingredients replaced by BSF larvae meal inclusion.

**Table 1:** Soybean meal and Fishmeal replaced by BSF Larvae meal

<table>
<thead>
<tr>
<th>Experimental diets</th>
<th>Soybean</th>
<th>Fishmeal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Starter Mash</td>
<td>Finisher Mash</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>T1</td>
<td>13.2</td>
<td>19</td>
</tr>
<tr>
<td>T2</td>
<td>26.3</td>
<td>46</td>
</tr>
<tr>
<td>T3</td>
<td>45.2</td>
<td>64</td>
</tr>
</tbody>
</table>

**Experimental birds, design and procedures:**

Two hundred and eighty eight (n=288) day old (COBB 500 ®) broiler chicks were reared for 49 days (7 days acclimatization phase and 42 days experimental feeding phase). During the acclimatization period, the chicks were kept in a common brooder for the first 3 days before being feather sexed and moved to 48 brooder cages (each accommodating 6 chicks) where they were allowed to finish the acclimatization period and start the feeding phase. Sexing was done to ensure that both sexes were equally represented in each treatment. The study was done in a completely randomized design with 12 replicates per treatment. The chicks were fed on a standard mixture containing all the diets during the first 3 days before randomly being assigned to one of the four diet treatments for the remainder of the acclimatization period and the entire feeding phase. At the start of the feeding phase the birds were weighed and allowed to continue with the assigned diets. Clean water and feed were provided *ad libitum.*

**Data collection:**

Group bird weight per cage was measured on a weekly basis. Administered feed was weighed at the start of each week and the difference at the end of the week weighed. The feed intake was determined for each pen. Each week, the cumulative weight gain and feed intake was determined and the ratio of cumulative weight gain to feed was calculated. Average daily gain (ADG) and average daily feed intake (ADFI) were then calculated.

**Statistical Analysis:**

All the data on weight gain and feed intake was analyzed using a one way analysis of variance (ANOVA). The statistical package R version 3.3.2 was used. The significance between the treatment means was tested at statistical significance level of $P=0.05$ and was separated using Tukey’s multiple comparison procedure.

**Results and Discussion**

The chemical composition of the treatment diets is shown in Table 2. The Dry matter ranged from 89.6 to 89.9%. The crude protein (CP) content of both the start and finisher diets was similar across the treatment
diets ranging from 20.9% DM to 22.5% DM for Starter mash and 19.2% DM to 20.3% DM for Finisher mash. The CP content of the treatment diets was within the requirements for broiler chicken (18%-23% CP). The fibre content, especially the acid detergent content, was generally low which implies it does not limit the intake of the diets.

**Table 2:** Proximate composition (%) of experimental diets

<table>
<thead>
<tr>
<th></th>
<th>Broiler starter mash</th>
<th>Broiler finisher mash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diet</td>
<td>DM</td>
<td>Ash</td>
</tr>
<tr>
<td>C</td>
<td>89.9</td>
<td>8.9</td>
</tr>
<tr>
<td>T1</td>
<td>89.8</td>
<td>9.6</td>
</tr>
<tr>
<td>T2</td>
<td>89.6</td>
<td>8.3</td>
</tr>
<tr>
<td>T3</td>
<td>89.6</td>
<td>7.7</td>
</tr>
</tbody>
</table>

The feed intake and growth performance of the birds are presented in Table 3. There was no significant (P>0.05) effect of the treatment diets on the average daily feed intake of the chicken. The feed intake ranged from 101.5 g/day for T3 diet to 106.9 g/day for T3. Inclusion of the BSF larvae in treatments T1, T2 and T3 did not adversely affect the palatability of the diets as the birds consumed the BSF containing diets similar to the conventional diet containing fishmeal or soybean meal.

**Table 3:** Effect of dietary inclusion of *Hermetia illucens* larvae meal on broiler chicken growth performance

<table>
<thead>
<tr>
<th>Experimental diets</th>
<th>C</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live weight (g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial (day-7)</td>
<td>171.8</td>
<td>168.6</td>
<td>170.1</td>
<td>165.2</td>
<td>0.0884</td>
</tr>
<tr>
<td>Final (day-49)</td>
<td>3045.0</td>
<td>3164.0</td>
<td>3004.0</td>
<td>3044.0</td>
<td>0.0707</td>
</tr>
<tr>
<td>BWG(^1) (g/day)</td>
<td>68.4</td>
<td>71.3</td>
<td>67.5</td>
<td>68.5</td>
<td>0.0825</td>
</tr>
<tr>
<td>FI(^1) (g/day)</td>
<td>104.4</td>
<td>106.9</td>
<td>103.2</td>
<td>101.5</td>
<td>0.342</td>
</tr>
<tr>
<td>FCR(^1)</td>
<td>1.53</td>
<td>1.50</td>
<td>1.52</td>
<td>1.48</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\)BWG – Body Weight Gain, FI – Daily Feed Intake, FCR – Feed Conversion Ratio

The inclusion of BSF larvae and therefore replacement of both soybean and Fishmeal in the diets resulted in similar effects (p>0.05) on body weight at slaughter (final weight), body weight gain and the feed conversion ratio. Cullere *et al.*, (2016) reported similar trends in weight gain of intensively reared growing quails fed on defatted *H. illucens* larvae meal. Elwert *et al.*, 2010 also reported similar results in weight gain when full fat *H. illucens* larvae meal was included in broiler starter diet. All chicks in the four treatments attained the ideal day-7 body weight (four times their day old body weight) recommended at this age by the hatchery where the birds were sourced. Results showed that the formulated diets met the dietary requirements of the chicks during this period. Dietary inclusion of *H. illucens* larvae meal in broiler diets had also had no adverse effect on the growth performance of the broiler chicken.
Conclusion

The BSF larvae meal can be used as an alternative feed source to replace other protein sources especially the expensive and scarce sources such as fishmeal and soybean meal in broiler diets. Black soldier fly larvae can be included in broiler diets without any adverse effect on performance.

Acknowledgment

This research work was supported by “INSFEED- Insect feed for poultry and fish production in Kenya and Uganda” project (Cultivate Africa Grant No.: 107839-001) funded by International Development Research Centre, Canada (IDRC) and Australia Centre for International Agricultural Research (ACIAR). The first author was funded by the same project through the Dissertation Research Internship Programme (DRIP) of icipe. We would like to thank the KALRO Non-ruminant Research institute management and Staff who facilitated the implementation of the current research.

References


Assessment of the Agricultural at the Coastal Research Centre as an Access Point for Information and Technologies region, Kenya

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Abstract

The Kenya Agricultural and Livestock Research Organization (KALRO) is the premier research organization in Kenya with the mandate to conduct research and disseminate findings on agriculture and veterinary sciences. Many clients visit KALRO research centers established all over the country to access agricultural knowledge, information and technologies. The soaring number of visitors to KALRO Research Centers leads to competition for researcher’s time spent on KALRO’s core business in research and handling visitors in the dissemination of technologies. There is therefore need to find a balance that will minimize the competition between research and technology dissemination on researcher’s time. This study was carried out at ICRC Mtwapa. The objectives were to: 1) evaluate the Research Centre as an access point for information and technologies, 2) characterize the clients who visit KALRO’s research centers, 3) define the types of knowledge, information and technologies sourced, 4) estimate the researcher’s time spent by visitors, 5) provide recommendations/strategies that will ensure harmonious discharge of KALRO’s research and dissemination services. Visits made to ICRI Mtwa-pa in the years 2013 to 2015 were evaluated in light of the given objectives. The time spent at KALRO and the rating of services were analyzed for the sample year 2015 to capture current trends. Results showed that the number of clients to the Centre increased between 2013 and 2015. The number of clients to the Centre seeking specific farming technologies or purchase of seed over the period was 65.4% of the total. Horticultural Technologies and poultry production were among the highest demanded by visitors. Researcher’s time spent with clients ranged between two minutes to nine hours per visit. KALRO Mtwapa proved to be an effective access point for agricultural information and technologies serving 6,384 clients in the study period. It is recommended that, persons other than research scientists be identified to handle the bulk of clients seeking information and technologies in order to reduce demand on Researcher’s time. KALRO’s research centers should commit adequate resources for the production and/ or commercialization of seed technologies.

Key words: KALRO Mtwapa, Researcher, Information, Visits, Technologies

Introduction

Of the 7.4 Billion people in the world 795 Million are hungry with the majority living in developing world (World meters, World hunger 2015). Low agricultural productivity is perceived as one of the major causes of hunger in Africa and it has been attributed to scarce knowledge on improved practices, low use of improved seed and fertilizers (Kwadwo Asenso-Okyere and Samson Jemanah 2011). Agricultural information and improved technologies can be accessed from many sources including internet websites but the need to verify information accessed is considered critical by serious entrepreneurs. The Kenya Agricultural and Livestock Research Organization (KALRO) is the premier national agricultural research organization in Kenya, with the mandate to conduct research and disseminate findings on agriculture and veterinary sciences to stakeholders. However, the core business of the organization is research. The many stakeholder visits made to KALRO research centres could indicate: 1) Entrepreneurs in agriculture are becoming increasingly aware of the risks of going into business without adequate information, 2) KALRO is known to provide good information to farmers.

However, the soaring number of visitors visiting KALRO leads to competition for researcher time and research time. Putting into consideration of the limited number of researchers existing in KALRO (Table
5), this becomes a problem that must be addressed with urgency. As a result of this KALRO Mtwapa saw the need of coming up with this study which was guided by five objectives as given below:

- To evaluate the Industrial Crops Research Centre (ICRC) Mtwapa as an access point for agricultural knowledge, information and technologies for the Coastal region
- To characterize the clients who visit the Centre,
- To define the types of agricultural knowledge, information and technologies sourced,
- To estimate the researchers time spent by the visits,
- To provide recommendations/strategies that will ensure harmonious discharge of KALRO’s research and dissemination services.

Materials and methods

The study was carried out at KALRO Centre Mtwapa based at the coast. This Centre is located (3° 56’S, 39°44’E) in the coastal lowland Agro - Ecological Zone 3 also known as coconut - cassava (Jaetzold and Schmidt, 1983). Clients visiting the Centre in the years 2013 to 2015 reported to the Customer care desk where they registered their names, time of arrival, contacts and purpose of visiting the Centre, these were tallied to give monthly and annual totals. Clients signed out and rated the services as: Excellent, very good, Good, Poor, very poor or unrated on departure to indicate customer satisfaction. The time spent at the centre and the rating of services were analyzed for the sample year 2015 to capture current trends. The analysis was based on visit counts; the clients who visited to access technologies were counted and the time they spent with the researcher noted. This was analyzed for mean, range and standard deviation

The reasons for visiting the Centre were in this study summarized as: i) Official visit: where individuals came to transact official business with the administration sections. ii) Visiting Scientists came to transact business with fellow researchers. iii) School visit: These were primary or secondary school students who visited on educational tour. iv) Group visit: were visits by farmer groups and University students in groups. v)Marketing: these were clients visiting the Centre to market their products to the Centre or staff. These included Bankers, Insurance companies and the like. vi) Meetings/ conferences: Clients came to attend meetings or conferences at the Centre conference hall. vii)Soil analysis: Clients came to seek the services of soil sampling/analysis. It is worth noting that the Centre does not have a soil laboratory. viii) Purchase seeds: clients came to procure seed or seedlings. ix) Field attachment: Clients were university or college students who came to seek industrial attachment. x) Crop farming: these were clients who came to seek technologies in crops. xi) Livestock farming: Clients seeking technologies in various livestock enterprises. The following categories of visitors were hosted by research scientists on arrival; field attachment, group visits, soil analysis, crop farming and livestock farming.

Results and discussions

Objective 1: Industrial Crops Research Centre Mtwapa as an access point for agricultural information and technologies

Number and types of visits to the centre

The number of visitors who frequented the Centre was used as an indicator of Centre popularity/effectiveness in the dissemination of technologies. The number of visitors to the Centre increased from 1,982 to 2,298 between 2013 and 2015.
Table 1: Number of stakeholder visits made to KALRO, ICRI Mtwapa in the years 2013 to 2015 and the Purpose of visiting

<table>
<thead>
<tr>
<th>Year</th>
<th>Office visit</th>
<th>School visit</th>
<th>Group visit</th>
<th>Market visit</th>
<th>Meeting visit</th>
<th>Soil visit</th>
<th>Seed visit</th>
<th>Field visit</th>
<th>Crop visit</th>
<th>Stock visit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>420</td>
<td>55</td>
<td>74</td>
<td>77</td>
<td>34</td>
<td>46</td>
<td>718</td>
<td>124</td>
<td>292</td>
<td>142</td>
<td>1982</td>
</tr>
<tr>
<td>2014</td>
<td>94</td>
<td>76</td>
<td>77</td>
<td>117</td>
<td>99</td>
<td>62</td>
<td>847</td>
<td>73</td>
<td>388</td>
<td>271</td>
<td>2104</td>
</tr>
<tr>
<td>2015</td>
<td>567</td>
<td>55</td>
<td>29</td>
<td>69</td>
<td>97</td>
<td>39</td>
<td>935</td>
<td>75</td>
<td>225</td>
<td>207</td>
<td>2298</td>
</tr>
<tr>
<td>Total</td>
<td>1081</td>
<td>186</td>
<td>180</td>
<td>363</td>
<td>230</td>
<td>147</td>
<td>2500</td>
<td>72</td>
<td>272</td>
<td>620</td>
<td>6384</td>
</tr>
<tr>
<td>Mean</td>
<td>360</td>
<td>62</td>
<td>60</td>
<td>88</td>
<td>36</td>
<td>49</td>
<td>833</td>
<td>91</td>
<td>302</td>
<td>207</td>
<td>2118</td>
</tr>
<tr>
<td>Percent</td>
<td>16.9</td>
<td>2.9</td>
<td>2.8</td>
<td>4.1</td>
<td>3.6</td>
<td>2.3</td>
<td>39.1</td>
<td>4.3</td>
<td>14.2</td>
<td>9.8</td>
<td>100</td>
</tr>
</tbody>
</table>

The annual mean number of visitors who came to the Centre was 2118. (Table 1). On customer satisfaction, staff and services were rated at 72% majority as good, very good and excellent. There was zero rating for poor and very poor. 28% of visitors did not rate the services. These had visited the Centre either to attend meetings or workshops at the KALRO Mtwapa Conference hall, were official visitors on duty from KALRO Headquarters, visiting scientists or bankers/ Insurance company representatives marketing their products (Table 2).

Table 2: Customer satisfaction rating of staff/services by farmers at KALRO, ICRI Mtwapa during visits to access technologies

<table>
<thead>
<tr>
<th>Months</th>
<th>Excellent</th>
<th>Very good</th>
<th>Good</th>
<th>Poor</th>
<th>Very poor</th>
<th>Unrated</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-15</td>
<td>71</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>28</td>
<td>107</td>
</tr>
<tr>
<td>Feb-15</td>
<td>87</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>45</td>
<td>139</td>
</tr>
<tr>
<td>Mar-15</td>
<td>81</td>
<td>26</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>38</td>
<td>149</td>
</tr>
<tr>
<td>Apr-15</td>
<td>47</td>
<td>42</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>34</td>
<td>127</td>
</tr>
<tr>
<td>May-15</td>
<td>85</td>
<td>16</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>33</td>
<td>136</td>
</tr>
<tr>
<td>Jun-15</td>
<td>81</td>
<td>19</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>29</td>
<td>130</td>
</tr>
<tr>
<td>Jul-15</td>
<td>82</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>110</td>
</tr>
<tr>
<td>Aug-15</td>
<td>68</td>
<td>21</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>33</td>
<td>125</td>
</tr>
<tr>
<td>Sep-15</td>
<td>68</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>47</td>
<td>134</td>
</tr>
<tr>
<td>Oct-15</td>
<td>31</td>
<td>34</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>37</td>
<td>112</td>
</tr>
<tr>
<td>Nov-15</td>
<td>28</td>
<td>32</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>28</td>
<td>90</td>
</tr>
<tr>
<td>Dec-15</td>
<td>24</td>
<td>9</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>17</td>
<td>53</td>
</tr>
<tr>
<td>Total</td>
<td>753</td>
<td>236</td>
<td>27</td>
<td>0</td>
<td>2</td>
<td>389</td>
<td>1412</td>
</tr>
<tr>
<td>Percent</td>
<td>54</td>
<td>17</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>28</td>
<td>100</td>
</tr>
<tr>
<td>Mean</td>
<td>63</td>
<td>20</td>
<td>2.5</td>
<td>0</td>
<td>0</td>
<td>32.4</td>
<td>117.7</td>
</tr>
</tbody>
</table>

Note: For the purposes of rating, School visits involving Primary and Secondary school students, Group visits where University students (Table 1) were excluded in the total number of clients who rated staff and services in the year 2015 (Table 2) because they missed the opportunity.

Objective 2: Characterization of the client visits to the ICRI Mtwapa

Clients’ visits were characterized based on the purpose of the visit. Eleven major categories of visits were identified: Official visit, Visiting Scientists, School visit, Group visit, marketing, Meetings/conferences, Soil analysis, Purchase seeds, Field attachment, Crop farming, Livestock farming. Two percent (2%) of all visitors came to demand soil analysis services; this is an eye opener on the demand for the service in the region (Table 1).
Objective 3: Types of knowledge, information and technologies sourced

The crop and livestock farming categories were further evaluated to capture what exactly in crops or livestock did clients come to learn at KALRO: ten sub categories were identified as; general crop farming, cassava, horticulture, cereals, coconut, cashewnut, general livestock farming, poultry, bee keeping and dairy (Table 3). The number of visitors who came to the Centre to seek specific farming technologies or purchase seed over the period was 65.4% of total visitors. Those who came for the sole purpose of purchasing seed materials were 39.1%. Purchasing seed was the single major reason for visitors to come to KALRO ICRI Mtwapa (Table 1).

Table 3: Specific crop and livestock technologies demanded by farmers during visits to KALRO, ICRI Mtwapa

<table>
<thead>
<tr>
<th>Year</th>
<th>General crop mgt</th>
<th>Cassava</th>
<th>Horticulture</th>
<th>Cereals</th>
<th>Coconut</th>
<th>Cashew</th>
<th>General L/stock mgt</th>
<th>Poultry</th>
<th>Bee keeping</th>
<th>Dairy</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>92</td>
<td>48</td>
<td>110</td>
<td>11</td>
<td>6</td>
<td>5</td>
<td>73</td>
<td>41</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2014</td>
<td>132</td>
<td>25</td>
<td>216</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>111</td>
<td>105</td>
<td>21</td>
<td>13</td>
</tr>
<tr>
<td>2015</td>
<td>141</td>
<td>8</td>
<td>34</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>129</td>
<td>43</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>365</td>
<td>81</td>
<td>360</td>
<td>19</td>
<td>7</td>
<td>5</td>
<td>313</td>
<td>189</td>
<td>29</td>
<td>19</td>
</tr>
<tr>
<td>Mean</td>
<td>122</td>
<td>27</td>
<td>120</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>104</td>
<td>63</td>
<td>10</td>
<td>6</td>
</tr>
</tbody>
</table>

Technologies in horticulture and general crop farming were highly rated among crop technologies; similarly, technologies in Poultry and general livestock farming were highly demanded among livestock production technologies. The increasing demand of poultry and bee keeping technologies as compared to dairy in the region, may be a reflection of changes in the environment; the effect of climate change. Increased demand for white meat is also a factor in the increased commercialization of poultry (Table 3).

Objective 4: Estimate of researcher time used during the visits

Time was estimated for the categories of visitors traditionally addressed by Scientists. The time visitors spent with Scientists was obtained by subtraction; as visitors registered the time at arrival and signed out indicating the time of departure (Table 4).

Table 4: Time (hours) spent by farmers at KALRO, ICRI Mtwapa during visits to access technologies

<table>
<thead>
<tr>
<th>Month</th>
<th>Crop farm</th>
<th>Field</th>
<th>Group</th>
<th>Livestock farm</th>
<th>Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-15</td>
<td>9</td>
<td>11</td>
<td>0</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Feb-15</td>
<td>16</td>
<td>2</td>
<td>0</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>Mar-15</td>
<td>22</td>
<td>3</td>
<td>2</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>Apr-15</td>
<td>17</td>
<td>5</td>
<td>0</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>May-15</td>
<td>17</td>
<td>21</td>
<td>1</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Jun-15</td>
<td>18</td>
<td>8</td>
<td>7</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>Jul-15</td>
<td>15</td>
<td>6</td>
<td>1</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>Aug-15</td>
<td>14</td>
<td>4</td>
<td>1</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Sep-15</td>
<td>22</td>
<td>3</td>
<td>1</td>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td>Oct-15</td>
<td>11</td>
<td>6</td>
<td>1</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Nov-15</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Dec-15</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Total attended</td>
<td>170</td>
<td>75</td>
<td>18</td>
<td>162</td>
<td>38</td>
</tr>
<tr>
<td>Average time spent</td>
<td>1:06</td>
<td>2:06</td>
<td>4:18</td>
<td>0:55</td>
<td>0:53</td>
</tr>
<tr>
<td>Minimum time spent</td>
<td>0:05</td>
<td>0:03</td>
<td>0:20</td>
<td>0:02</td>
<td>0:14</td>
</tr>
<tr>
<td>Maximum time spent</td>
<td>8:15</td>
<td>9:20</td>
<td>8:10</td>
<td>4:05</td>
<td>1:55</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>1:08</td>
<td>2:39</td>
<td>2:52</td>
<td>0:39</td>
<td>0:24</td>
</tr>
</tbody>
</table>
This study reveals that the time spent by the visitors at ICRI Mtwapa between 53 minutes to 4.18 hours on average depending on purpose of visit. At least eight Clients visited the Centre daily which means scientist working hours were spent with visitors on a daily basis. According to this finding the time left for the researchers to conduct their day to day activities was less than 50% of their time. KALRO saw this problem and created the Technology Innovation Units (TIUs) in Centers, which needs to be enhanced. Researchers need more than 90% of their time to conduct research, package the new technologies and to document. The time visitors spend with Scientists ranged between 0.02 hours to 09.20 hours (Table 4). The big range indicates lack of standardized information delivered to clients.

Table 5: KALRO, ICRI - Mtwapa Staff as at 31 December 2014

<table>
<thead>
<tr>
<th>No</th>
<th>Staff category</th>
<th>Number in post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Research Scientists</td>
<td>22</td>
</tr>
<tr>
<td>2.</td>
<td>Technical Officers</td>
<td>4</td>
</tr>
<tr>
<td>3.</td>
<td>Laboratory technologist</td>
<td>3</td>
</tr>
<tr>
<td>4.</td>
<td>Technical Assistants</td>
<td>10</td>
</tr>
<tr>
<td>5.</td>
<td>Laboratory Technicians</td>
<td>1</td>
</tr>
<tr>
<td>6.</td>
<td>Administrative Support Staff</td>
<td>19</td>
</tr>
<tr>
<td>7.</td>
<td>Drivers</td>
<td>7</td>
</tr>
<tr>
<td>8.</td>
<td>Plant Operators</td>
<td>1</td>
</tr>
<tr>
<td>9.</td>
<td>Mechanics</td>
<td>1</td>
</tr>
<tr>
<td>10.</td>
<td>Auxiliary Staff</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>84</td>
</tr>
</tbody>
</table>

Note: Adapted from KALRO Mtwapa Annual report 2014

The visitors were able to meet with KALRO staff from various research programmes which include food crops, Horticultural and industrial crops, Natural resource management, Livestock and Socio-economics and applied statistics. The mandate of the Centre is to address agricultural constraints in farming specific to the agro-ecological and socio-economic conditions of coastal lowland Kenya. The mandate area (Kwale, Mombasa, Kilifi, Lamu and Tana River Counties) covers about 66,368 km² and has about 581,973 households and a human population of about 3.0 m (KNBS 2009).

**Conclusion**

The Research Centre proved to be an effective source of livestock and crops information and technologies for the coastal farmers. The many visits made to the Centre is an indication of the trust Clients have on the Organization. 72% of the visitors rated the services as good, very good and excellent on customer satisfaction. Clients recognize KALRO due to various services offered by the centre e.g sale of certified seeds, industrial attachment for students, conferences facilities, school visits, technology transfers of crops, livestock and soils among other reasons.

**Recommendations**

1. Technology Innovation Units should be enhanced by providing staff other than research scientists to handle the bulk of visitors seeking to access information and technologies, in order to reduce demand on researcher’s time used for visits
2. Financial resources should be availed for the production of extension materials such as leaflets, brochures etc. to ensure standard/uniform information is provided to clients.
3. KALRO’s research centers should commit adequate financial resources for the production and/ or commercialization of seed technologies.

**Acknowledgements**

The authors thank the Director General, KALRO, Institute Director ICRI, Centre Director – ICRI, Mtwapa for the enabling environment to carry out the study, Dr. R. W. Muinga for initiating collection of the visits
data, the Customer care staff for politely asking visitors to register their visits on arrival and sign out on departure, esteemed visitors for dutifully recording their visits and Mr. Ali Ramadhan for data analysis.

References


KARI Mtwapa Annual report 2014


World hunger (2015); State of food security in the world


World meters; population clock http://www.worldometers.info/world-population/
Effect of Storage Conditions on growth of Mould on Liquid Brewer’s Yeast along the supply chain and the risk units’ suitability as on-farm feed supplement on smallholder dairy farms in Githunguri, Kenya

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Abstract

A study was conducted to ascertain the growth levels of mould on Liquid brewer’s yeast (LBY) along the supply chain and assess its safety as in-expensive nutrient dense on-farm feed supplement for lactating cows under smallholder dairy farms in Githunguri, Kenya. Samples were collected in September, October and November, 2015 from three different sources, stored at 10°C, 20°C and 30°C then tested at day 0, 7, 14 and 21. The aim of this study was to evaluate the effect of pH, temperatures and storage period on the growth of mould in LBY that would later assist on designing the most appropriate health precautionary measures during handling and feeding of the by-product to lactating dairy cows. A total of 384 analyses were performed and the results indicated average Mould growth for supplier was 2.05±0.67, distributors 2.93±0.39 and farmers 3.55±0.19 log₁₀ Cfu/Ml with pH 4.13±0.074, 4.10±0.074 and 4.06±0.074 for supplier, distributor and farmers respectively. A significant difference (p<0.05) between distributors and farmers was observed while growth at supplier and distributors level were the same. Results for different temperature range did not show any statistical significance (p>0.05). A gradual increase in population of mould from days 0 (1.52±0.53 log₁₀ Cfu/Ml) up to a maximum level at day 21(4.22±0.53 log₁₀ Cfu/Ml) was observed, an indication that longer storage period encouraged multiplication of mould in LBY. The results indicated that mould growth in LBY from the study area was within acceptable levels. However, there is need for hygienic handling of LBY by the distributors and farmers.

Introduction

Livestock production is an important part of the national economy, especially in the developing countries as a result of increased demand for animal products. In Kenya, dairy farming is dominated by smallholder farmers who contribute over 80% of the milk produced (Leone et al., 2014). However, inadequate and poor quality feed resources are among the major challenges experienced by dairy farmers (Makau et al., 2016). In addition, commercial concentrates are expensive resulting in low levels of supplementation. Milk production is therefore low resulting in food insecurity, poverty and low income at farm level. In order to improve dairy production, in-expensive and nutrient dense feeds need to be fed to dairy cattle. Conversely, the available conventional protein sources (e.g. cotton seed cake, soya bean meal, fish meal, sunflower seed cake etc) are the most expensive nutrients in rations fed to dairy cattle, hence the need for alternative feed resource.

The by-products from brewing process that includes wet and dry brewer’s grain, brewer’s condensed soluble, and liquid and dry brewer’s yeast are normally sold by brewing industries as feedstuffs for both ruminants and non-ruminant nutrition (Westendorf & Wohlt, 2002; Mussatto et al., 2006). However, Liquid Brewers’ Yeast, (LBY) is seldom used for a longer period as it spoils quickly due to its high moisture content that has been found to correlate significantly with the rates of microbial growth and rates of many degradation reactions, thus a useful indicator of potential product stability and microbial safety (Mussatto et al., 2006). This paper examines storage conditions that expose LBY to mould growth which may eventually lead to mycotoxin production under favorable conditions and result in mycotoxin poisoning especially from the resource poor smallholder dairy farms in Kenya that feed LBY as an inexpensive nutrient dense feed supplement to lactating dairy cows.
Materials and method

Research site

The study was carried out in Githunguri, Kiambu County, Kenya. Sample analysis performed at Guildford Dairy Institute laboratory, Egerton University, Kenya.

Sampling and storage of LBY

The samples of LBY were taken from three different sources (sole supplier, distributors and farmers) in order to identify the possible contamination source along the supply chain and to develop the most appropriate storage conditions. Samples were obtained from supplier’s storage tank immediately after receiving LBY from the breweries out let line. Sampling at distributors’ level was conducted immediately after delivery of the by-product by the supplier and at farmer’s point on the day of purchase. Sampling was done in 250 ml containers then immediately cooled and transported to the laboratory for analysis. For each sampling time, microbiological evaluation was performed.

Microbiological analysis

Microbiological analysis were done following the approved methods (AOAC, 2000). Enumeration was done following the surface spread plate technique of diluted samples on potato dextrose agar and incubated at 25°C for 5 days. Results were expressed as CFU g⁻¹.

Temperature and pH Measurements

The pH was determined using a previously calibrated digital pH meter (Knick, Portamess, Germany) while temperature was measured using a thermometer.

Statistical Analysis

Experimentation employed a 3 x 3 x 4 factorial arrangement with the following factors; 3 LBY Sources (Sole supplier, Distributors, and Farmers), 3 Interventions (10 °C, 20 °C and 30 °C) and 4 Storage periods (0, 7, 14, and 21 days). In order to increase precision in the trial, LBY samples were obtained in two different periods from the sources while mould analysis was carried out in triplicate. Data analysis was done using the GLM procedure of Statistical Analysis System, SAS (2001) to carry out analysis of variance (ANOVA). Means were separated using LSMEAN statement at P = 0.05 level of significance.

Results

The effect of sampling source on the growth of Mould

The result of study on the effect of different LBY sources on growth of Mould is presented on fig 1. The analyses showed that average mould count for supplier was 2.05±0.67, distributors 2.93±0.39 and farmers 3.55±0.19 CFU/ml.
The effect of storage temperature on growth of Mould

Temperature tested at three levels had means for 10 °C of 2.31±0.46, 20°C at 2.97±0.46 and 30°C at 3.25±0.46 cfu/ml, respectively. The results did not show any statistical significance (p>0.05), an indication that the growth of mould was not affected by the three different temperature levels as shown on figure 2. The findings further demonstrated that dominance of mould is unaltered by the lower trial temperatures used during the extended storage periods.

The effect of storage period on the growth of Mould

Mould enumerated during storage showed means of 1.52±0.53, 2.38±0.53, 3.25±0.53 and 4.22±0.53 for days 0, 7, 14 and 21, respectively. There was a gradual increase in population of mould from days 0 up to a maximum level at day 21, an indication of possible depletion of nutrients to other microorganisms or reduction in pH that inhibited multiplication of other microorganisms. A statistically significant level was
observed on days 0 and 14, 0 and 21, and 7 and 21 while days 0 and 7, 7 and 14 and 14 and 21 were statistically the same as shown on figure 3.

![Figure 13. Effect of time (days) on growth of Mould (log10 cfu/Ml) on liquid brewer’s yeast](image)

**Discussion**

**The effect of sampling source on the growth of Mould**

Mould count reported for supplier (2.05±0.67 log10CFU/Ml), distributors (2.93±0.39 log10 CFU/Ml) and farmers (3.55±0.19 log10 CFU/Ml) were low as compared to those reported by Mwende et al., (2016). In their research, they reported that commercial feeds had mould count of 4.2 log CFU/g while Farm-sourced feeds had counts of 4.3 log CFU/g. In addition, they reported that feed concentrates had the highest fungal count of log 4.92 ±0.4 CFU/g as compared to log 3.99±0.9 CFU/g for forages. These values are much higher as compared to the LBY from the three sources indicating that LBY may be safer as compared to the concentrates and forages that small holder dairy farmers are using. In addition, the counts obtained for suppliers, distributors and farmers in this research could be categorized as relatively safe according to the Cooperative Resource International (2006). According to them, mould counts between 1.0 - 4.0 log CFU/g can be categorized as relatively safe, between 4.0-5.0 log CFU/g as being in the transition zone and counts between 5.0-7.0 log CFU/g as being unsafe and cautionary measures advised. The observed increase was statistically significant between supplier and farmers. However, there was no significant increase observed between distributors and supplier but higher growth levels were realized at distributor than supplier. This could be an indication that the quality of LBY from supplier was better than at distributor and farmers. This demonstrates that possible deterioration of quality could possibly occur at distributors’ level and is carried over by farmers during purchase of LBY or at farm level due to poor storage conditions. In a previous study in smallholder dairy farms in Kenya, on-farm production and handling of animal feeds in peri-urban dairy farms where intensive management predominate was reported to impair the quality of feeds (Makau et al., 2016). According to Čabarkapa et al., (2009), agricultural and storage practices determine the microbial feed safety hazards. Handling of containers used by distributors as well as farmers could have a direct impact on the microbiological quality of the by-product. Due to its high moisture content, LBY stored under such handling conditions may result in contamination with mycotoxin producing fungi (Mussatto et al., 2006). According to Makau et al. (2016) there is a dire need to improve on storage and handling conditions of animal feed. The study concluded that animal feed from commercial sources as well as those formulated
on the farm required attention in order to reduce exposure of dairy animals to aflatoxins which end up in the milk consumed by human beings. *Aspergillus spp.* have been known to produce aflatoxins in food and feed (Mangal *et al.*, 2016; Kocsúbé *et al.*, 2013; Reddy *et al.*, 2010; Sweeney & Dobson, 1998). Earlier studies found the optimum pH for aflatoxin production by the *Aspergillus spp.* to be between 3.5 to 8.0 (Oviedo *et al.*, 2011). Sivakumar *et al.* (2014) observed the optimum pH range for growth of *Aspergillus flavus* and *Aspergillus fumigatus* at 4-4.5. The pH levels observed in this research fall in this range and thus the potential for aflatoxin production in the LBY is high if the feed were to be contaminated with the two species of fungus and/or other species. However, the findings differ with that of other researchers who have reported an optimum level of growth at pH levels between 5.5 to 6.5 (Al-Gabr *et al.*, 2013). The presence of mycotoxicogenic fungi in animal feeds increases the risk of mycotoxin food poisoning in animals and in turn in human beings (Sivakumar *et al.*, 2014). The existing but grossly ignored challenge of mycotoxin contamination of dairy feeds can be addressed by utilization of fungal free raw materials for animal feeds processing or safer brewing by-products like LBY and ensuring proper storage conditions of the agricultural produce along the supply chain up to final use.

**The effect of storage temperature on growth of Mould**

The occurrence and magnitude for growth of mycotoxin producing moulds varies with geographical and seasonal factors as well as conditions under which a food or feed crop is grown, harvested and stored (Lanyasunya *et al.*, 2005). The set temperatures for the present study were 10 °C - 30 °C to practically cover temperature range for most dairy farming regions in Kenya. Various fungal species can grow at wide range of temperatures. According to Sivakumar *et al.*(2014) higher temperatures, 28 – 30 °C are optimal for the growth of *Aspergillus species* of fungi while temperatures as low as -2 °C are reported to support growth of some *Fusarium species* such as *Fusarium sporotrichioides* (Sweeney & Dobson, 1998). Thus, the range of temperatures between 10-30°C would favour growth of a wide range of fungal species that may possibly contribute to mycotoxin contamination in LBY in the event that appropriate storage conditions are not observed. In this study, the growth of moulds was not significantly affected by temperature range tested. This may be an indication that LBY is an ideal product for fungal species that can grow under a wider temperature range. However, a gradual increase in mould count with increase in temperature was noted. Previous studies found out that the optimum growth temperatures for mycotoxin producing fungi could be higher than the temperatures tested in this research. *Aspergillus niger* one of the producers of mycotoxins in agricultural produce was found to grow well at temperatures between 7.0-45.7 °C with an optimum at 34.9 °C (Kocsúbé *et al.*, 2013; Dagnas *et al.*, 2014), however, the optimum pH for *Aspergillus niger* growth is 7-7.5 (Sivakumar *et al.*, 2014). LBY is more acidic (overall mean temperatures pH 4.09) therefore, the growth can be inhibited by reduction in pH. Other researchers had previously reported temperature range of between 10-12 °C to 42-43 °C with an optimum growth at 32-33 °C for *Aspergillus flavus* and *Aspergillus parasiticus*. This may explain the slow but gradual increase in growth at temperatures between 10-30 °C in this trial. Nevertheless, growth at these temperatures would still be noticeable as the fungi can grow at temperatures as low as 4 °C (Gougouli & Koutsoumanis, 2012) or 9 °C (Dagnas *et al.*, 2014). The overall mean temperatures pH reported in this study is 4.09. Previous work (Sivakumar *et al.*, 2014) indicate that the pH range of 4-4.5 is appropriate for *Aspergillus flavus* and *Aspergillus fumigatus* that present a challenge in storage conditions for LBY due to high probability for the species growth and eventual production of mycotoxins. Furthermore, the temperature and pH reported in this research would still permit the production of aflatoxins as this mycotoxin can be produced at temperatures between 15-37°C (ICMSF, 1996; Koehler, Beuchat, & Chhinnan, 1985) and pH as low as 3.0 with an optimum at 6.0 (ICMSF, 1996). The optimum temperature for aflatoxin production as reported by Joffe & Lisker, (1969) is 24 °C which is about the room temperature in the study area.

**The effect of storage period on the growth of Mould**

This study revealed a significant increase in growth of moulds during storage from day 0 up to a maximum level at day 21. This continuous increase in mould counts can be attributed to the means of storage employed
by actors especially the distributors and farmers at the end of the supply chain. Despite the fact that the supplier uses steel tanks to transport the LBY to the distributors, distributors and the farmers use plastic containers to handle the LBY. The plastic containers are difficult to clean, which may lead to accumulation of moulds at every batch both at distributors and farmer’s levels. Moreover, there is no any appropriate quantifiable cleaning mode practiced by distributors and farmers. This may result to infection of LBY by mycotoxigenic fungi leading to poisoning of livestock when they consume the contaminated feeds.

According to Makau et al., (2016), high aflatoxin contamination in feeds in peri-urban dairy farms may be attributed to prolonged storage of animal feeds (hay, concentrates and silage) under precarious conditions in small stores. This is so because the peri-urban farmers practice stall feeding as opposed to grazing. Thus, these farmers have to buy feeds and any form of supplements such as concentrates or brewing by-products like LBY and store as they continue using them. The storage conditions as well as handling of these feeds may contribute to the multiplication of moulds and eventual production of mycotoxins in the feeds.

The gradual reduction in pH can be attributed to the acid producing lactic acid bacteria which are very common in LBY. Presence of lactic acid bacteria may also result in production of antifungal substances that may curb the growth of moulds (Asurmendi et al., 2016; Rouse et al., 2007). The decrease in pH would result in a decrease in the rate of growth of moulds. Again the optimum growth pH is around 6.0 (ICMSF, 1996). This may explain the low mould counts in this study.

Conclusion

This study revealed that LBY can be safely used as an in-expensive nutrient dense feed supplement for lactating dairy cows in smallholder farms in Kenya. Appropriate handling practices along the supply chain and proper storage and utilization would reduce the likelihood of livestock poisoning and concentration of mycotoxin residues in milk destined for human consumption. The findings of this study demonstrate the importance of adherence to appropriate health precautionary measures during handling and feeding of LBY to lactating dairy cows that would reduce mould count on the by-product.

Recommendation

The research recommends storage of the by-product in hygienic containers and to avoid pooling of fresh LBY with previously supplied product. Additionally, prolonged transportation and storage in plastic containers, under high environmental temperatures should be discouraged. On the contrary, storage in a cool and less humid environment, regular cleaning of feed troughs to prevent contamination of fresh feeds, are some of the good handling practices that need to be observed along the supply chain. This will enable prevention of major risk factors that can contribute to increase in contamination of LBY with mycotoxigenic fungi.

Finally, there is need to have a long term nationwide contribution towards feed safety. This could be through surveillance, regular feed inspection and farmer’s capacity building on feed handling, storage and feeding techniques.

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