Enhancing the productivity of Galla Goats (*Capra hircus)* using estrus synchronization and controlled mating in Kenyan's Southern Rangelands

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university

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DEDICATION

I dedicate this thesis to my dear late wife Rose Sidika who encouraged me to pursue MSc studies while in her terminal ailment, my lovely children Enos, Abel, Paul, Joel, Elon,Victoria, and my niece Susan.

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

ADC	Agricultural Development Corporation
AI	Artificial Insemination
ANOVA	Analysis of Variance
ART	Assisted Reproductive Technique
ASALs	Arid and Semi-Arid Lands
BCR	Benefit-Cost Ratio
BEG	Buck Effect Group
CCPP	Contagious Caprine Pleural Pneumonia
DGAK	Dairy Goat Association of Kenya
ES	Estrus Synchronization
FAO	Food and Agriculture Organization of the United of Nations
FSH	Follicle Stimulating Hormone
GnRH	Gonadotropin-Releasing Hormone
GTZ	Gesellschaft fur Technische Zusammenarbeit (German Agency for Technical Corporation)
GoK	Government of Kenya
HEG	Hormone Effect Group
IPCC	Intergovernmental Panel on Climate Change
ISLP	Integrated Small Livestock Project
KALRO	Kenya Agricultural and Livestock Research Organization
KCSAP	Kenya Climate Smart Agricultural Project
KDPG	Kenya Dual-purpose goat

KNBS	Kenya National Bureau of Statistics
LH	Luteinizing Hormone
LSD	Least Significance differences
Mcg	Microgram
MGBA	Meru Goat Breeders Association
MHz	Megahertz
MoALF&I	Ministry of Agriculture, Livestock, Fisheries and Irrigation
MOLD	Ministry of Livestock development
ml	Milliliters
MR	Mating Ratio
NM	Natural Mating
NS	Not significant
SPSS	Statistical Package for the Social sciences
Std	Standard
PD	Pregnancy Diagnosis
PGF2α	Prostaglandin Gonadotropin Factor 2alpha hormone
PMSG	Pregnant Mare Serum Gonadotrophins
RVF	Rift Valley Fever
USAID	United States of Agency for International Development

ABSTRACT

This study aimed to increase Galla goat (*Capra hircus*) productivity in the Southern rangelands of Kenya. This was achieved by synchronizing kidding with feed availability that boosts the survival of dams and kids, and reducing pro-longed kidding interval. The study site was at KALRO Kiboko research station in Makueni County. Out of the two hundred and two (202) Galla goats used in this study 195 were cycling does of between first and fourth parity and 7 were fertile breeding bucks. The objectives of the study were to assess the effectiveness of the use of hormone treatment and the buck effect on estrus response alongside its economic aspect. The study also assessed the mating ratio on Estrus synchronization (ES). Data collected on expression of estrus, conception rate, mating ratio and benefit - cost ratio was subjected to statistical analysis using Analysis of variance (ANOVA) and IBM SPSS version 22 software of 2013. The least significant difference method (LSD) at 5% was used for mean comparison. Estrus response and the conception data analyzed, showed that there was significant difference ($P< 0.05$) between the hormone and the buck effect treatments. However, on estrus responses, statistically there was insignificant differences between the two treatments. The buck effect group and had higher estrus response of 90% than those administered with exogenous hormone 66.67% .The buck effect response on conception recorded 76.67% than the hormone treatment 20.69% one. The performance of the three Mating ratios; 1:10 .1:15 and 1:20, showed that there were no significant differences ($P> 0.05$) between them. The benefit-cost ratio analysis (BCR) showed estrus stimulation using the "buck effect" was more beneficial than the use of hormones on Galla Goat. The buck effect had a BCR of 1.38, while the hormone effect had a BCR of 0.25. Therefore, adopting of assisted reproductive techniques of using the "Back effect" may improve productivity in Galla goats and enhance their resilience in an ever-changing environment.

Keywords: Galla goats, Synchronization, Buck effect, Hormones

CHAPTER ONE

INTRODUCTION

1.1 Background

According to Food and Agricultural Organization (FAO) database, there are about one billion goats in the world, of these 388 million goats are found in African countries (FAO, 2018). The goat population in Kenya is estimated at 28 million (KNBS, 2019). The total annual meat production in Kenya is 702,090 metric tons (KIPPRA, 2018) of which 7% is chevon (goat meat). Chevon accounts for 8% of the 104 billion Kenya shillings that is generated annually by the livestock sector in Kenya (Nyariki and Amwata 2019). The Galla goats due to their body size and eating habit are spread across high potential to very arid agro-ecological zones of the country (Behnke and Muthami, 2011).

Given the increasing human population, improved economies and urbanization, there is high demand for food from animal sources (Thornton, 2010). The contribution of small ruminants (sheep and goats) to food production is perhaps their most widely recognized role in Kenya (Mbae *et al.,* 2020). Today, there is an increasing intensification trend in which medium to large-scale production systems utilize a narrow range of commercial livestock breeds (Udo *et al.*, 2011). However, given the fact that, climate change is real, there is a need to keep and promote a more resilient breed, especially if their productivity can be improved. The effect of drought has led to abortions in Galla goats in the southern rangelands of Kenya. A survey by Okello et al., (2016) reported that over 93.92% of farmers in Kajiado and Makueni claimed that abortion was a major breeding problem caused by environmental stressors like drought and diseases.

The Galla or Somali goat (*Capra hircus)*, is a hardy breed that is indigenous to the northern rangelands of Kenya. It is a good producer of meat and milk and it does well in arid and semi-arid lands (ASALs). Galla goats' phenotypic characteristics are distinguished from other goats by having a smooth white shorthaired coat with black skin observed around the vulva, anal and nostrils. The ears are long and dropping while the horns are small and curved backward (ALLPRO, 2007). Galla is a dual-purpose goat adapted to the ASAL environment. It regains weight quite fast after a dry spell and it performs even better than a dairy exotic Toggenburg (Ndeke *et al*., 2015).

The livestock industry in Kenya has not succeeded to establish and sustain genetic improvement programmes. As early as 1965 to date, there have been attempts to promote goat production through genetic improvement. The attempts were; to promote productivity of bees, pedigree ruminants and non-ruminants. Another attempt was to crossbreed local goats (Galla and East African) with the Toggenburg to a level of 75% exotic blood, with the aim of increasing, meat and milk production in sheep and goats and also decrease the kidding interval (Ahuya, 1998). The main reason for farmers failing to adopt upgrading initiatives; is that project implementers never consulted farmers when implementing new projects to address farmer needs, therefore, projects died as soon as the project ended (Kosgey *et al.*, 2006).

To manage genetic resources in a growing nation like Kenya, the adoption of genetic advancement techniques that will demand cheap experts and infrastructure are required (Kahi *et al.*, 2005). Now that the world population is increasing and natural resources are, becoming limited, alternative ways to increase food from livestock may be explored to close the expected supply gap. Goats utilize forages and crops to produce meat, milk and fiber (Dong *et al*., 2013; Joshi *et al*., 2004). In a harsh environment, goat's toughness enables them endure heat stress. Goats also can be used in the ecological conservation of the rangelands through; preventing spread of noxious weeds, promotion of local vegetative species by moderate grazing. Goats also are water-efficient than large ruminants (Lipson *et al.,* 2019).

Various assisted reproductive technologies (ARTs) are utilized in breeding of goats (Omontese, 2018). In this study, estrus synchronization and controlled natural mating were applied to mitigate the effects of climate change on Galla goat reproduction with the aim of increasing production.

Reproductive Techniques developed reduce factors that constrain reproductive efficiency in the ASALs. Prolonged drought leading to reduced body conditions of goats influence fertility and the kidding interval (Joshi *et al.*, 2018). The average mating ratio of ram/ buck to ewe/does is 1:30 and males run with the flock through at least two cycling periods (40-45 days) for maximum fertility (Ridler *et al*., 2012). A mating ratio of equal or less than 10 (≤1:10) is recommended for ewes when the estrous cycle is controlled by progesterone inserts (Ridler *et al.*, 2012). Prior to this study, the information of the mating ratio of hormone synchronized Galla goat was not known. Unlike other domestic animals such as poultry, sheep and cattle, less research has been done on goats with data being scanty. However,in recent times effort to multiply goats using ARTs have been sdopted by many developing countries. Therefore, there is a need to hasten the multiplication of locally adapted Galla goats using ARTs in Kenya. Artificial insemination (AI) and Estrus Synchronization are the commonly utilized biotechnology methods in goats amongst other ARTs such as multiple ovulation, in vitro fertilization and embryo transfer (Omontese, 2018). The study utilized estrus synchronization and controlled natural mating methods to improve on reproductive performance of goats.

1.2 Problem statement

There is kid mortality amongst agro-pastoralists in southern rangeland Kenya caused by shortage of feeds due to change in weather patterns. Kids born and dams lactating during feed shortage are usually weaker and some die, as a result, low productivity in goat production occurs.

Another cause of reduced productivity in goat farming arises from the prolonged kidding interval. The prolonged drought influences directly and indirectly nutritional, pathological, hormonal, genetic and even managerial factors, which limit goats' reproductive efficiency in ASALs. These factors influence fertility by delaying breeding, leading to a long inter-kidding period (Joshi *et al.*, 2018). This results in low goats population growth and eventually low production of goats in terms of meat, milk and income from sales. The adoption of the assisted reproductive technique of using the buck effect to synchronize breeding with the availability of feeds will reduce the effects of adverse drought. Finally, the study also sought to find the best economical method of estrus synchronization by calculating benefit–cost ratio analysis between the use of exogenous hormones and the use of the buck effect.

1.3 Objectives

Main objective

To enhance Galla goat productivity as a source of red meat through assisted reproductive technique of estrus synchronization.

Specific objectives;

1. To test the effectiveness of the use of exogenous hormone (gonadotrophin and Prostagladin) and the "buck effect" to stimulate estrus synchronization in mature Galla goat does.
2. To determine the mating ratio for optimum fertilization on hormone synchronized does.

3. To conduct benefit: cost ratio analysis on estrus synchronization between using hormones and bucks

1.4 Research Hypothesis

The following null hypotheses were postulated;

1. There is no significant difference in the use of exogenous hormone or bucks effect to stimulate estrus on mature does.
2. There are no significant differences in conception rates amongst different mating ratios.
3. There is no significant difference in the benefit: cost ratio of estrus synchronization between using exogenous hormones and buck effect

1.5 Justification of the study

This work aimed at enhancing the productivity of Galla goat to address the supply gap for foods of animal origin towards feeding the growing human population. The climate change has caused the Country to be food insecure. Therefore, this study aimed at increasing the productivity of Galla goat to contribute red meat and milk as animal proteins. Why the Galla goat? The Galla or Somali goat (*Capra hircus)*, was originally habitat of Northern Eastern Kenya and it has spread to the southern region covering Makueni, Kajiado and Taita Taveta counties (ALLPRO, 2007).

The animal can trek long distances in rocky and dense bushes, during drought, the goat can survive longer than other animals without supplementary feeding. Due to their small size and higher surface area to the body weight, they adapt well to the ASALs. Also, they have good survival traits such as; the ability to conserve body water, limited subcutaneous fat cover, and their hairy coat that enables them to adapt to a wide variety of climatic conditions (Ndeke *et al*., 2015). These

Galla goats mature faster than the Small East African goats attaining higher weights such as 60-70 kg for males and females to attain 45-55 kg. Again Galla goats are preferred for quick cash because they attain market weight at around six months and can be breed, half-a-year sooner than the local breeds. The growth of up to six feet long is an advantage over small East African goats, for they can browse at higher level on shrubs, thus increasing chances of survival during drought.

Synchronizing breeding allows kid crops to be born at the same time for easier management. A farmer will keenly observe, feed, and treat Kids if sick when all are of the same age as opposed to a few in the flock spread over the whole year. Therefore, routine livestock practices such as vaccination, drenching, weaning and off-take are well budgeted and planned for because they are handled at the same time. The services of a veterinarian can be planned at critical times like during kidding to handle any dystocia cases.

Since in ASALs, feeds are seasonal, breeding should be planned so that does kid when there is plenty of feeds. This will enable does to suckle the kids without affecting their body conditions. Synchronizing breeding with feed availability becomes handy in reducing mortalities that could occur due to feed scarcity.

To show the importance of goats in sustaining families during hunger, Mango et al, (2011) reported that families in Nyando households in 2010–2011, survived two hunger months on products from Galla goats alongside other climate-smart farming activities. The Galla goat meat that is much sought for roasting is flavorsome, succulent, tender, extremely attractive and very tasty. Kenyans consume an average of 15-16 kg of red meat (meat and offal from cattle, sheep, goats and camels) per capita annually (Behnke and Muthami 2011).

As much as Galla goats are hardy, adverse prolonged weather conditions interfere with reproductive efficiency. In order to increase goat population, reproductive biotechnologies, innovations and management practices can be employed to mitigate the effects of drought (Pilling *et al*., 2007).

CHAPTER TWO
LITERATURE REVIEW

2.1 Small ruminant production in Kenya

The main livestock species in Kenya include cattle (15.7 million), sheep and goats (47.3 million), camels (4.6 million), pigs (0.4 million), poultry (38.8 million), donkeys (1.2 million) and rabbits (0.5 million) (KNBS, 2019). According to 2019 Livestock census result, Small ruminants' population are the highest in Kenya. There are 47.32 million sheep and goats across the country. Small ruminants provide food and nutritional security to disadvantaged groups and small farmers in arid and semi-arid rain-fed regions. There is a preference for goats to sheep. The total population of goats includes both dairy goats (i.e. Anglo-Nubian, Toggenburg, German Alpines and Saanen) and meat goats (i.e. Galla, Small East African and Boer). The sheep includes those suited to high potential areas East African fat rumped type, Hampshire Down, Merino and Corriedale. Those suited for medium altitude are East African fat tailed type, East African fat rumped type and Dorper. Red Maasai, Dorper and Black head Persian are the low altitude suitable breeds (Ahuya *et al.*, 2005).

The usefulness of small ruminants is in both tangible benefits such as meat, regular cash income, manure, milk from goats and intangible benefits like insurance against risk and uncertainties. Indigenous genotypes are common among the pastoralist, while exotic and mixed crosses are common with the smallholders. Both smallholder and pastoralist consider indigenous small ruminants better in terms of drought and heat tolerance, though they have small body size, low growth rate and fertility. The breeding bucks are selected based on body size and performance traits. Uncontrolled mating is predominant in tradition production systems (Kosgey *et al.*, 2008).

2.2 Advantages of Small ruminants over other domestic animals

The following are some of the characteristics advantageous to small ruminants over larger ruminants;

The small size trait in relation to cattle, camel and buffalos. Small size is associated to earliness of maturity that leads to shorter generation period. Again small ruminant have a rapid growth rate and therefore enabling them to attain puberty and sexual maturity early. Again, small size means lower nutrient requirements, which fits well in the limited resources of small farms and marginal grazing land that cannot support larger animals throughout production cycle. The reproductive efficiency of short gestation period of 150 days, allows three parturitions in two years (Knights and Garcia, 1997). Less feeds are needed; Goats and sheep eat low quality food, particularly fibrous vegetation that cannot be eaten by human beings and non- ruminants such as poultry and pigs. While up to 70% of production costs in monogastric animals go to feed, small ruminants can be completely raised on browse, pasture and agricultural waste products (Riaz *et al*., 2014). Low initial cost; the raising of small ruminants is less capital intensive. This is less risk investment due to lower capital cost per head and potentially more rapid cash flow. More preference to small ruminant is because small size yields little milk and meat that meets daily needs for subsistence families (Njarui *et al.*, 2016). The negative of smallness is proneness to theft and predators (Broekhuis *et al*., 2018).

The feeding behavior characteristics of sheep and goats is that they are selective feeders. For the case of goats, browsing reduces exposure to endo-parasites. Goats utilizes a broad range of plant species than sheep and cattle. The advantage under dry range condition is that the surviving vegetation tends to be deep-rooted shrubs and bushes (Breman *et al*., 2012).

There are almost no cultural barriers against keeping goats and meat or eating their meat. In contrast, Muslims and Jews do not keep pigs nor eat pork and the Hindus do not slaughter cattle (Mukherjee, 2014), therefore sheep and goats can be reared and consumed across different faiths in the world.

2.3 Importance of indigenous small ruminants

In addition to the importance of small ruminants mentioned in section 2.2 above, the Indigenous, small ruminants are able to utilize the dry range areas where rearing exotic breeds and arable farming is not possible (Salem and Smith, 2008). These areas comprise about 70% of the total land areas of Kenya. For the agro-pastoral and smallholder farmers, manure is used to restore soil fertility for subsistence cropping and natural pasture (Juma *et al.*, 2010).

Indigenous small ruminants are well known for genetic variability. The genetic traits of economic importance in Indigenous Small ruminant are utilized for cross breeding with exotic ones to obtain offspring with better production and adaptability (Kosgey *et al*., 2006).

2.3.1 Galla goat description, population and feeding

Galla goats (Other names Boran or the Somali goat) are indigenous in the rangelands of Kenya to the Northern, Eastern and southern parts. The southern region includes Makueni, Kajiado and Taita Taveta counties .Three subtypes of classification exist among the Galla goat. The first type is known as "Degyir'; a small- eared middle-sized goat, the second known as "Degeun is a bigger and white whose mature males can weigh up to 70 kg and females at kidding can weigh between 45-55 kg. Boran keeps a third type believed to have high milk yields. They have black spots around the head, legs and spine.

Galla breed can only be registered in the Kenya studbook if they have black skin under the tail, nose, and legs and white hair. Galla females remain fertile even after 10 years of age. They prefer warmer environment and perform best in low altitude. These goats have high compensatory growth after dry spell and their long body enables them to browse at higher levels of browse and trees than small East African goats.

During dry season, the Galla goat breed survives longer than most other animals without supplementary feeding. Goats' small size and higher body surface area to body weight ratio enable them to adapt to hot environment. Galla goats can grow up to 6 feet long which enables them to browse at higher levels of trees and shrubs. Livestock farmers (Behnke and Muthami, 2011) already keep the Galla goats.

Local goats give an average of 0.5 litres to 0.75 litres of milk per day under good management system but if poorly managed, produce less than 0.3 litres per day (Kinyanjui *et al*., 2010). Galla goats like other indigenous goats, due to tolerance to environment and nutritional stress, have lower change in milk production from normal mean than the exotic dairy goat (Mc Dowell, 1989). Vegetation in ASALs during long period of drought is scarce, but can support grazers and browsers that can convert low quality grasses, forbs and browse into meat and milk that addresses the needs of people (Muir et al., 2015).

There are no clear records showing actual number of Galla goat but amongst the two indigenous goat kept by pastoralist and agro-pastoralist, Galla goat are the majority. Looking at table 2.1 below, it is clear that small ruminants is a major component of the southern region counties families' sources of income (Juma *et al*., 2010).

Table 2.1 Human and Livestock population

District	Area (Km^2)	Human population	Population		
			Cattle	Goats	Sheep
Narok	15,087.80	460,795	113,832	227,035	372,610
Kajiado	21,902.90	609,346	243,886	489,556	498,670
Garissa	44,952	329,939	265,633	563,400	287,480
Loitokitok	7,876.50	201,500	212,488	93,997	104,222
Mutomo	7,148	212,800	153,141	65,508	1,250
Kitui	20,402	515,422	184,248	463,501	13,819
Baringo	8,646	264,978	139,937	571,696	153,602
Mombasa	294.6	665,018	4,471	6,726	1,158
Taita	17,000	260,000	120,000	200,000	300,000
Taveta	680	61,817	24,430	30,110	15,000
Kinango	404,759	210,890	147,613	231,000	73,000
Kilindini	135		3,100	4,000	700

Sources: *District Livestock Production Annual Reports (DLPOs 2007).*

Livestock keepers of southern rangelands are mainly pastoralist and because of subsisting more on goats, their numbers are lower than sheep (MoLFD 2006; Kibiru 2007). Sheep plays minimal role among the agro-pastoral communities of Kitui and Mutomo districts (Katiku *et al.*, 2012). Feeding in ASALs depends on the vegetation available. Fodder trees include Acacia, Balanitis, and Grewia species amongst others. Drier areas and places where farmers plough land have less natural grasses. Shrubs and trees support browsers with the nutritional contents of feeds being generally low during the dry and drought period. Naturally, goats obtain protein from Acacia pods and minerals from natural salt licks (Sagala *et al.*, 2021).

2.4 Production systems

Small ruminants, depending on the availability of land, can be reared under extensive, semi intensive or intensive production systems.

2.4.1 Extensive production systems

Under extensive production systems, goats and sheep under herdsman or shepherd graze and browse freely. The bucks and rams should be separated to avoid random mating, but it common in such system to have uncontrolled breeding. Kids and lambs likewise are separated to avoid suckling while in the field. Animals are supplemented with concentrates and mineral salts. Sheep and goats are housed in night sheds for security from predators. A *boma* is an enclosure for animals made up of tree branches that form a thick perimeter fence. Acacia thorny trees are preferred to deter intruders and confine the animals within the *boma* at night. Each goat or sheep should have space area of $1m^2$ (for instance, 30 goats will require area of 10m x3m) (ALLPRO, 2007).

The production systems adopted by pastoralist in extreme dry regions is nomadism and transhumance (Opiyo *et al.*, 2015). Agro-pastoral and ranching condition, stocking rate must be observed strictly, because the available land is fixed. In pastoralism, nomadic lifestyle of the stock keepers helps manage pastures to ensure availability throughout the year.

2.4.2 Intensive production system

The area for grazing and browsing is limited and the system has smaller flock than extensive system. Goats and sheep are confined, zero-grazed and mating is controlled. With this system, all classes of sheep and goats are kept separately. Small ruminants can be kept on a raised sloped and slatted floor. The floor should be 30 cm above the ground while sloping on side. This allows ease of cleaning, water and urine to run. The structure can be constructed using local materials like timber, poles, and grass for roofing or iron sheets (ALLPRO, 2007).

2.4.3 Semi-Intensive System

This production system includes both intensive and extensive systems. Goats browse out in the field and are supplemented later in the day. Water, concentrates and mineral salts are provided. Mating is controlled where by bucks are separated from does in order to inbreeding.

2.5 Climate change and variability - including effects of climate on goat production.

A climate change of a locality is termed so, when there is a long-term variation as over 30 years in mean state of temperature, precipitation and wind. The change in climate pattern could be because of natural diversity and human activity (IPCC, 2007).

The climate change influences directly and indirectly nutritional, pathological, hormonal, genetic and even managerial factors, which limit goats' reproductive efficiency in ASALs. Climate changes affect certain parasites and pathogens, which could result in health conditions on host animals. Increases in air temperature reduce livestock production during the long dry season with partial offsets during the short-wet season. Heat and scarcity of water constraint animals' growth, milk production and reproduction performance in arid areas. These factors influence the fertility of goats by delaying breeding, leading to long inter-kidding period beyond average 240 days (Getaneh *et al*., 2023). Food production decreases also due to global warming affected by changes in temperature, moisture, carbon dioxide, invasion of insects, plant diseases and emergence of weeds (Malhi *et al*., 2021).

2.6 Indigenous goat genetic resources

Sheep and goats are thought to be the first ruminants to be domesticated in Asia before 7500 BC aGoats belong to genus *Capra* and sheep belong to genus, *Ovis*, but both fall within the tribe of family Bovidae (Terrill, 1979; Wilson, 1991).

Breed types are classified according to the purpose for which they are kept, hence there are meat type, milk type, fiber or pelt types (Porter, 2020). The predominant indigenous goats in Kenya are the Galla and East African goat. The East African is a meat goat while Galla found in North Eastern and Eastern counties of Kenya is a dual-purpose goat. Both Galla and East Africa goat are concentrated in ASALs. They are the most popular breed due to their ability to cope with a range of climatic conditions with disease challenges, inadequate feed resources and low management (Tibbo and van de Steeg, 2013).

These two breeds have variable traits that can be beneficial in cross breeding with exotic breeds to promote food security to the increasing population. Galla goats have small size traits, short generation interval and have a remarkable recovery capacity from drought (Rodriguez, 2017).

2.7 Production characteristics of some indigenous local goat genetic resources

Goats are important to man from early times of civilization. Apart from playing cultural and religious roles, goats have been sources of food in terms of milk and meat. They are also source of skin and fiber (Joshi *et al*., 2004; Dong *et al*., 2013).

The accurate description of Kenya's indigenous goats has not been done (Githui *et al.*, 2016). Classification of the three breeds of small East African (SEA), Galla and their crosses are based on phenotype/morphology (ALLPRO, 2007). Cross breeding without consideration of initial gene pool endangers the unique genotype. The Table 2.2 below shows reproduction performance between Galla and SEA goat.

Table 2.2 Goat Breeds and their fertility aspects

Breed	Fertility	Fertility	Fertility	Litter size	Birth weight (kg)	Weaning Weight (kg)
	Age at first mating (day)	Kidding interval (day)	Kidding rate (%)	Number of Kids		
E.A. goat	458-655	399 ± 256	65	0.95 – 1.0	3.0	6.3
Galla	425-598	411 ± 189	72	1.03	3.6	10.3

Source: AIC documentation Unit Kenya, Devendra and McLeroy, (1982)

Reproductive performance of a flock is critical to productivity and profitability. Kidding percentage and weaning percentage are parameters that indicate where management can be improved. Birthweights, growth rate and mature weights are important factors in meat goats. Attainment of 70 kg of mature male Galla goat implies more meat. Rangelands goat weight gain may range between 100-200 g per day compared to Boer that is approximately 200 g per day (Mc Gregor, 2007).

2.8 Genetic upgrading initiatives

Livestock industries in developing countries have failed to establish and sustain genetic improvement programmes. The main reason for failure was that donors never consulted livestock owners to be part of the upgrading initiatives. Because of this, many projects tend to collapse upon the departure of donor (Kosgey *et al.*, 2006).

To manage genetic resources in a developing nation like Kenya, it requires adoption of genetic advancement techniques that will demand low cost of human capacities and infrastructure (Kahi *et al.*, 2005).

2.8.1. Development initiative programs

2.8.1.1. Agricultural Development Corporation (ADC) Livestock improvement farms

It was formed through parliament in 1965 to transfer land programmes to locals from European settlers after country's independence. It meant to maintain quality livestock and keeping breeding programmes. Its mandate on the side of livestock was to promote the production of

Kenya's essential pasture seed, pedigree ruminant (cattle, sheep and goats), non-ruminant (pigs, and poultry) and bees (Musalia *et al.*, 1989).

2.8.1.2. To increase production of milk and meat using indigenous breeds.

Food and Agriculture Organization, United Nations Development Programme and the Government of Kenya (FAO/UNDP/GOK) Sheep and Goat Project was from 1971 to 1983. Its purpose was to increase the production of milk and meat. Indigenous local breed; Galla and East African were characterized and crossbred with Boar, Toggenburg and Anglo-Nubian. There were Attempt to create a model dairy goat semi-intensive farming system for crosses with exotic and pure exotic goats. The project was unsuccessful *(Rewe et al., 2002).*

2.8.1.3. Kenya Dual purpose goat

Another initiative was Small Ruminant – Collaborative Research Support Programme

(SR-CRSP). This programme was established in 1980 by GOK and the United States of America International Development Agency (USAID), supported by a battery of participating.

US institutions. Two indigenous breeds and two exotic breeds (i.e. Galla X E. A goat X Toggenburg X Anglo-Nubian) (Ruvuna *et al.,* 1995). This was to promote milk and meat production in Western Kenya. The KDPG produces about 1.1 kg of milk daily with highest occurring on the 7th week after kidding. It constantly produces milk for 4 months. This is from the F1 offspring. There was programmes to share hire bred male goats to farmers (Ruvuna *et al*., 1988).

2.8.1.4 Farm-Africa Dairy Goat and Animal Health-Care Project.

FARM-Africa**,** a British nongovernmental organization was initiated in 1996 with the introduction of Toggenburg dairy goats from Britain. The main aim was to improve the milk production and decrease kidding interval of the local goats (Galla and East African) through crossbreeding with the Toggenburg to a level of 75% exotic blood. Farmers had FIs born within six years (Ahuya, 1998).

2.8.1.5. Upgrading Galla and Small East African goats

The Integrated Small Livestock Project (ISLP). This was initiated in 1992 in central Kenya supported by GOK and the German government technical assistance agency (GTZ). The aim was to upgrade Galla and Small East African to blood level of 87.5% of the Alpine exotic breed. In 1994, the Dairy Goat Association of Kenya (DGAK) was launched (Theuri, 1998).

2.8.2 On-going sheep and goat improvement efforts

2.8.2.1. Meru Goat Breeders Association

Meru and Tharaka Nithi Dairy project started in 1976 and Farm Africa and the MoALD implemented it. Small-scale farmers in Meru Central and Tharaka Nithi were assisted to acquire improved dairy goat by upgrading Galla goats with Toggenburg dairy goat buck. Farmers were encouraged to produce pure Toggenburg for sustainability of producing breeding bucks. The farmers were assisted to set up Meru Goat Breeders Association (MGBA) that was to take over dairy project when Farm Africa ceases it operations from the project in December 2003.

2.8.2.2. Sheep and Goat Breeding/Multiplication Stations.

Operating under the Ministry of Agriculture Livestock Development (MOALD), Station were concerned for breeding, making policy and multiplication of various breeds of goats and sheep. They provide extension services and supply breeding bucks and Rams for upgrading farmers stock. However, during the last few years, virtually all the stations had been operating at about 30 per cent of their capacities due to low funding and deterioration of the infrastructures.

2.8.3 Impact of genetic Improvement initiatives

Since there are no stud flocks of Galla and EA goat established in Kenya and the Kenya Dual purpose goat (KDPG) existing, it means the projects were unsuccessful to meet the objectives. A survey on performance on KDPG projects in different farms reported poor progress because the consumption of dairy goat milk was not popular (Gichohi, 1998). The idea of forming Dairy Goat Association of Kenya **(**DGAK) was good because through it, genetic improvement policies were to be designed and implemented (Mburu *et al*., 2014).

2.8.4 Breeding strategy

The projects need to match genotype with the environment while having few and appropriate objectives. The previous initiatives utilized similar strategies such as crossbreeding, upgrading, and breed replacement without regarding the threats these strategies have on indigenous genetic resources. The genotype did not matched with the environment. Other causes of failure were lack of funds to sustain the projects, inadequate infrastructure and lack of extension personnel (Jasiorowsky, 1991). The conclusion from previous attempts showed that one should obtain sufficient relevant and reliable information on available genotypes before formulating a breeding program.

2.9 Galla goat production and reproduction

2.9.1 Galla goat reproduction

Heritability of reproductive traits in goats (h^2 for age at first kidding is 0.23 and kidding interval is 0.05) is usually low therefore, improvement should target management practices on breeding strategies, cross breeding, disease control and proper feeding (García-Peniche *et al*., 2012). Female attainment of puberty is based on nutrition, age, type of birth and season. Depending on the breed, males mature sexually between 4 and 8 months. Galla goat sexually mature at 4 months, Alpines at 6 months and Boer goat at around 5 months (Blackburn and Field, 1990).

Estrus cycle hormonal control begins with stimuli from the environment (such as nutrition, light, temperatures and presence of bucks) to the central nervous system. The stimulus from the central nervous system inform of neurotransmitter factors goes to hypothalamus, which produces gonadotropin-releasing hormone (GnRH). The GnRH targets anterior pituitary gland, which releases follicle - stimulating hormone to ovary for maturity. The ovary has estrogen that acts on anterior pituitary gland to produce luteinizing hormone. Increased level of Estrogen triggers heat signs. The luteinizing hormone raptures the follicles to release ova. The raptured follicles develop into corpus luteum to release progesterone hormone that maintains pregnancy (Soren *et al*., 2012).

Goats are seasonal breeders in temperate regions following differences day length, while those in tropics can be bred any time (Chimineau *et al*., 2004). Less daylight hours stimulates heat. Breeding does at one-year-old have long lifespan in production (Alefe, 2014).

The following are heat signs noted in does; frequent bleating, wiggling the tail, drop in milk yield, swollen vulva, and discharge mucus, changes in vulva color from pale to bright. The females mount others and those does on heat stand to be mounted (Tsuma *et al*., 2015).

Heat duration from proestrus, estrus, metestrus and diestrus takes about 36 hours depending on breed and environmental factors. Does can be mated from the onset of heat signs because spermatozoa can be kept viable for 30 to 48 hours and ovum can only survive for 16 to 23 hours. The heat cycle can vary between 18 to 22 days, depending on the breed,nutrition and reproductive stage. Pregnancy period takes about 150 days, also depending on various factors including sex of the fetus and the number of fetuses in the uterus. For instance young female kids earlier, male fetus take longer gestation period, twins and triplets pregnancy takes shorter period (Alves *et al*., 2018).

2.9.2 Kidding interval

There are a number of causes leading to prolonged inter-kidding periods in goats. One of them is; the adverse climatic conditions that affect feed availability. A study done by Maurya and Tripathi, (2013) revealed that service period significantly increased by about 89.00% during drought (4.53±0.19) months from normal (2.40±0.10) months. Since service period affects kidding interval, the, adverse weather conditions cause anestrus and lowers the rate of conception. Secondly, goat diseases prolong kidding interval (Singh & Prasad, 2008). A study on performance of female Dwarf goats raised in tradition condition reported a kidding interval of 203.7 ± 46 days (Khanum *et al*., 2007). Kidding interval should be about 240 days and physiologically it's influenced by pregnancy period and lactation (Farooq *et al.*, 2018).

2.9.3 Livestock management practices

Some of the management practices affecting breeding indirectly are; trimming of feet for ease movement, grouping of animals by separating males and females and vaccinations.

Separating does and bucks in different pasture fields and joining them for breeding induces ovulation. This management practice can be used to synchronizing breeding with feed availability and marketing. (Whitley & Jackson, 2004). The pheromones found in the buck hair but not in urine induce estrus (Birch *et al*., 1989). Vaccination in the tropics is done mainly against contagious caprine pleuropneumonia, CCPP, enterotoxaemia and tetanus. Vaccination in wholesome prevents death of goats and guarantees survival of kid**.** This is done before breeding season and 4 to 6 weeks before kidding (Menzies, 2012).

2.9.4 Breeding buck

Examination of the testes is good practice in selecting breeding bucks. Testes should be approximately firm on touch, no lump and of similar size. Any testicular abnormalities show that the buck is not good for breeding. On examination, the penis pizzle should not be hard anywhere. A veterinarian (Raji and Ajala, 2015) should check this. According to a study on performance of breeding bucks and interaction of nutrition and reproduction in the management of the mature male ruminant, changes in feed intake has little effect on gonadal endocrine function, but has profound effect on sperm production (Martin *et al*., 2010). Undernourishment causes changes size of seminiferous tubules and spermatogenetic efficiency. The body condition score are weighted subjectively on a scale from 1 to 5 defined as; 1- very thin, 2- thin, 3- normal, 4- fat and 5- very fat (Koyuncu and Altinçekiç, 2013).

2.9.5 Hormones

Estrus synchronization in goats has the advantage of having easy management of pregnant does and similar kid offspring. Physiologically, exogenous hormones can change sexual cycle events and use of light (by decreasing exposure to artificial lights may cause does to begin secreting more melatonin and start cycling) or exposure to bucks as non-hormonal methods (Raymundo et al., 2010).

The Estrous rhythm is controlled by neurotransmitter chemicals and hormones released from hypothalamus and pituitary glands respectively. Follicle stimulating hormone
(FSH) and Luteinizing hormone (LH) released into blood target uterus and ovaries (Michael & Thomas, 2005; Soren *et al*., 2012). Luteal phase has longer duration than estrus period. FSH and LH are used to control function of corpus luteum by stimulating follicular development and regulating ovulation sequence, respectively (Kareta *et al*., 1999).

Prostaglandins with synthetic analogues induce follicular phase of estrous cycle; they are applied either intramuscularly or by subcutaneous injection to cause luteolysis in a method of estrus synchronization in goats (Niekerk, 2011).

2.9.6 Factors affecting estrus responses

The reported factors affecting estrus response following administration of prostaglandins include the dosage of prostaglandin (Niekerk, 2011), the period between administration of prostaglandin and the effect of prostaglandins on corpus luteum /or stage of estrus cycle (Vasquez *et a*l, 2010), season and the inclusion of gonadotropin as co-treatments (Dogan *et al*., 2016). Gonadotrophins such as FSH, PMSG and GnRH, have been included in the prostaglandin protocol, resulting into improved estrus responses.

2.9.7 Protocol of synchronizing estrus

The two main advantages of using prostaglandin are that they can be administered by intramuscular injection (i.m) and are immediately metabolized in the lungs. This means there is less hormone residue in the blood.

(Westover *et al*., 2012). Two injections of prostaglandin F2α are administered 9–11 days apart resulted in better response (Fatet *et al*., 2011). Double treatment according to (Omontese *et al.*, 2013) with use of cloprostenol sodium administered i.m given 11 days apart, had a positive estrus response of 92.8% against 75% of single treatment in Red Sokoto does.

The sequence protocol of GnRH - PGF2α - GnRH on days 0-day 7 and day 9 respectively has been used and any protocol can be employed to synchronize estrus according to Cinar *et al.,* (2017). Estrus synchronization of does can be controlled by use of Vasectomized bucks. (Jackson, 2004**).**

2.9.8 Pregnancy diagnosis

Before the use of scanner to check pregnancy, the techniques used in the goat over the last decades were; rectal abdominal palpation, vaginal cytology, laparotomy and radiography. In addition, hormone concentration of progesterone in blood and milk was used. The problem with these hormonal assays, one could not differentiate between a pregnancy and pseudo pregnancy (Karadaev, 2015). Pregnancy diagnosis using a B-mode ultrasound scanner that has a sector transducer of 5 MHZ started early 1980s (Erdogan, 2012). It is a real-time device for ultrasonography of uterus. Scanning examination is preferably done when goats are raised on the table or milking stable. An area of the right ventral abdominal wall is shaved if hairy in front of the udder. This improves image quality because of better contact between the skin and the transducer. The sonography is observed from the right side to avoid filled rumen impeding clear observation of the uterus (Matthews, 2016).

2.10 Artificial insemination technologies and their application

Artificial insemination (AI) is man's intervention of- with the help of suited equipment that enables collection of sperm cells manually and deposits at right site of female reproductive tract. The use of speculum with light makes it easier to inseminate goats than cows. The advantages of AI are that sires merit is proved in a short time and it is easier to get a wide choice of sires from anywhere in the world because semen is not as bulky as importing alive animal. Still the AI technology has the advantage of controlling the cost of rearing a buck and spread of reproductive diseases like fibrosis and brucellosis (Matthews, 2016).

The disadvantages of artificial insemination are due to human errors as follows; since AI is dependent on human, one must learn to identify animals that are on heat, and know the right time to deposit semen in the female reproductive tract (Tsuma *et al*, 2015). Another disadvantages is loss of genetic variability (Yatsentyuk *et al.*, 2023) during upgrading indigenous breeds with the exotic ones.

2.11 Challenges and opportunities for Galla goat production

2.11.1 Challenges to Galla goat production

As much as sheep and goats are important for the pastoralists for their livelihood, the communities are constrained in many ways; Great losses following disease outbreaks, slow growth of goat population as in the case reported by Singh and Prasad (2008) in India. In a report from a 15-year study, from 1991 to 2005, four diseases accounted for about 74% of deaths. The diseases were;

Peste des Petits Ruminants (PPR), sheep and goat pox, enterotoxaemia and CCPP. An outbreak of Rift Valley Fever (RVF) disease in Kenya in 2006 and 2007, caused death of over 900,000 heads of livestock including goats. Vaccination undertaken against RVF outbreak in 2007 was low in that only 11% of cattle, 1.2% of camels, 4.8% of sheep and 5.9% of goats were vaccinated. In relation to diseases, there is lack of sufficient veterinary services and extension personnel to advise farmers on livestock management. Livestock farmers require knowledge on breeding, feeding, disease control and production systems. Controlling the diseases is an expensive exercise (Kimani *et al*., 2016).

The primary ways through which drought and climate condition affect livestock are changes in feed-grain production, availability and their prices, changes also in pastures, forage crop production and quality, animal health, growth, and reproduction, and disease and pest distributions. (Rötter and Van de Geijn, 1999),

Arid and semi-arid areas are characterized by irregular and unreliable rainfall that affect vegetation growth. The body condition and performance of goats are affected when they lack basal diet from vegetation. It also leads to livestock rustling and tribal conflict that arises following limited natural resources such as grazing pasture and water (IPCC, 2007).

Unavailability and unreliable rotational breeding bucks are common problems to livestock farmers where by, the breed genetic make-up keeps on dropping due to inbreeding (Kumalo, 2014). Another challenge is predation in rangelands. Most areas in ASALs in Kenya are bordering game reserves and national parks inhabited by wild animals such as lion, leopards, cheetahs and hyenas (Kissui, 2008). Pastoralists protect their livestock by enclosing them properly at night.

Finally, pastoralist and agro-pastoralist often lack markets and distribution channels for their produce. They end up making losses through middle traders (Chepkemoi, 2020).

2.11.2 Opportunities for Galla goat production

Some of the opportunities for Galla goat production are;

1. Goats utilize feeds efficiently without trampling vegetation like cattle and camels because of their small body size
2. Goats are cheaper to buy and maintain. Every poor and vulnerable household own goats. The breed is available within the pastoral communities. There is no need to sources them afar or import.
3. They have higher turnover i.e they reproduce faster than cattle and camel that are adapted in the same environment.
4. Goats can easily be traded either for cash or barter trade
5. Adapted well to climate change, feed demand is low compared to cattle and camels
6. Can provide protein nutrient cheaply especially, to the vulnerable groups
7. Galla goats can grow as long as six feet making it advantageous to other breeds in accessing browse of higher height.

Areas of improvement in Galla goat production are intense selection for dairy line. It is believed that amongst breeds, there are those that have more milk production than others do.

2.11.3. Benefit-Cost Ratio analysis

The benefit-cost ratio (BCR) that can be expressed in either qualitative or monetary terms is used to summarize the overall relationship between the relative costs and benefits of a proposed project.

(Zangeneh and Rahimi-Kian, 2010). Benefit-Cost Ratio is calculated considering the present values (PV) of benefit and costs using the formula below;

Benefit-Cost Ratio (BCR) = PV of Expected Benefits / PV of Expected Costs

The higher the BCR the better the investment. The general rule of thumb is that if the benefit is higher than the cost the project is a good investment. The benefit cost ratio (or benefit-to-cost ratio) compares the present value of all benefits with that of the cost and investments of a project or investment.

Value Range of Benefit Cost Ratio, interpretation of the values

BCR = 1: Investment option is neither profitable or loss

BCR > 1: Investment option is profitable

BCR < 1: Investment option generates losses (Zangeneh & Rahimi-Kian, 2010).

2.12 General considerations and conclusions

To benefit from these indigenous genetic resources, the pastoral community need capacity building on proper animal husbandry practices. This will lead to adoption of new technologies on breeding to conserve genetic resources and maintain pure lines. Since Galla goats compared to the available drought tolerant breeds, are larger and have faster growth rate than East African goat, enhancing its production should be given priority. Any genetic improvement on goats or any other livestock must involve the farmers and ensure they own the project for it to be sustainable. In addition, the buck rotation and exchange should be maintained to avoid inbreeding among the goats. A few enlightened ASAL goat keepers use aprons fitted on breeding bucks to breed only at the appointed time (Tsuma et al., 2015).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

This study was carried out at KALRO- Kiboko Research station, located in Makindu Subcounty, Makueni County. It is about 170 km South Eastern of Nairobi, the capital city of Kenya.

The study is 1000 m above sea level lying between 2.3^{o} S latitude and 37.8° E longitude. The region, which is under ecological zone V and it, has a bimodal annual mean rainfall of 615 mm (Mnene, 2006). An unreliable rainfall occurs in March, April and May while the reliable rainfall occurs in October, November and December.

3.2 Design and protocol

A total of 202 Galla goats, comprising of 195 cycling does and 7 breeding bucks were selected from KALRO – Kiboko Research station flock. The does ranged between 1st to 4th parity with a mean weight of 32.94 ± 4 .00 kg, the mean age of 4.61 ± 2.02 years and the mean body condition score (BCS) was 3.00 ± 0.57 based on a scale range of 1 to 5 (Detweiler *et al*., 2008). The BCS scale range of 1 to 5 indicates that 1- the animal is very thin, 2- thin, 3- normal, 4- fat and 5 – very fat (Koyuncu and Altinçekiç, 2013). The breeding bucks had a mean weight of 62.67 ± 4.92 kg, a mean age of 5.2 ± 1.25 years and with mean body condition score of 4.667 ± 0.236. External genitals of breeding bucks were physically examined and bucks with testes of the same size, firm to the touch and devoid of lumps were selected.

The Galla goat does and bucks were acclimatized in the experimental unit for one week before the onset of hormone injection (Table 3.1). Both does and bucks were dewormed with albendazole 10% administered at the rate of 2.5 ml per kg bodyweight. They were also given antibiotics Enrofloxacin injection against respiratory infection, butasol and multivitamins. Mineral lick and water were provided ad-libitum. On days; 0, 7 and 9 the does were injected relevant hormones in the morning hours and from days 10, 11 and 12 the does were allowed to mate with the bucks (Table 3.1)

Table 3.1 Program for Estrus Synchronization and controlled Natural Mating

Day	Time	Does	Bucks
7days before onset of experiment		Deworm, Inject multivitamins, supplement with mineral salt	Deworm, Inject multivitamins, supplement with mineral salt
0	07:00 hrs	Inject 1ml i/m GnRH	
7	07:00 hrs	Inject 2 ml i/m PGF2α	
9	07:00 hrs	Inject 1 ml i/m GnRH	
	15:00 hrs	Breeding	Join for mating
10	Whole day	Breeding	Join for mating
11	Whole day	Breeding	Join for mating
12	15:00hrs	Breeding	Withdraw bucks
After 45 days		Ultrasound scanning for pregnancy	

The protocol sequence used was administration of 1ml GnRH on day 0, 2 ml Prostaglandin on day 7, and 1ml GnRH on Day 9 (Figure 3.1).

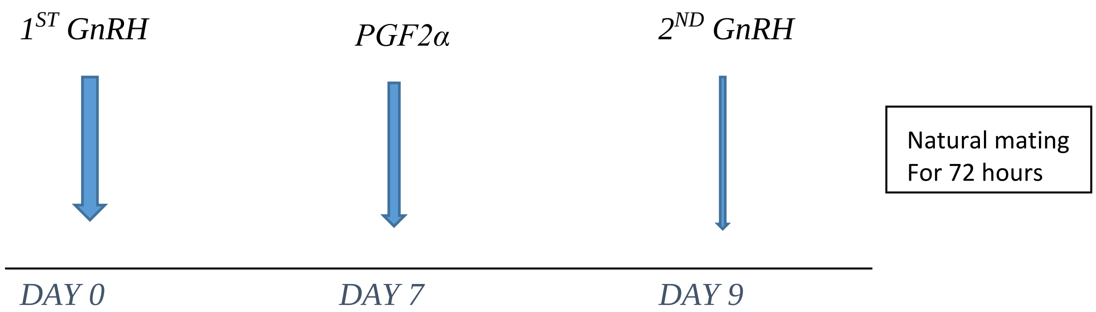

Figure 3.1 Estrus Synchronization protocol chart

Thereafter, behavioral and morphological signs of estrus were observed and recorded in an excel spreadsheet. The number of mountings by bucks was observed for three days and the record was kept. After 45days, the pregnancy diagnosis was done on does to assess conception using a B-mode ultrasonic scanner that has a sector transducer of 5 MHz

3.3 Effectiveness of hormone versus "buck effect" on estrus.

A total of 60 cycling Galla goats and six bucks were used in this experiment. All the goats were maintained in a free range grazing system by casual herders who had exposure to managing goats. They were housed in the roofed iron sheet pens in the evening from 17:00 hrs and released for grazing at 08:30 hrs.

There were two treatments; the Hormone effect group (HEG) (n=30) was given hormone treatment and the Buck effect group (BEG) (n=30) was assigned male treatment. Each treatment was replicated three times with each sample unit of 10 does. Bucks were joined to does for 21 days. At 18:00 hrs, a paint was applied to the breeding bucks for identifying the does that were mounted at night. The behavioral and morphological heat signs were observed daily and recorded.

3.4 Determination of mating ratio (MR) on estrus synchronization

One hundred and thirty-five does and 3 breeding bucks were utilized in determining mating ratio on estrus synchronization. The does were divided into 3 groups of n=10, n=15 and n=20 does. Each group of does was assigned a buck that alternated for mating after ES. In table 3.2, MR of 1:10 implies that one buck was given 10 does for mating and conception rate (CR) was recorded. A, B and C represents three bucks used in experiment

Table 3.2. Experimental Layout

	Breeding ratios		
Buck	**1:10**	**1:15**	**1:20**
A	CR	CR	CR
B	CR	CR	CR
C	CR	CR	CR

Key: CR –Conception rate, A, B &C –represents bucks, 1:10, 1:15 and 1:20 -buck to doe ratio

The hormones used were Prostaglandin (Enzaprost®) and GnRH (Cystorelin®). Estrus was stimulated by administration of 1ml (50 mcg) GnRH on day 0; 2 ml (100 mcg) prostaglandin was given on day 7, then a second dose of 1ml GnRH on day 9 followed by natural mating after 8 hours for 72 hours (Cinar *et al.*, 2017).

In a mating ratio of 1:10 group, 30 does were randomly allocated to three (3) pens labeled as

MR1:10 G1, MR1:10 G2 and MR1:10 G3 with assigned mature breeding bucks having; tag number MW3, notch numbers 381 and 104 respectively. The three bucks were alternated to the 1:10, 1:15 and 1:20 after resting for 14 days.

After 45 days, pregnancy diagnosis was done to assess conception using a B-mode ultrasonic instrument scanner that has a sector transducer of 5 MHZ. Conception test was conducted when goats were raised on the table or milking stable. An area of the right ventral abdominal wall was not shaved because the Galla does have little hair in front of the udder. The short hair improved image quality because of better contact between the skin and the transducer

The sonography was observed from the right side to avoid filled rumen impeding clear observation of the uterus (Matthews, 2016).

3.5 Effects of exogenous hormones and buck effect on benefit-cost ratio analysis on ES

The benefits were obtained from the projected numbers of kids expected to be born from the conception assuming that all the kids survive to off take. Valued kid's contribution margin at finishing, assuming finishing the goats at 1.5 years with a contribution margin of Kshs. 1,200.00 prevailing market price (William & Magnan, 2017)

The value of cost was obtained from cost of inputs incurred for both breeding protocols i.e. using hormone and using 'buck effect to stimulate estrus and mating. The cost analyzed was incurred in terms of labour, feeds, and purchase of drugs, hormones and acaridae sprays.

3.6 Data analysis

The experimental design used was completely randomized design. The collected data were entered into computer spreadsheet Excel and summarized in tables and figures. The quantitative data was analyzed statistically using IBM SPSS version 22 software of 2013. Models for evaluation of synchronized mature Galla goat was as follows ’Dependent = estrous response (expression) and Conception (pregnancy) rate. Data collected was subjected to statistical analysis of variance (ANOVA) and mean comparison using least significant difference method (LSD) at 5% .

The benefit-cost ratio and gross margins (GM) used the following formulas to analyze the data

Benefit: Cost Ratio = present value of expected benefits / Present Value of expected costs

GM = Total Revenue – total cost. (Zangeneh and Rahimi Kian 2010)

CHAPTER FOUR
RESULTS

4.1. Buck effect versus hormone effect on estrus stimulation and conception in mature Galla goat does.

4.1.1 Response of the "buck effect" on does estrus and conception

In buck effect group 1, (Table 4.1) 80% of the does, showed heat signs within the period of 21 days. Heat signs observed in does in estrus were continuous bleating, restlessness, frequent tail twitching, does mounting on others and standing to be mounted. Those on heat had swollen vulva, reddened and moist with clear stringy mucus discharge.

Table 4.1 “Buck effect” Mean percentages on estrus and conception

Replicate Groups	N	% of does on Estrus	Number of does conceived (ultrasound scan)
BEG1	10	80% (8/10)	8
BEG2	10	100% (10/10)	7
BEG3	10	90% (9/10)	8
Total	30	Mean%=90%(27/30)	mean%=76.67% (23/30)

Key; BEG1- Buck effect groups 1, BEG2- Buck effect group2, BEG3- Buck effect groups 3 and N-represents number of does in each sampling unit.

The pregnancy diagnosis using ultrasound scan revealed 100% conception of all the does mated in BEG1. Each replicate group has a corresponding figure indicating how estrus was expressed within the 21 days.

First heat signs were observed in two does on the second day, one doe on the third day and one doe on the sixth day. Four does on day 7 and one each on days; 9th, 10th , 16th and 19th respectively (Figure 4.1). Two does showed repeated heat. These results were taken during the dry and wet period. Seven out of ten showed heat sign within seven days.

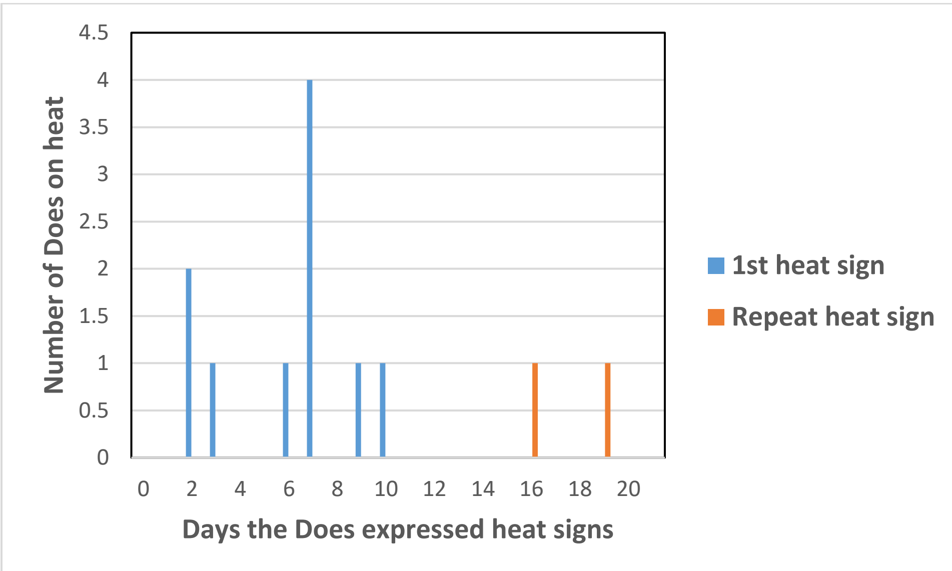

Figure 4.1. BEG 1 Heat expression against time

Each doe showed heat signs on day1, 2, 3, 6, 7, 8, 9, 13, and day 15th. On day 8, three came on heat (Figure 4.2). Two did show repeated heat signs. Five out of ten came on heat within seven days. 100% of the does were stimulated to estrus, but only 70% of the does that came on heat and served conceived (Table 4.1).

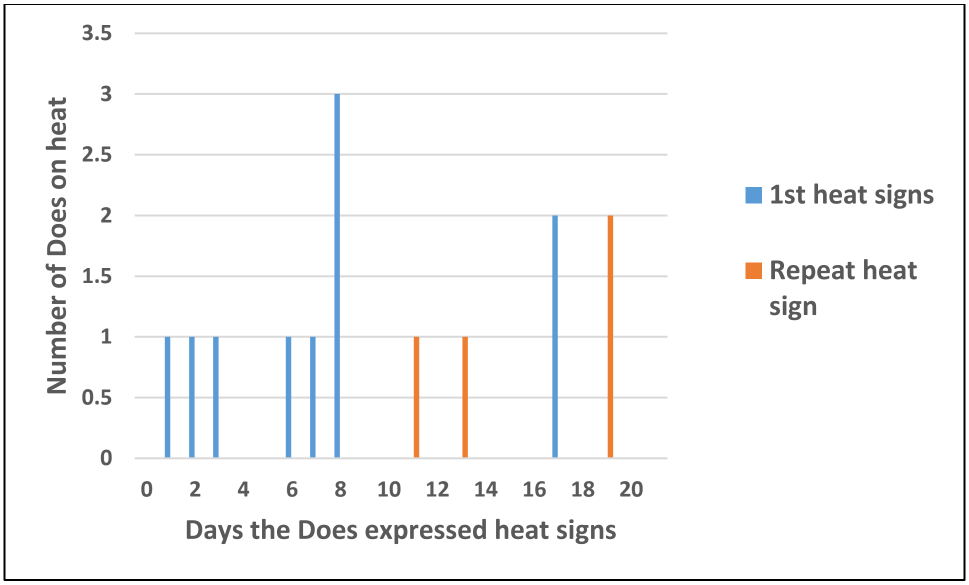

Figure 4.2. BEG2 Heat expression against Time.

In BEG3, 90% of the does went into heat within 13 days (Table 4.1) ranging from day2 to 13. (Figure 4.3). Out of the 9 does that were served, 8 conceived.

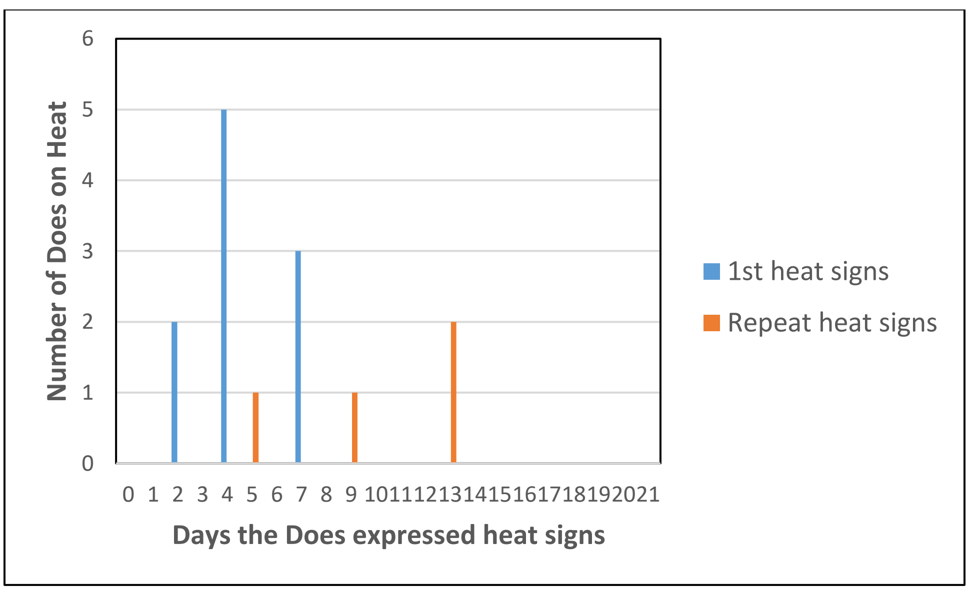

Figure 4.3. BEG3 Heat Expression against time.

The graph showing the combined buck effect group (Figure 4.4) reveals that within the first eight days from joining bucks to does, 90% of the does had shown heat signs.

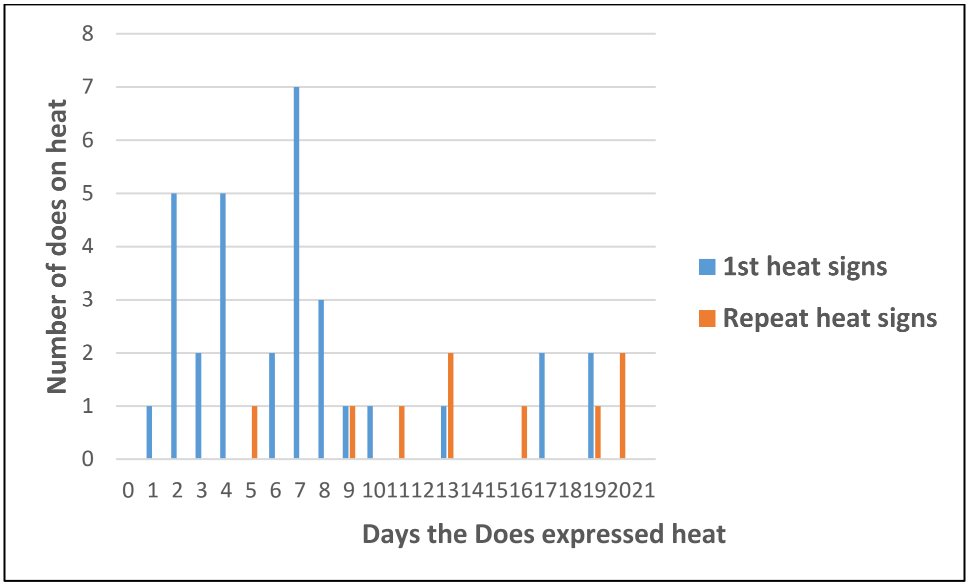

Figure 4.4. Combined BEGs Heat expression against time**.**

4.1.2 Hormone effect group (HEG)

In the replicate group HEG1, 50% showed typical heat signs and were served, but only 40% of them conceived (Table 4.2.) Half the does did not come on heat despite being given hormone injections and 60% did not conceive with natural mating.

For HEG2 (Table 4.2), one doe tag no. 826 was omitted from the experiment following abortion as a result of a prostaglandin injection .Within 72 hours, a total of nine does out of nine (100%) showed heat signs. Three does had swollen vulva and clear discharges but no hyperactivity. The rest of the 6 does actively showed typical signs. 22.2% conceived out of the 9 does that came on heat.

Within the 72 hours in the HEG3 group, 50% did show heat signs (Table 4.2). The pregnancy rate was 40%. The average estrus expression was 66.67% and conception rate 20.7% when hormones were used to assess performance in Galla goats.

Table 4.2 Hormone treatment mean percentages on estrus expression and conception

Replicated Groups	N		% of does on Estrus	Number of Does conceived (ultrasound scan)
HEG1	10		50% (5/10)	2
HEG2	9		100% (9/9)	2
HEG3	10		50% (5/10)	2
Total	29	Mean	% = 66.67% (19/29)	mean%=20,69% (6/29)

On comparing the buck- effect and the use of exogenous hormones to stimulate estrus, the result showed that the buck-effect was 90% effective while the use of exogenous hormones was only 66.67% (Table 4.3). The deviations from means of 90% and 66.67% indicated in (Table 4.3) were the standard errors of means from the population. Statistically, there was insignificant difference (p >0.05) in the use of either bucks or hormones on estrus stimulation.

Table 4.3 Analysis of buck effect versus exogenous hormones on estrus stimulation

	Treatment	N	Mean
Estrus	Buck Effect	3	90.0 ±5.8
	Hormone use	3	66.67 ±16.7
P - Value			0.074

N-represents the number of replications

The results on conception responses (Table 4.4) indicated that there was a significant difference ($P< 0.05$) between the buck effect and the use of hormones on conception rates.The mean conception percentage (76.67%; 23/30) for Buck- effect group (Table 4.1) was more than the hormone- effect treatment (20.69%) (Table 4.2).

Each treatment had three replications, column N (Table 4.4), and the mean number of conceptions deviated by standard error means in a population of BEG and HEG was (7.33 ± 0.333) and (2.00 ± 0.000) respectively.

Table 4.4 Analysis of buck effect versus exogenous hormone on Conception

	Treatment	N	Mean
Conception	Buck Effect	3	7.33 ±0.33
	Hormone use	3	2.00 ± 0.00
P - Value			0.016

Key: N- represents number replication in each treatment.

4.2 Determination of mating ratio on ES

Conception rates (CR) were calculated as the percentages of the total number of pregnancies over total number of actual does served. The replicated groups were assigned buck’s number MW3, N381 and N104. In the mating ratio (MR) of 1:10 group (Table 4.5) the overall mean conception rate was 37.7% .The respective CR in replicated groups of bucks MW3, N381 and N104 were 66.7%, 22.2% and 50%, respectively. Arithmetically on average, one buck was able to serve 5.3 does with a total of 10 services. The highest number of mating recorded was 19 times on 9 does, but with only 2 conceptions in that particular sampling unit,

Table 4.5 Mating and conception performance in the MR of 1:10 group

Replicated groups	buck	Number of does Exposed	No of does served	Total bucks services plus repeats on does served	PD Scan +ve No.	Conception Rate
MR1:10G1	MW3	10	3	4	2	66.7%
MR1:10G2	N381	9	9	19	2	22.2%
MR1:10G3	N104	10	4	7	2	50.0%
Total	3	29	16	30	6	
Mean			5.3	10	2	37.7%

PD scan +Ve No. Number of doe conceived, PD-pregnancy diagnosis

The average CR in the mating ratio of 1:15 was 9.5% (Table 4.6). The conception rate in replication group 1:15G3 was 25%, while the other two were 0%. The average number of does served per buck was 7, with a mean of mating of 9.67 times. The three bucks, MW3, N381, and N104, were able to mate seven, twelve, and ten times, respectively. In the same buck arrangement sequence, the number of does served was 6, 7, and 8 respectively. On pregnancy examination using the ultrasound scan, only 2 out of 8 were pregnant.

Table 4.6 Mating and conception performance in the MR of 1:15 group

Replicated groups	buck	Number of does Exposed	No of does served	Total bucks services plus repeats on does served.	PD Scan +ve No.	Conception Rate
MR1:15G1	MW3	15	6	7	0	0%
MR1:15G2	N 381	15	7	12	0	0%
MR1:15G3	N104	14	8	10	2	25%
Total	3	44	21	29	2	
Mean			7	9.67	0.67	9.5%

PD scan +ve No. Number of does scanned conceived, PD-pregnancy diagnosis

The overall CR in the MR of 1:20 group was 25.2% (Table 4.7). Three bucks served 16 does, and only four were confirmed pregnant. Buck Number MW3 mated 11 times with five does, implying at least six repeats. Another buck, Number N381, mated four does five times. The third buck served seven times. Each buck was able to mate 5.3 does, on average with a total of 8.7 services plus repeats.

Table 4.7 Mating and conception performance in the mating ratio of the 1:20 group

Replicated groups	buck	Number of does Exposed	No of does served	Total bucks services plus repeats on does served	PD Scan +ve No.	Conception Rate
MR1:20 G1	MW3	20	5	11	0	0
MR1:20 G2	N381	20	4	5	0	0
MR1:20 G3	N104	20	7	10	4	57.1%
Total	3	60	16	26	4	
Mean			5.3	8.7	1.3	25.2%

PD scan +ve No. Number of does conceived, PD-pregnancy diagnosis

The summary of the three mating ratios (Table 4.8) gives the statistically analyzed means of the number of does served and the number of does conceived. In all the groups of mating ratios of 1:10, 1:15 and 1:20, the numbers of does served were not proportional to the number of does conceived. The experiment clearly indicates that there were no significant differences (P>0.05) among the three sets of MR for both the number of does served and conceived. The respective conception rates for MR 1:10, 1:15 and 1:20 were 37.7%, 9.5% and 25.2%.

Table 4.8 Analysis of CR, mean number of does served and does conceived

Mating Ratios	Mean number. of does served	Mean number of does conceived	Conception Rates
MR 1:10	5.7[a]	2.00[a]	37.7%
MR 1:15	7.0[a]	1.33[a]	9.5%
MR 1:20	5.3[a]	1.33[a]	25.2%
SEM	1.98	1.217	
P-value	NS	NS	

Columns mean with the same letter of superscript not significantly different at P > 0.05

The standard error of mean amongst the three mating ratios on the mean number of does served and conceived was 1.98 and 1.217, respectively..

4.3 Benefit-cost ratio analysis on ES using exogenous hormones and the buck effect on does for at least one estrus cycle.

The BEG1 group, a sampling unit with 10 does, had eight pregnant does (Table 4.9). The projected output was computed using the kid's contribution margin at finishing. It was assumed, finishing the goats at 1.5 years with a contribution margin of Ksh. 1,200.00 prevailing market price (Eik & Asheim 2002; William & Magnan, 2017).

The following were the input costs incurred on 30 does that were kept for 21 days while in the "buck effect" experiment; three casuals were engaged in herding goats and were paid at a rate of Ksh. 367.00 per day for 21 days. The veterinary medicines included multivitamins 150 mls at

Ksh. 600.00, Butasal at Ksh. 1,700.00, Oxytetracycline 100 mls at Ksh. 300.00 and Penicillin-Streptomycin 100 mls at Ksh. 450.00. The Albendazone l-litre dewormer was priced at Ksh. 1,000.00. Three 5 kg mineral blocks costed Ksh. 1,650.00 each, 100 kg range cubes costed Ksh. 4,000.00, and Acaricide triatix 1 litre costs Ksh. 2,500.00.

Table 4.9 Revenue gross margin contribution from "Buck effect" treatment

Replicated Groups	Number of Pregnancy (ultrasound scan)	Revenue (Ksh.)
BEG1	8	9,600.00
BEG2	7	8,400.00
BEG3	8	9,600.00
Total		27,600.00

NB 1.5 years old galla goat @Ksh.1, 200.00 contribution gross margin, BEG-buck effect groups 1, 2 and 3.

In addition to the Buck effect group's input cost, the hormone effect group's input cost included Cystorelin (GnRH) and Enzaprost (PGF 2α on 30 does). Cystorelin (GnRH) was purchased in three bottles for Ksh. 3,100.00 each; Enzaprost (PGF) in 1 bottle plus 10 ml for Ksh. 4,560.00 and Ultrasound Gel in five litres for Ksh. 1,500.00.

Table 4.10 Revenue gross margin contribution from Hormone treatment.

Replicated Groups	Number of Pregnancy (ultrasound scan)	Revenue (Ksh.)
HEG1	2	2,400.00
HEG2	2	2,400.00
HEG3	2	2,400.00
Total	6/29	7,200.00

Key: HEG -hormone used sampling unit; NB 1.5 years old galla goat @Ksh.1, 200.00 contribution gross margin

The experiment obtained the benefit-cost ratio and gross margin calculation results at an optimizing level of 90 (Table 4.11). The use of bucks in ES in this experiment had a BCR of 1.38 with a positive GM of K. 23,079.00. The GM for the hormone treatment was a loss, KES. 65,601.00 with a BCR of 0.25.

Table 4.11 Benefit-cost ratio and gross margins analyses of use of bucks and hormone on estrus synchronization**.**

Estrus synchronization Method	N	Cost (Ksh.)	Revenue at optimizing Level (Ksh.)	Gross margin (Ksh.)	BCR
Use of Bucks	90	**59,721**	82,800.00	23,079.00	1.38
Use of Hormone	90	**87,201**	21,600.00	(65,601.00)*	0.25

*Key; N-represents the number of does, * figure in brackets is negative*

CHAPTER FIVE

DISCUSSION, CONCLUSION, AND RECOMMENDATION

5.1.1 Hormone versus Buck effect

The focus in this study was to assess the effectiveness of estrus synchronization between the use of exogenous hormones and the 'buck effect' on mature Galla goats. Estrus synchronization enables a farmer to plan for the right time of kidding to avoid unfavorable climatic periods (Lopez-Sebastian *et al*., 2007; Rahman *et al*., 2008a; Imasuen and Ikhimioya, 2009).

From the results, female goats came on heat at different times, and yet they were exposed to the breeding bucks at the same time. This arises from differences in the reproductive physiological status of individual animals. Those that had mature ovum came on heat earlier than the others did (Tsuma *et al.,* 2015).

There were cases of repeated heat expression, and this happened in some does within 21 days. False heat can appear because the doe can receive sensory stimulation that can trigger hormonal changes in the brain. At that time, false heat occurs when the ovum is not ready for fertilization. (Matthews, 2016).

The graph (figure 4.4), showing combined buck effect groups, showed that, within the first eight days, 90% of the does had shown heat signs. This is similar to another study by Parmar *et al.,(*2020*),* who recorded 100% estrus within 19–21 days. The olfactory stimulus sense plays a major role in the response of intact does in the male effect (Gelez *et al*., 2004). Ovulation is stimulated when LH concentration in the blood is increased when males and does are kept together in the same pen (Bedos *et al*.2010).

Observing from the analyzed results (Table 4.2), the mean estrus response (66.67%) by use of hormone on Galla does, was low and in agreement with Greyling *et al.,* (2000) and Vinoles *et al.* (2001), who indicated that estrus response vary significantly, depending on goat breed. The improved goats respond better on hormone stimulation of heat than unimproved indigenous goats. In the case of Boer goats and unimproved indigenous South African goats (Lehloenya *et al*., 2012), the estrus response was 100% versus 88.9% (Fhulufhelo et al., 2012). The results on estrus response showed that, although the use bucks (90%, 27/30) performed better than the use of hormones (66.67% (19/29), statistically, there were no significant differences ($P > 0.05$) between the two ways of arousing estrus, The results further, showed that there were significant differences ($p<0.05$) between the use of bucks and hormones on conception rates. The mean percentages for the buck effect and the use of hormones were (76.67%; 23/30) and (20.69%; 6/29) respectively.

The experiment with BEG took place in the month of November, at the peak of the drought, when the mean body condition score was (3.00 ± 0.57). Feed availability affects body condition. However, some published data show that body score of an African goat does not have an effect on its reproductive performance (Silva *et al*., 2011; Raymundo *et al*., 2010). The HEG was carried out in the middle of the wet season with green vegetation in December, whereas, the experiment with BEG. Some of the possible factors which may have led to low estrus response following the application of hormones are; the period between administration of prostaglandin and the effect of prostaglandins on corpus luteum and/or stage of the estrus cycle. Prostaglandins are effective only if there is the presence of CL (Vasquez *et al.,* 2010) and season and the inclusion of gonadotropin as a co-treatment (Dogan *et al*., 2016). The current mean pregnancy rate of 20.69% with the use of hormones is in agreement with a similar study, which gave lower pregnancy rates due to the duration of progestogens (Fhulufhelo *et al*., 2012).

A similar tendency was reported at 43.6% with short-term progestogen and 34.3% with long-term treatment of progestagen (Vinoles *et al*., 2001; Tibary, 2009; Karaca *et al*., 2010). The lower pregnancy rate in long-term progestagen treated does might be due to poor sperm cell transportation in the reproductive tract. Poor sperm cell transportation is associated with an increased amount of cervical mucus usually observed when this protocol is used (Tibary, 2009). The low level of feeding affects synchronization of estrus, ovulation rate and embryo loss in goats (Mani *et al*., 1992).

5.1.2 Mating ratio

The conventional average mating ratio without exogenous hormones of ram/buck to ewe/does is 1:30, and males run with the flock through at least two cycling periods (40-45 days) for maximum fertility (Ridler *et al*., 2012). A mating ratio of less than 1:10 is recommended for ewes when progesterone inserts (Ridler *et al*., 2012) control the estrous cycle. The mating ratio information for the case of Galla goats on synchronization was missing. The current study was to provide an optimum-mating ratio when controlled with hormones and to shorten the period of running bucks with does from 45 days to only 2-3 days.

It was noted that in all the groups of mating ratios of 1:10, 1:15 and 1:20, there were no significant differences (P>0.05) between them. The mating ratio of 1:10 with a conception rate of 37.7%, was higher than that of the MR 1:15 (9.5%) and 1:20 (25.2%) ratios. This is in agreement with an earlier report indicating that for rams and bucks, the mating ratio is less than 1:10 (Ridler et al., 2012).

Several possible reasons could explain these inconsistent results as reported by Omer and Bari (2012). Both the male and female factors may have affected the pregnancy rates. The heavy use of males for mating may have led to its sexual exhaustion limiting regular semen production, libido, ejaculation, and litter yield. Using old breeders should be avoided; in this case, the average mean age of bucks was (5.2 ± 1.25 years. The period between administration of prostaglandin and the effect of prostaglandins on corpus luteum and/or stage of estrus cycle (Vasquez *et al*., 2010), season, and the inclusion of gonadotropin as co-treatments (Dogan *et al.,* 2016) are reported factors affecting estrus response following prostaglandin administration**.** Gonadotrophins such as FSH, PMSG and GnRH have been included in the prostaglandin protocol, resulting into improved estrus responses. According to Raymundo *et al*., (2010) and Morgan-Davies *et al*., (2008) suggested that a good BCS of a doe was responsible for the optimum estrus response. In contrast, Silva *et al.* (2011) and Raymundo *et al.* (2010) stated that the body condition score of an African goat does not affect its reproductive performance. In estrus synchronization, it is necessary to take precautions against extremely hot and arid climatic conditions. An adverse climate affects feed availability. The high-energy nutritional level of energy feed performed better in conception rates than those on low and medium levels of energy feed (Kusina *et al.,* 2001). Weather conditions affect goat productivity as mentioned by Mellado *et al*. (1996); revealing that a reduction of kidding rates to approximately 50% is noted when mating and gestations are under range condition. This can be mitigated by having a sufficient number of bucks used in rotation. The mating ratio of 1:10 with a conception rate of 37.7%, which was higher than that of the MR 1:15 and 1:20 ratio, seems to agree with Ridler, (2012), who reported that for rams and bucks the mating ratio is less than 1:10.

5.1.3 Benefit: cost ratio

The result from the computation (Table 4.11), the benefits, and the cost of production indicated that the buck effect method was more beneficial than using an exogenous hormone to stimulate estrus. The buck effect had a BCR of 1.38, while the hormone effect had a BCR of 0.25. When the BCR is greater than 1.0, using bucks to synchronize estrus is a worthwhile recommendation and implementation for the end user. However, if BCR is equal to or less than 1.0, then the method is not worthy of being recommended. The results are in agreement with Keskin (2003), who reported that the use of the buck effect to stimulate estrus was more economical than using exogenous hormones. The cost incurred with the use of bucks to stimulate estrus is the cost of routine livestock management (casual labourer's wage, veterinary supplies, and feeds), but with the use of exogenous hormones, the cost is over and above the basic expenses. The use of hormones requires trained personnel to administer the injections according to protocol. There are possible errors with the use of exogenous hormones that could affect their effectiveness in stimulating estrus and subsequent conception. One of the possible causes of low conceptions with the use of exogenous hormones is poor sperm transportation associated with increased cervical mucus observed when long-term progestagen protocol is used (Tibary, 2009).

5.2 Conclusion

This study in a broad objective, focused on addressing the consistent supply of animal-origin food from small ruminants, especially the Galla goat to feed the increasing population. The two noted areas in goat production that limit Galla goat potential growth, especially in the southern rangelands of Kenya are; a prolonged kidding interval and mortalities on kids born and dams lactating during drier periods. A prolonged kidding interval reduces the number of goats available as food supply. Deaths of kids and dams likewise reduce the number available for utilization. In this study, exposure of females to males after a period of isolation for at least 3 weeks and one mile away, can be used for induction and synchronization of estrus during the breeding and non-breeding season without additional treatments in goats. The buck – effect group, conception percentage mean of 76.7% (23/30) (Table 4.1), was more significantly higher than the hormone –effect treatment percentage mean of 20.7% (Table 4.2). In this case, treatment with hormone may not impact positively to increase reproductive efficiency in Galla goat does.

The mating ratio of 1:10 with a conception rate of 37.7%, which was higher than that of the MR 1:15 (9.5%) and 1:20 ratio (25.2%), indicates that the mating ratio is less than 1:10 on estrus synchronized Galla goat does. The Benefit- cost ratio of more than 1 is worthy recommendation, therefore, since buck- effect group had a BCR of 1.38 and hormone treated group BCR of 0.25, it is better to use bucks to synchronize goats for more productivity.

5.3 Recommendations

The results from this experiment recommend the use of the "buck effect" to synchronize estrus in indigenous Galla goats for greater productivity. Controlled Natural mating is recommended on does synchronized with exogenous hormones only if there is a mating ratio of one buck with less than 10 does. Considering increased income, it is cost-effective to use bucks for estrus synchronization in indigenous Galla goats in an extensive system of production.

REFERENCES

Ahuya, C. O. (1998) Proc. Goat development in East Africa: practical experience and the way forward. Embu, Kenya p 21-23.

Alefe, T. (2014). Phenotypic characterization of indigenous goat types and their production system in shabelle zone, southeastern Ethiopia. An MSc Thesis, Haramaya University, Haramaya, Ethiopia. 112pp.

ALLPRO, (2007). Sheep and goats manual; for The Arid and Semi-Arid Lands of Kenya,

Ministry of Livestock department, African development Fund; ASAL Based Livestock and Rural Livelihoods support project.

Alves, N. G., Torres, C. A. A., Guimarães, J. D., Moraes, E. A., Costa, P. B., & Silva, D. R. (2018). Ovarian follicular dynamic and plasma progesterone concentration in Alpine goats on the breeding season. *Arquivo Brasileiro de Medicina Veterinaria e Zootecnia*, *70*(6), 2017–2022. https://doi.org/10.1590/1678-4162-9734

Bedos M, Flores J.A, Fitz-Rodriguez G, Mathieu K, Beniot M, Pascal P, Delgadillo J.A, (2010). Four hours of daily contact with sexual active males is sufficient to induce fertile ovulation in anestrous goats. *Hormones and behavior* 58(3), 473-477, 2010

Behnke, R. and Muthami, D. (2011). The contribution of livestock to the Kenyan economy. *IGAD Livestock Policy Initiative Working Paper No. 03–11. 03*, 1–62.

Birch, E. J., Knight, T. W. & Shaw, G. J. (1989). Separation of male goat pheromones responsible for stimulating ovulatory activity in ewes. *New Zealand Journal of Agricultural Research*, *32*(3), 337–341. https://doi.org/10.1080/00288233.1989.10421750

Blackburn, H. D., & Field, C. R. (1990). Performance of Somali Blackhead sheep and Galla goats in northern Kenya. *Small Ruminant Research*, *3*(6), 539-549.

Breman, H., & Kessler, J. J. (2012). Woody plants in agro-ecosystems of semi-arid regions: with an emphasis on the Sahelian countries (Vol. 23). Springer Science & Business Media.

Broekhuis, F., Thuo, D., & Hayward, M. W. (2018). Feeding ecology of cheetahs in the Maasai Mara, Kenya and the potential for intra-and interspecific competition. *Journal of Zoology*, *304*(1), 65-72.

Chemineau P, Daveau A, Cognié Y, Aumont G, Chesneau D. (2004); Seasonal ovulatory activity exists in tropical Creole female goats and Black Belly ewes subjected to a temperate photoperiod. BMC Physiology; 4: 12

Chepkemoi, R. S. (2020). An Economic Evaluation of the role of land and livestock dynamics in livelihood diversification in Baringo County, Kenya (Doctoral dissertation, University of Nairobi).

Cinar, M., Ceyhan, A., Yilmaz, O., and Erdem, H. (2017). Effect of estrus synchronization protocols including PGF2α and GnRH on fertility parameters in hair goats during breeding season. *Journal Animal, Plant Science, 27*(4), 1083-1087.

Detweiler, G., T. Gipson, R. C. Merkel, A. Goetsch, and T. Sahlu. (2008). Body Condition Scores in Goats. Pages 127-133 in Proc. 23rd Ann. Goat Field Day, Langston University, Langston, OK.

Devendra, C., McLeroy, G. B. (1982). Goat and sheep production in the tropics. Publisher;Longman Group. Chapter 2-10 pp 9-114. ISBN: 0582609356.

Dogan, I., Nur, Z., & Dogan, S. (2016). Different progestagen treatment duration on estrous synchronization during the natural breeding season in non-lactating Anatolian black goats. *Animal Reproduction*, *13*(4), 806–810. https://doi.org/10.21451/1984-3143-AR811

Dong, Y., Xie, M., Jiang, Y. U., Xiao, N., Du, X., Zhang, W., & Wang, W. (2013). Sequencing and automated whole-genome optical mapping of the genome of a domestic goat (Capra hircus). *Nature biotechnology*, *31*(2), pp.135-141.

Eik, L. O. Asheim, L. J. (2002). Introducing organic sheep and Cashmere goat farming systems in Norway. In Organic meat and milk from ruminants: Proceedings of a joint international conference organised by the Hellenic Society of Animal Production and the British Society of Animal Science (Vol. 106, p. 147). Wageningen Academic Publishers.)

Erdogan, G. (2012). Ultrasonic assessment during pregnancy in goats–a review. *Reproduction in domestic animals*, *47*(1), pp.157-163.

Farooq, M. Z., Ahmad, H. I., Yaqoob, M., & Bhatti, J. A. (2018). Factors Contributing to Kid's Mortality in Goat Kept under Desert Land Conditions .*Scholars Journal of Agriculture and Veterinary Sciences* (SJAVS) July, 2018. https://doi.org/10.21276/sjavs.2018.5.7.2

FAO, (2018). Statistics database. Food and Agriculture Organization, Rome Italy.

Fatet, A., Pellicer-Rubio, M. T., & Leboeuf, B. (2011). Reproductive cycle of goats. *Animal Reproduction Science*, *124*(3–4), 211–219. https://doi.org/10.1016/j.anireprosci.2010.08.029

Fhulufhelo Vincent Ramukhithi, Tshimangadzo Lucky Nedambale, Ben Sutherland, Johannes Petrus Carl Greyling & Khoboso Christina Lehloenya (2012) Oestrous synchronisation and pregnancy rate following artificial insemination (AI) in South African indigenous goats, *Journal of Applied Animal Research*, 40:4, 292-296, DOI: 10.1080/09712119.2012.685280

García-Peniche, T. B., Montaldo, H. H., Valencia-Posadas, M., Wiggans, G. R., Hubbard, S. M., Torres-Vázquez, J. A., & Shepard, L. (2012). Breed differences over time and heritability estimates for production and reproduction traits of dairy goats in the United States. *Journal of Dairy Science*, *95*(5), 2707–2717. https://doi.org/10.3168/jds.2011-4714

Gelez, H., & Fabre-Nys, C. (2004). The "male effect" in sheep and goats: a review of the Respective roles of the two olfactory systems. *Hormones and behavior*, *46*(3), 257-271.

Getaneh, M., Taye, M., Shibabaw, W., & Kebede, D. (2023). Reproductive performances of Ethiopian indigenous goat populations under different management conditions for assisting selective breeding schemes. *Journal of Applied Animal Research, 51*(1), 276-281.

Gichohi, C. M. (1998) Proc. Goat development in East Africa: practical experience and the way forward. Embu, Kenya p 7-8.

Githui, E., Kibegwa, F., Kamau, J., Mutura, S., Okwany, Z., Ngigi, D., & Mwangi,E.(2016). Genetic relationships of indigenous goats reared by pastoralists in Kenya based on mitochondria D-loop sequence. Animal Genetic Resources/Ressources Génétiques Animales/Recursos Genéticos Animales, 59, 73-80. doi:10.1017/S2078633616000217

https://fiascofarm.com/goats/breeding.htm#olddoe

Greyling, J. P. C., & Van der Nest, M. (2000). Synchronization of oestrus in goats: dose effect of progestagen. *Small Ruminant Research*, *36*(2), 201-207.

Imasuen, JA, Ikhimioya, I. (2009). An assessment of the reproductive performance of estrus synchronised West African Dwarf (WAD) does using medroxyl-progestrone acetate (MPA). *African Journal of Biotechnology*, 8: 103–106. [Web of Science ®], [Google Scholar]

IPCC (2007): Africa, Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge

UK, 433-467.)

Jasiorowsky, W. A. (1991). In “On the Eve of the Third Millennium. The European challenge for Animal Production” EAAP publication, No. 148: 127-141

Joshi, A., Kalauni, D., & Bhattarai, N. (2018). Factors Affecting Productive and Reproductive Traits of Indigenous Goats in Nepal. *Archives of Veterinary Science and Medicine*, *01*(01), 19–27. https://doi.org/10.26502/avsm.003

Juma G P, Ngigi M, Baltenweck I, and Drucker A G. (2010). Consumer demand for sheep and goat meat in Kenya. *Small Ruminant Research* Vol 90, Issues 1-3 pages 135-138.

Kahi, A. K., Rewe, T. O., & Kosgey, I. S. (2005). Sustainable community-based organizations for the genetic improvement of livestock in developing countries. *Outlook on AGRICULTURE*, *34*(4), 261-270.

Karaca, F., Doğruer, G., Saribay, M. K., & Ateş, C. T. (2009). Oestrus synchronization with short-term and long-term progestagen treatments in goats: The use of GnRH prior to shortterm progestagen treatment. *Italian Journal of Animal Science*, *9*(1), 117–120. https://doi.org/10.4081/ijas.2010.e22

Karadaev, M. (2015). Pregnancy diagnosis techniques in goats – A review. *Bulgarian Journal of Veterinary Medicine*, *18*(3), 183–193. https://doi.org/10.15547/bjvm.837

Kareta, W., Smorag, Z., Gajda, B., Jura, J., & Cegla, M. (1999). Estrus synchronization and superovulation in goats. In *Roczniki Naukowe Zootechniki* (Vol. 26, Issue 4).

Katiku P. N, Kimitei R. K, Korir B. K, Muasya T.K, Chengole J. M, Ogillo B. P, Munyasi J.W and Karimi, S. K, (2012). Value chain assessment of small ruminant production, challenges and opportunities: The case of southern rangelands of Kenya and

KNBS (2019).Kenya Population and Housing Census, Kenya National Bureau of statistics. Government of Kenya publications.

Keskin, M. (2003). Influence of buck effect and exogenous hormone treatments on oestrus synchronisation and litter size in Shami (Damascus) goats. *Turkish Journal of Veterinary & Animal Sciences*, *27*(2), 453-457.

Khanum, S. A., Hussain, M., & Kausar, R. (2007). Assessment of reproductive parameters in female Dwarf goat (Capra hircus) on the basis of progesterone profiles. *Animal Reproduction Science*, *102*(3-4), 267-275.

Kibiru S K (2007). Calf health and production under Maasai pastoral systems in Kajiado district of Kenya. Veterinary Epidemiology Faculty of Veterinary Medicine. PhD Thesis, University of Nairobi, Kenya

Kimani, et al. (2016). Public Health Benefits from Livestock Rift Valley Fever Control: A Simulation of Two Epidemics in Kenya No Title. Ecohealth, 13, pp.729–742

Kinyanjui, A., Murage, A. and Mbugua, D. (2010) Socio-economic Effects of Dairy Goat Production in Kenya, KARI, Naivasha

Kenya Institute for Public Policy Research and Analysis (KIPPRA), 2018. Kenya economic report 2018: Boosting investments for delivery of the Kenya Vision 2030. Nairobi: KIPPRA

Kissui, B. M. (2008). Livestock predation by lions, leopards, spotted hyenas, and their vulnerability to retaliatory killing in the Maasai steppe, Tanzania. *Animal conservation*, *11*(5), 422-432.

Knights, M., & Garcia, G. W. (1997). The status and characteristics of the goat (Capra hircus) and its potential role as a significant milk producer in the tropics: a review. *Small Ruminant Research*, *26*(3), 203-215.

Kosgey IS, Baker RL, Udo HMJ, Van Arendonk JAM. (2006). Successes and failures of small ruminant breeding programmes in the tropics: a review. *Small Ruminant Research* 61:13-28

Kosgey, I. S., Rowlands, G. J., van Arendonk, J. A., & Baker, R. L. (2008). Small ruminant production in smallholder and pastoral/extensive farming systems in Kenya. *Small Ruminant Research*, *77*(1), 11-24.

Koyuncu, M., & Altinçekiç, Ş. Ö. (2013). Importance of body condition score in dairy goats. *Macedonian Journal of Animal Science*, *3*(2).

Kumalo, M. (2014). Characterization of sheep and goat production systems amongst small-scale farmers in the Southern Free State. *Doctoral dissertation, Bloemfontein: Central University of Technology, Free State.*

Kusina, N. T., Chinuwo, T., Hamudikuwanda, H., Ndlovu, L. R., & Muzanenhamo, S. (2001). Effect of different dietary energy level intakes on efficiency of estrus synchronization and fertility in Mashona goat does. *Small Ruminant Research*, *39*(3), 283-288.

Lehloenya (2012). Oestrous synchronisation and pregnancy rate following artificial insemination (AI) in South African indigenous goats, *Journal of Applied Animal Research*, 40:4, 292-296, DOI: 10.1080/09712119.2012.685280

Lipson, J., Reynolds, T., & Anderson, C. L. (2019). Environmental implications of livestock series: goats. *Gates Open Res*, *3*(343), 343.

Lopez-Sebastian, A, Gonzalez -Bulnes, A, Carrizosa, JA, Urrutia, B, Diaz-Delfa, C, Santiago-Moreno, J and Gomez-Brunet, A. (2007). New estrus synchronisation and artificial insemination protocol for goats based on male exposure, progesterone and cloprostenol during the non-breeding season. *Theriogenology,* 68: 1081–1087. doi:10.1016/j.theriogenology.2007.08.003

Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability*, *13*(3), 1318.

Mango, J., Mideva, A., Osanya, W., & Odhiambo, A. (2011). Summary of Baseline Household

Survey Results: Lower Nyando, Kenya. *September 2011*, 1–32. https://cgspace.cgiar.org/rest/bitstreams/18920/retrieve

Mani, A. U., McKelvey, W. A. C., & Watson, E. D. (1992). The effects of low level of feeding on response to synchronization of estrus, ovulation rate and embryo loss in goats. *Theriogenology*, *38*(6), 1013-1022.

Martin, G., Blache, D., Miller, D., & Vercoe, P. (2010). Interactions between nutrition and reproduction in the management of the mature male ruminant. Animal, 4(7), 1214-1226. doi:10.1017/S1751731109991674

Matthews, J. G. (2016). Diseases of the Goat. 4th Edition; Revised and updated edition; John Wiley & Sons

Maurya, R. K., & Tripathi, H. (2013). Impact of drought on productive and reproductive performance of goats in bundelkhand region of Uttar Pradesh. *The Indian Journal of Small Ruminants*, *19*(1), 92-94.

Mbae, R., Kimoro, B., Kibor, B. T., Wilkes, A., Odhong, C., Dijk, S. V., & Khobondo, J. O. (2020). The Livestock Sub-sector in Kenya's NDC: a scoping of gaps and priorities. UNIQUE (Livestock sub- sector report). Global Research Alliance on Agricultural Greenhouse Gases (GRA) & CGIAR Research programon climate changeAgriculture and food security (CCAFS).

Mburu, M., Mugendi, B. J., Makokha, A., & Muhoho, S. (2014). Factors affecting Kenya Alpine dairy goat milk production in Nyeri region. http://hdl.handle.net/123456789/2735

McDowell, L. R. (1989). Vitamin C in vitamins in Animal Nutrition. L.R. McDowell, (ed) Academic Press, San Diego, CA Pages 365-387

McGregor, B. (2007). Reproduction management of fibre and meat goats. Department of Environment and primary Industries (Vic),2007

Mellado, M., Cantu, L. and Surez, J.E. (1996). Effects of body condition, length of breeding period, buck: doe ratio, and month of breeding on kidding rates in goats under extensive conditions in arid zones of Mexico, *Small Ruminant Research 23: 29-35.*

Menzies, P. I. (2012). Vaccination programs for reproductive disorders of small ruminants. In *Animal Reproduction Science* (Vol. 130, Issues 3–4, pp. 162–172).

https://doi.org/10.1016/j.anireprosci.2012.01.010

Michael, L. D., and Thomas, W. G. (2005): Hand book of Estrous Synchronization (vol. 14).Western Region Publication. The Ohio State University/Ohio Agricultural Research and Development Center, Ohio. Pp 1-41

Mnene, W. N. (2006). Strategies to increase success rates in natural pasture improvement through re-seeding degraded semi-arid rangelands of Kenya. *Doctoral dissertation, University of Nairobi.*

MoLFD, (2006). Ministry of Livestock and Fisheries Development. Draft National Livestock Policy by the Technical Stakeholders' Working Group. Government printer, Nairobi, Kenya.

Morgan-Davies, C., Waterhouse, A., Pollock, M. L., & Milner, J. M. (2008). Body condition score as an indicator of ewe survival under extensive conditions. *Animal Welfare*, *17*(1), 71-77.

Muir, J. P., Pitman, W. D., Foster, J. L., & Dubeux Jr, J. C. (2015). Sustainable intensification of cultivated pastures using multiple herbivore species. *African Journal of Range & Forage Science*, *32*(2), 97-112.

Mukherjee, S. R. (2014). "Global Halal: Meat, Money, and Religion" *Religions* 5, no. 1: 22-75. https://doi.org/10.3390/rel5010022

Musalia, L. M., Semenye, P. P., & Fitzhugh, H. A. (1989). Mineral status of dual-purpose goats and forage in Western Kenya. *Small Ruminant Research*, *2*(1), 1-9.

Ndeke, A. N., Mutembei, H. M., Tsuma, V., & Mutiga, E. R. (2015). Reproductive Performance of the Galla and Toggenburg Goats and their Crosses in Mwingi Sub-county of Kenya. *Journal of Agricultural Science and Food Technology*, *1*(6), 78–83.

Niekerk H. V & Greyling J. P.C. (2011). Different synchronization techniques in Boer goat does outside the normal breeding season (Vol. 98, pp. 1–2).

Njarui, D., Gichangi, E., Gatheru, M., Nyambati, E., Ondiko, C., Njunie, M., & Ayako, W. (2016). A comparative analysis of livestock farming in smallholder mixed crop-livestock systems in Kenya: 1. Livestock inventory and management. *Development*, *28*(4).

Nur Z, Nak Y, Nak D, Ustuner B, Tuna B, Simsek G, Sagirkaya H. (2013). The use of progesterone-supplemented co-synch and Ovsynch for estrus synchronization and fixed-time insemination in nulliparous Saanen goat. *Turkish Journal Veterinary Animal Science*. 37:183–188.

Nyariki D & Amwata D, (2019). The value of pastoralism in Kenya: Application of total economic value approach. Pastoralism: Research, Policy and Practice 9: Article No. 9. https://doi.org/10.1186/s13570-019-0144-x

Okello, G, (2016). Integration of Indigenous Knowledge With the Farmers' Preferred Phenotypes and Breeding Practices on Capra Hircus Populations in Kajiado and Makueni Counties. *MSc thesis, University of Nairobi*

Omer Ucar and Bari Uslu (2012) Causes and remedies for non-infectious infertility in sheep and goats, December 2021 Jurnal Kedokteran Hewan - *Indonesian Journal of Veterinary Sciences* 15(4):132-139 DOI: 10.21157/j.ked.hewan.v15i4.20795

Omontese, B. O., Rekwot, P. I., Ate, I. U., Ayo, J. O., Kawu, M. U., Rwuaan, J. S., Nwannenna, Mustapha A. I., R. A., & Bello, A. A. (2016). An update on oestrus synchronisation of goats in Nigeria. *Asian Pacific Journal of Reproduction*, *5*(2), 96–101. https://doi.org/10.1016/j.apjr.2016.01.002

Omontese, B. O., Rekwot, P. I., Rwuaan, J. S., Ate, I. U., & Makun, H. J. (2013). Effect of prostaglandin and equine chorionic gonadotrophin on estrus behaviour of Sahel goatsduring the harmattan season. *Livestock Research for Rural Development* (Vol. 25, Issue 2).

Omontese, Bobwealth Oakina. (2018). Estrus Synchronization and Artificial Insemination in Goats. *Goat Science*. https://doi.org/10.5772/intechopen.74236

Opiyo, F., Wasonga, O., Nyangito, M. *(2015)*. Drought Adaptation and Coping Strategies Among the Turkana Pastoralists of Northern Kenya. *International Journal Disaster Risk Science* 6, 295–309 (2015). https://doi.org/10.1007/s13753-015-0063-4

Parmar C.P, Dhami A.J, Patel J.A, Belsare V.P, (2020). Efficiency of Different Estrus Synchronization Protocols in Surti Goats. *Indian Journal of Vet Science and Biotech* (2020):
10.21887/ijvsbt.15.3.6)

Pilling, D., Cardellino, R., Zjalic, M., Rischkowsky, B., Tempelman, K. A., & Hoffmann, I. (2007). The use of reproductive and molecular biotechnology in Animal Genetic Resources management - a global overview. *Animal Genetic Resources Information*, *40* (April), 1–13. https://doi.org/10.1017/s1014233900005708

Porter, V. (2020). Mason's world dictionary of livestock breeds, types and varieties. 6th edition. CABI.

Rahman ANMA, Abdullah RB, Wan-Khadijah WE., (2008); Oestrus synchronization and Superovulation in goats: a review. *Journal Biological Science;* 8: 1129-1137.

Raji, L. O., & Ajala, O. O. (2015). Scrotal Circumference as a Parameter of Breeding age for

West African Dwarf Bucks. *Turkish Journal of Agriculture - Food Science and Technology*, *3*(8), 668. https://doi.org/10.24925/turjaf.v3i8.668-671.453

Raymundo, R.V., C. Evaristo, R.M. Rafael, L. Carlos, M. Miguel and V. Francisco, (2010). Effect of body condition score of does and use of bucks subjected to added artificial light on estrus response of Alpine goats. *Tropical Animal Health and Production*, 42: 1285-1290

Rewe, T. O., Ogore, P. B., and Kahi, A. K. (2002), 'Integrated goat projects in Kenya: impact on genetic improvement', *Proceedings of the 7th World Congress on Genetics Applied to Livestock Production,* 19–23 August, Montpellier, Vol 33, pp 385–387.

Riaz, M. Q., Südekum, K. H., Clauss, M., & Jayanegara, A. (2014). Voluntary feed intake and digestibility of four domestic ruminant species as influenced by dietary constituents: A meta-analysis. *Livestock Science*, *162*, 76-85.

Ridler, A. L., Smith, S. L., & West, D. M. (2012). Ram and buck management. *Animal Reproduction Science*, *130*(3–4),180–183. https://doi.org/10.1016/j.anireprosci.2012.01.012

Rodriguez, M. (2017). Defining the terms; resistance, tolerance and resilience. 18. https://stud.epsilon.slu.se/10470/7/Rodriguez_M_170707.pdf

Ruvuna, F., Kogi, J. K., Taylor, J. F., & Mkuu, S. M. (1995). Lactation curves among crosses of Galla and East African with Toggenburg and Anglo Nubian goats. *Small Ruminant Research*, *16*(1), 1-6.

Ruvuna, F., Cartwright, T. C., Blackburn, H., Okeyo, M., & Chema, S. (1988). Gestation length, birth weight and growth rates of pure-bred indigenous goats and their crosses in Kenya. *The Journal of Agricultural Science*, *111*(2), 363-368.

Sagala, J. I., Gachuiri, C. K., Kuria, S. G., & Wanyoike, M. M. (2021). Effects of supplementing lactating camels with Acacia tortilis pods and 'Chalbi salt'on milk yield and calf growth in the peri-urban area of Marsabit town, Kenya. *International Journal of Agricultural Research, Innovation and Technology*, *11*(1), 117-122.

1103, DOI:10.1080/1828051X.2022.2093657

Salem, H. B., & Smith, T. (2008). Feeding strategies to increase small ruminant production in dry environments. *Small ruminant research*, *77*(2-3), 174-194.

Silva, L.M., D. Rondina, A.A. Araujo, C. Sargentini, I.M.T. Lima, M.R.C. Rodrigues, A.L. Souza, A. Giorgetti, C.H.A. Oliveira and F.V. Rodrigues, (2011). Reproductive responses and progesterone levels of postpartum oestrus synchronization in goats with different body reserves. *Italian Journal of Animal Science,* 10: 42-46

Singh, B., & Prasad, S. (2008). Modelling of economic losses due to some important diseases in goats in India. *Agricultural Economics Research Review*, *21*(347-2016-16708), 297-302.

Soren, P. Rodning, Michelle, F. Elmore, Misty, A. Edmondson, Joshua, B. Elmore, Julie,A. Gard, and Andrew, S. Lovelady (2012). Estrus Synchronization and Artificial Insemination Programs for Beef Cattle, Alabama Cooperative Extension System ANR-1027 www.aces.edu assessed on September 2017 Publishing, Oxford, pp. 23–25.

2008 Mar 15; 69(5):651. PMID: 17889303

Terrill, C. E. (1979). The distribution of breeds of sheep as related to domestication and development of modern genotypes. In The Domestication of Sheep; Their Ancestors, Geography, Time Period, and People Involved. pp 41-112. The International Sheep and Goat Institute, Utah State University, Logan , Utah.

Tibary A. (2009). Estrus synchronization and AI: methods for successful and timely pregnancy. 81st Western Veterinary Conference. Washington State University, Pullman, WA, USA [Internet]. Available from: www.omnibooksonline.com /data/ papers/ 2009V552.pdf [Google Scholar]

Theuri, W. (1998) *Proc.* Goat development in East Africa: practical experience and the way forward. Embu, Kenya p 15-20.

Thornton, P. K. (2010). Livestock production: recent trends, future prospects. Philosophical Transactions of the Royal Society B: *Biological Sciences*, 365(1554), 2853-2867.

Tibbo, M., & van de Steeg, J. (2013). Climate change adaptation and mitigation options for the livestock sector in the near east and North Africa. *Climate change and food security in West Asia and North Africa*, 269-280.

Tsuma, V.T, Khan, M.S., Okeyo, A.M. and Ibrahim, M.N.M. (2015). A training manual on artificial insemination in goats**.** ILRI Manual 19. Nairobi, Kenya: *International Livestock Research.*

Udo, H. M. J., Aklilu, H. A., Phong, L. T., Bosma, R. H., Budisatria, I. G. S., Patil, B. R., ... & Bebe, B. O. (2011). Impact of intensification of different types of livestock production in smallholder crop-livestock systems. *Livestock Science*, *139*(1-2), 22-29.

Vinoles, C, Forsberg, M, Banchero, G and Rubianes, E. (2001). Effect of long-term and short-term progestagen treatment on follicular development and pregnancy rate in cyclic ewes. *Theriogenology*,55: 993–1004.doi:10.1016/S0093-691X(01)00460-5 [Crossref], [Google Scholar]

Westover, A. J., Hooper, S. B., Wallace, M. J., & Moss, T. J. M. (2012). Prostaglandins mediate the fetal pulmonary response to intrauterine inflammation. *American Journal of Physiology - Lung Cellular and Molecular Physiology*, *302*(7), 664–678. https://doi.org/10.1152/ajplung.00297.2011

Whitley, N. C., & Jackson, D. J. (2004). An update on estrus synchronization in goats: a minor species. *Journal of Animal Science*, *82 E-Suppl*, 270–276. https://doi.org/10.2527/2004.8213_supplE270x

William M. Thompson, Nicholas Magnan (2017). Predicting Success in a Productive Asset Transfer Program: A Goat Program in Haiti. First published 02 March 2017 https://doi.org/10.1093/aepp/ppx021

Wilson, R. T. (1991). Small ruminant production and the small ruminant genetic resource in tropical Africa (Vol. 88). Food & Agriculture Organiztion.

Yatsentyuk, S. P., Borunova, S. M., Gnezdilova, L. A., Pigina, S. Y., Pozyabin, S. V., & Abramov, P. N. (2023). Viral contamination of bull semen used for artificial insemination. In *AIP Conference Proceedings* (Vol. 2817, No. 1). AIP Publishing.

Zangeneh, A., Jadid, S., & Rahimi-Kian, A. (2010). Normal boundary intersection and benefit–Cost ratio for distributed generation planning. European Transactions on Electrical Power, 20(2), 97–113.

APPENDICES 1. Approval of proposal by Faculty Biosafety, Animal use and Ethics committee

UNIVERSITY OF NAIROBI
FACULTY OF VETERINARY MEDICINE
DEPARTMENT OF VETERINARY ANATOMY AND PHYSIOLOGY

P.O. Box 30197, Tel: 4449004/4442014/ Ext. 2300 6
00100 Nairobi, Direct Line. 4448648
Kenya.

REF: FVM BAUEC/2021/320
Mr. Levi Mulongo Wambulwa.
Dept. Animal Production,
University of Nairobi.
22/10/2021

Dear Mulongo,

<u>RE: Approval of proposal by Faculty Biosafety, Animal use and Ethics committee</u>
Enhancing productivity of Galla Goats using estrus synchronization and controlled natural mating in southern Rangelands, Kenya.

Mr. Levi Mulongo J56/36058/2019

We refer to your MSc. proposal submitted to our committee for review and your application letter dated 14th October 2021. We have reviewed your application for ethical clearance for the study.
The study set up, number of does and bucks and protocols used to assess use of hormones in estrus synchronization compared to the use of bucks in enhancing productivity of Galla Goats meets the minimum standard of the Faculty of Veterinary medicine ethical regulation guidelines.
We have also noted that registered veterinary surgeons are supervising the study.
We hereby give approval for you to proceed with the project as outlined in the submitted proposal.

Yours sincerely,

Dr. Catherine Kaluwa, Ph.D
Chairperson, Biosafety, Animal Use and Ethics Committee,
Faculty of Veterinary Medicine,
University of Nairobi

Appendix 2: Approval of research proposal and supervisors

UNIVERSITY OF NAIROBI
OFFICE OF THE DEPUTY VICE-CHANCELLOR
(ACADEMIC AFFAIRS)

Telephone: 020 4910000
E-mail: pg@uonbi.ac.ke
Our Ref: J56/36058/2019

P. O. Box 30197 - 00100
NAIROBI, KENYA
June 7, 2022

Wambulwa Levi Mulongo
c/o Department of Animal Production
Faculty of Veterinary Medicine

Dear Levi,

APPROVAL OF RESEARCH PROPOSAL AND SUPERVISORS

This is to inform you that the Deputy Vice-Chancellor (Academic Affairs) has approved your masters research proposal entitled: **"Enhancing Productivity of Galla Goats using Estrus Synchronization and Controlled Natural Mating in Southern Rangelands Kenya".**

The DVC (AA) has also approved **Prof. Joseph Jung'a, Dr. Rawlynce Bett** and **Dr. Samuel M. Mbuku** as the supervisors of your thesis.

You should therefore begin consulting your supervisors and undertake supervised research over a minimum period of six months. You will be expected to give notice of intent to submit the thesis for examination to the Dean, only at the expiry of six months with effect from February 2022. The Guidelines on Postgraduate Supervision can be accessed on our website (http://academics.uonbi.ac.ke) while the Research Notebook is available at the University Bookstore.

This letter supersedes our earlier one dated May 19, 2022.

Yours sincerely,

CATHERINE NJUE (MS.)
FOR: ACADEMIC REGISTRAR

c.c Dean, Faculty of Veterinary Medicine
Chairman, Department of Animal Production
Prof. Joseph Jung'a (Supervisor)
Dr. Rawlynce Bett (Supervisor)
Dr. Samuel M. Mbuku (Supervisor)

CN/jg

Appendix 3: protocol for estrus synchronization and natural mating on mature Galla goats does

PROTOCOL FOR ESTRUS SYNCHRONIZATION AND NATURAL MATING ON MATURE GALLA GOAT DOES.																			
30 does	15START BEG	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30			Nov-21
	1	2	3	4	END BEG	6	7	8	9	10	11	12	13	14	15	16			Dec-21
30 does	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Dec-21
Day	0	1	2	3	4	5	6	7	8	9	10	11	12						
45 does	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Jan-22
	25	26	27	28	29	30	31												
60 does	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Feb-2022
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30			
PD	BEG		14th JAN.22																
	1ST LOT 30		31st JAN 2022																
	2ND LOT 45		1ST MAR 2022																
	3RD LOT 60		22nd MAR 2022																
	KEY																		
	(red)	CYSTORELIN™ INJECTION DAY 0 AND DAY 9																	
	(yellow)	ENZAPROST™ INJECTION DAY 7																	
	(green)	JOINING BUCKS FOR NATURAL MATING.																	

Appendix 4: Analysis of buck effect vs exogenous hormone on estrus stimulation T-Test

Group Statistics

	Treatment	N	Mean	Std. Deviation	Std. Error Mean
Estrus	1	3	90.00	10.000	5.774
	2	3	66.67	28.868	16.667

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Estrus Equal variances assumed	5.765	.074	1.323	4	.256	23.333	17.638	-25.639	72.305
Equal variances not assumed			1.323	2.473	.295	23.333	17.638	-40.209	86.876

Appendix 5: Analysis of buck effect vs exogenous hormones on conception

T-Test

Group Statistics

	Treatment	N	Mean	Std. Deviation	Std. Error Mean
Conception	1	3	7.33	.577	.333
	2	3	2.00	.000	.000

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
						Sig. (2tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		F	Sig.	t	Df				Lower	Upper
	Equal variances assumed	16.000	.016	16.000	4	.000	5.333	.333	4.408	6.259
Conception	Equal variances not assumed	16.000	.016	16.000	2.000	.004	5.333	.333	3.899	6.768

There was a significant difference ($P<0.05$) in conception rates between the use of bucks and hormones on Galla goats. Buck responded higher 76.67% than us of hormones 20.69%.

Appendix 6: Analysis of mating ratio on estrus synchronization using Hormones (10, 15 and 20)

Oneway

ANOVA

Conception

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.222	2	2.111	2.375	.174
Within Groups	5.333	6	.889		
Total	9.556	8			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Conception LSD

(I) Treatment_	(J) Treatment_	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
2	3	1.667	.770	.074	-.22	3.55
	4	.667	.770	.420	-1.22	2.55
3	2	-1.667	.770	.074	-3.55	.22
	4	-1.000	.770	.242	-2.88	.88
4	2	-.667	.770	.420	-2.55	1.22
	3	1.000	.770	.242	-.88	2.88

APPENDIX 7: Benefit-cost ratio analysis on estrus synchronization between the of use hormones and the buck effect

Buck effect group BCR

Item	Amount (30 Goats)	Optimizing Level Amount (90 Goats)
Revenue		
23 goats@1,200 (Contribution Margin)	**27,600**	**82,800**
Variable Cost		
Casual (3*367*21)	23,121	23,121
Multivitamin (150mls)	600	1,800
Butasal	1,700	5,100
Oxytetracyclines (100mls)	300	900
Penstrip (100mls)	450	1,350
Dewormer albendazole (1 lt)	1,000	3,000
Mineral block (3*5kg)	1,650	4,950
Range cubes (100kg)	4,000	12,000
Acaricide triatix (1lt)	2,500	7,500
Total	**35,321**	**59,721**
Gross Margin		**23,079**
BCR		**1.38**

Hormone effect group BCR

Item	Amount (30 Goats) Kshs.	Optimizing Level Amount (90 Goats)
Revenue		
6 Goats@1,200 (Contribution Margin)	**7,200.00**	**21,600.00**
Variable Cost		
Casual (3*367*21)	23,121.00	23,121.00
Multivitamin (150mls)	600.00	1,800.00
Butasal	1,700.00	5,100.00
Oxytetracyclines (100mls)	300.00	900.00
Penstrip (100mls)	450.00	1,350.00
Dewormer albendazole (1 lt)	1,000.00	3,000.00
Mineral block (3*5kg)	1,650.00	4,950.00
Range cubes (100kg)	4,000.00	12,000.00
Acaricide triatix (1lt)	2,500.00	7,500.00
Hormone		
Cystorelin (GnRH) 3 bottles	3,100.00	9,300.00
Enzaprost (PGF 2alfa) 1 bottles + 10mls	4,560.00	13,680.00
Ultrasound Gel	1,500.00	4,500.00
Total	**44,481.00**	**87,201.00**
Gross Margin		**(65,601.00)**
BCR		**0.25**

ANNEXES I: Plates from the study

Feeding range cubes

Drenching does

Estrus virginal discharge

Buck sniffing during mating

Mating behavior of goats

Mounting sign of heat

Ultrasound scanner

Dr. Lilian Mathai (in blue) of University of Nairobi

Kids born out of Estrus synchronization

Kids born out of Estrus synchronization