PREVALENCE OF MASTITIS AND ASSOCIATED RISK FACTORS IN DAIRY GOATS IN MACHAKOS COUNTY, KENYA

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN VETERINARY EPIDEMIOLOGY AND ECONOMICS (MVEE) OF THE UNIVERSITY OF NAIROBI

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JUNE 2017

DECLARATION

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

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This thesis is dedicated to my family; Loving wife Beatrice Ndunge Ngunga, son Evans Makau Ngunga, daughter Abigael Nthambi Ngunga and our parents Wanza Makau and late father Makau Maingi.

ACKNOWLEDGEMENTS

I wish to thank most sincerely my supervisors, Profs Philip M. Kitala, Jackson N. Ombui and Victor T. Tsuma for their guidance, advice, encouragement, moral support, patience and constructive criticism throughout this study.

I am deeply indebted to the Department of Public Health, Pharmacology and Toxicology, University of Nairobi for providing all the necessary support in terms of manpower and facilities throughout my study period. I am sincerely grateful to the staff of bacteriology laboratory in the department: Chief technologist Mr Nduhiu Gitahi and laboratory technologists Alfred Mainga and Robert Ronoh for their technical assistance.

Special thanks go to the Coordinator of East Africa Agriculture Productivity Project (EAAPP) and the desk officer of the project for the financial support for collection of data in the field.

I also express my sincere gratitude to the Secretary/Chief executive officer National Commission for Science, Technology and Innovation (NACOSTI) for financial assistance in the Science, Technology and Innovation Research Grant (Msc.) which was used for the purchase of laboratory chemicals and equipments.

Special thanks go to the Principal Secretary Ministry of Agriculture, Livestock and Fisheries Development (MOALFD) and the Director of Veterinary Services for granting me study approval without which this study could not have been accomplished.

I am also grateful to the Machakos County Director of Veterinary Services for assigning me “Light” official duties during the study period so as to get enough time to carry on the research work. I thank all veterinary and livestock staff members in Machakos County who assisted me in the field work. My special thanks go to Gideon Mutinda of Mwala, Peter Kioko of Matungulu, Bibiana Mwanzia of Machakos Central and Richard Mbolonzi of Yathui for their support in the field.

This study would not have succeeded without the many roles the dairy goat farmers and their families played in allowing access to their animals. They provided the answers to the questionnaires and any other relevant information required.

Finally, I wish to express my deep appreciation and special thanks to all members of my family for their support and patience; particularly my parents for laying a good education foundation, my loving wife, son and daughter, for their untiring support throughout the study. I would also like to thank my sisters, brothers and friends for their encouragement, love, support and understanding and all those who made this work possible - may God bless you.

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LIST OF ABBREVIATIONS AND ACRONYMS

AHA- Animal Health Assistant
CAMP- Christie, Atkins and Munch-Petersen
CL^- -Chloride
CMT-California Mastitis Test
CNS- Coagulase Negative *Staphylococcus*
CPS- Coagulase Positive *Staphylococcus*
DLC- Direct Leucocyte Count
DMSCC- Direct Microscopic Somatic Cell Count
DNA- Deoxyribonucleic Acid
DOE - Female goat
EAAPP- East Africa Agricultural Productivity Project
IMVIC- Indole, Meyhylred, Voges-Proskauer and Citrate utilization tests
K^+- Potassium
KNBS- Kenya National Bureau of Statistics
LF- Lactose Fermenter
MA- MacConkey Agar
MLEE- Multi Locus Enzyme Electrophoresis
MOALFD-Ministry of Agriculture, Livestock and Fisheries Development
MOF and P- Ministry of Finance and Planning
MSA- Mannitol Salt Agar
Na^+- Sodium
NACOSTI- National Committee for Science Technology and Innovation
NCCLS-National Committee of Clinical Laboratory Standards

NLF- Non Lactose Fermenters
OR- Odds Ratio
REA- Restriction Endo-nuclease Analysis
SCC- Somatic Cell Count
SCLPO – Sub County Livestock production officer
SCVO -Sub County veterinary officer
SE- Sensitivity
SP- Specificity
Spp- Species
TSI- Tripple Sugar Iron
UV- Ultra-Violet
VO- Veterinary Officer
X^2 -Chi-Square

ABSTRACT

Dairy goat production is playing an important role in the improvement of income of the poor farmers, poverty and hunger alleviation, though the enterprises are still faced with numerous challenges such as diseases, inbreeding, poor feeding, lack of market and poor management practices. One of the major diseases that affect the dairy goat production is mastitis. It occurs after several microbes invades and colonizes the secretory tissue leading to inflammation of the mammary gland.

This study was carried out on dairy goats kept under zero grazing, semi-zero grazing and free range system in Machakos County, Kenya, from February 2014 to January 2015. The objectives of the study were to: (1) Characterize the bacteria causing mastitis in dairy goats in Machakos County; (2) Estimate the prevalence of clinical and sub clinical mastitis in dairy goats in Machakos County; and (3) Determine the risk factors for mastitis in dairy goats in Machakos County.

A cross-sectional survey was conducted to determine the prevalence of mastitis and the associated risk factors in dairy goats in Machakos County, Kenya. Four wards with the highest density of dairy goats in Machakos County were purposively selected. Each of the four wards had an average dairy goat population of 1100. Thereafter, 320 lactating dairy goats were selected randomly from 280 households within the four wards for the study.

Data was collected at both farm and animal level. The data collected at farm level included, name of the ward, gender and age of the farmer, number of dairy goats kept, other livestock kept, size of the farms, duration of the dairy goat farming, housing status of the goats, frequency of manure removal, grazing system, type of feeds, prevalent goat

diseases in the area, state of extension services, marketing of milk and whether hygiene milking was practiced. At the animal level data collected included, breed, age, stage of lactation, parity, kidding date, breeding method, pregnancy status, the current health status, length of teats and lesions on teats and udder of the lactating does. Later milk samples were aseptically collected from the does. Clinical mastitis was determined by palpation and visualization of the udder and use of strip cup to check for abnormalities such as clots, flakes and discolored milk. Subclinical mastitis was determined using California Mastitis Test and bacterial culture.

Bacterial isolation was done in blood agar. The biochemical tests for bacterial characterization included gram stain, catalase test, coagulase test, MacConkey agar, Triple Sugar Iron, CAMP test and the Imvic test. A panel of eight antimicrobials was used to test for the sensitivity of the bacterial isolates. The antimicrobials included ampicillin, tetracycline, cotrimoxazole, kanamycin, gentamycin, norfloxacin, sulphamexazole and streptomycin. The sensitivity tests were done using the disc diffusion test on Mueller-Hinton agar.

Tests of association between potential risk factors and the development of mastitis were done using the Chi-Square (χ^2) statistic ($P<0.05$) and the strength of the association using the odds ratio (OR). A univariate logistic regression analysis was additionally done to screen for risk factors potentially associated with occurrence of mastitis. Variables with a p value of ≤ 0.1 were considered significant in the univariate analysis and were included in the multivariate logistic regression model where p-values of less than 0.05 were considered significant. Kappa statistic was used to test for the agreement between the results of the California Mastitis Test (CMT) and bacterial culture.

The prevalence of clinical mastitis was 1.9% while the estimated prevalence of subclinical mastitis was 30.3% by CMT and 15% by bacterial culture. There were no significant ($P<0.05$) differences in the prevalence between the four study wards. A variety of bacteria were isolated in the milk samples, including Coagulase negative Staphylococcus (58.1%), Coagulase positive Staphylococcus (25.8%0, Streptococcus epidydimis (8.1%), Streptococcus agalactiae (4.8%) and Citrobacter (3.2%). Resistance of the bacterial isolates was common to most of the tested antimicrobials. Multidrug resistance was observed especially by the Streptococci and Citrobacter isolates.

Several factors were positively associated with the development of mastitis including poor milking hygiene (P=0.029, OR=2.2), high parity (P=0.037, OR=2.6), late stage of lactation (P=0.026, OR=2.2), infrequent removal of manure from goats house (P=0.025, OR=2.03) and the presence of lesions on teats and udder (P=0.0099, OR=2.73).

In conclusion, mastitis was detected in the dairy goat herds of Machakos County and a variety of bacteria were isolated some of which exhibited multidrug resistance. There is a need to educate the dairy goat farmers of Machakos County on the risk factors of mastitis with the aim of reducing the levels of mastitis.

CHAPTER ONE: INTRODUCTION

1.1 Introduction

Goats are the third most important group of milk producing animals after dairy cattle and buffaloes in both temperate and tropical agriculture (Farnworth, 2002). Their ability to adapt into different agro-ecological zones makes them the best source of milk in different regions. They can withstand high temperatures, parasites and diseases (Ogola *et al.,* 2010). Dairy goats are important in the rural areas where they contribute in alleviating poverty through provision of skins, meat and milk. It is also easy to keep dairy goats as the initial investment is low; they require less feed and have a good feed efficiency compared to the cow (Ogola *et al.,* 2010).

Dairy goat farming in Kenya has become a preferred business both in the highlands and in the semi-arid areas. Fragmentation of land in the highlands has resulted into small land portions that cannot optimally support dairy cattle farming. The fact that goats can be reared in small land holdings is especially useful in these highly populated areas (Kinuthia, 1997; Ogola *et al.,* 2010; MOALFD, 2013). In the semi arid areas, adverse weather conditions have resulted in the production of insufficient feed which is not sufficient for dairy cattle enterprise. The animal feed available in these areas has poor nutrition and is comprised of crop residues, shrubs and weeds. The farmers in these dry areas prefer to keep the dairy goats as they are cheap to maintain and have also high returns (MOALFD, 2013).

Although the dairy goat industry in Kenya is emerging as a high-return option for small scale-farmers, it has been faced by challenges such as inbreeding, lack of market, poor feeding, diseases and poor management practices (Ndegwa *et al.,* 2000; Ogola *et al.,* 2010). One of the major diseases that affect the dairy goats is mastitis. It occurs after

several pathogens invades and colonizes the secretory tissue leading to inflammation of the mammary gland (Ogola *et al.,* 2010; Gebrewahid *et al.,* 2012; Razi *et al.,* 2012). The microbial pathogens are yeast, viruses or bacteria while risk factors include poor management practices, inadequate feed, failure to practice hygiene milking, late stage of lactation and area under study (Radostits *et al.,* 2007). These factors determine the type of microbial agent isolated from mastitis cases (Ndegwa *et al.,* 2000; Radostits *et al.,* 2007). Among the bacterial agents, the most isolated in mastitis cases include Coagulase Positive *Staphylococcus,* Coagulase Negative *Staphylococcus, Streptococci epidydimis, Streptococci uberis, Klebsiella and Escheria Coli* (Radostitis, 2001; Gitau *et al*., 2011; Gitau *et al.,* 2014).

The economic loss due to mastitis has been reported to be one of the major setbacks in the dairy enterprise (Bradley, 2002; Radostits *et al.,* 2007). Besides reducing milk production, mastitis also poses a major risk for transmission of zoonotic diseases to humans (Radostits *et al.,* 2007; Gebrewahid *et al*., 2012).

The signs of mastitis are either clinical or subclinical. In cases where there is no visible changes in appearance of milk and udder but the milk composition is altered with presence of bacteria accompanied by decreased milk production then subclinical mastitis is diagnosed (Erskine, 2001; Radostits *et al.,* 2007; Gebrewahid *et al*., 2012).. Clinical mastitis is characterized by the visible changes in the udder and milk with the animal showing signs of anorexia and lethargy (Bradley *et al.,* 2007). Subclinical mastitis exceeds the clinical form by 15-40 times (Erskine, 2001; Radostits *et al.,* 2007; Gebrewahid *et al*., 2012). Sub clinical mastitis is diagnosed by measuring the quantity of somatic cells in milk, or through culture of the milk samples to determine the type of organisms in the sample (Quinn *et al.,* 1994; Gitau *et al*., 2011; Gitau *et al.,* 2014).

Dairy goats are important sources of animal protein in Machakos County (Machakos County Livestock Report, 2013). Although the milk is produced in small quantities, the farmers of Machakos County have a regular source of animal protein.

Dairy goats were introduced in Machakos County in 2009; however, there has been systematic decline in milk production from these goats (Machakos County Livestock Report, 2013). Among other factors, the decline in milk production has been suspected to be due to mastitis.

1.2 Objective

1.2.1 Overall objective

To determine the prevalence of mastitis and associated risk factors in dairy goats in Machakos County, Kenya.

1.2.2 Specific objectives

1. Characterize the bacteria causing mastitis in dairy goats in Machakos County.
2. Estimate the prevalence of clinical and sub clinical mastitis in dairy goats in Machakos County.
3. Determine the risk factors for mastitis in dairy goats in Machakos County.

1.3 Statement of the problem

Dairy goats are important sources of animal protein in Machakos County, but their full milking potential is affected by udder infections and yet very little has been done towards establishing the occurrence and prevalence of mastitis and associated risk factors in dairy goats as compared to the dairy cow in Kenya.

1.4 Justification

The adverse weather conditions in Machakos County, has resulted in the production of insufficient feed which is not adequate for dairy cattle enterprise (Machakos County Livestock report, 2013). The animal feeds available in Machakos County are of poor quality and mainly comprise of weeds, shrubs and crop residues. The farmers in Machakos County prefer to keep dairy goats as they are cheap to maintain and have also high returns (Machakos County Livestock report, 2013).

Despite the milk being produced in small quantities, the farmers have regular supply of protein throughout the year (Machakos County Livestock report, 2013). The decreased milk production could be due to mastitis and its associated risk factors. Besides reducing milk production, mastitis also poses a major threat to humans due to transmission of zoonotic diseases (Radostits *et al.,* 2007; Gebrewahid *et al*., 2012).

CHAPTER TWO: LITERATURE REVIEW

2.1 Population and breeds of dairy goats in Kenya

In Kenya, small ruminant farming plays an important part in rural areas by providing household income, milk, manure, skins, insurance and meat (Swai *et al.,* 2008). Other factors that encourage the rearing of ruminants are; high reproduction rates, low risk of total loss, low initial cost and low cost of maintenance (Peacock, 2005; Ogola *et al.,* 2010).

Kenya has an estimated 28 million goats of which about 80,000 are dairy goats (MOALFD, 2009). The breeds of dairy goats kept in Kenya include German Alpine, Toggenberg, Saanen, Boer, British Alpine, Anglo Nubian, Crosses, and Galla (Kinuthia, 1997; Ogola *et al.*, 2010; MOALFD, 2013). The crosses were obtained through a cross breeding programme between the indigenous goats and the exotic breeds (MOALFD, 2013). The exotic breeds survive in different climatic conditions and require specific rearing conditions in order to thrive. They provide a quick source of milk for consumption or sale and are thus of immense value especially to poor households (Kinuthia, 1997; Ogola *et al.,* 2010; MOALFD, 2013).

2.1.1 Galla goats

The Galla goat is indigenous to Northern Kenya. It is also known as the Boran or Somali goat. It is the milk queen of the Kenyan arid and semi-arid areas. They are white haired with black skin pigmentation, on the nose (muzzle), feet and underneath the tail (Plate 2.1). The Galla produces about one litre of milk per day (Ogola *et al.,* 2010).

Plate 2.1: A female Galla goat

2.1.2 Saanen Goats

This is the milk queen in the goat world. It originated from Switzerland. It is all white or creamy colored with pink skin pigmentation (Plate 2.2). Under good management it produces 3-5 litres of milk per day depending on management (Kosgey et al., 2007). They are prolific and have high twinning rate. Sometimes the kids are born with both male and female organs (hermaphrodite). This has been observed on polled goats. Udders are usually shapely and well attached.

Plate 2.2: Saanen goats

2.1.3 Toggenburg goats

The Toggenburg originated from Switzerland and Britain with the British breed being bigger than the Swiss breed. They have average milk yield of 1-3litres per day depending on management (Ogola *et al.*, 2010). The breed is suited for the higher cooler regions where heat stress is not a problem and good quality fodder is freely available (Plate 2.3).

Plate 2.3: A female Toggenbug goat

2.1.4 Alpine goats

The breed originated in the French Alps. They are medium to large in size and are hardy and adaptable animals thriving in many climates. The goat has average milk yield ranging from 2.5-4litres subject to levels of management (Ogola *et al.*, 2010). The goats are easy to milk. Their body does not have set markings, has erect ears and a dish face (Plate 2.4).

Plate 2.4: A female Alpine goat

2.1.5 Cross bred dairy goats

There are many crosses depending on the breeds used. The exotic breeds have been crossed with the local breeds to get a better adapted and higher yielding animal than the local goats. This is the best starting point for those with the local goats wishing to keep dairy goats. The performance of the crosses has varying degree of success depending on environment and management (Kosgey et al., 2007). There are also crosses between the exotic breeds for instance Saanen and Alpine (Plate 2.5).

Plate 2.5: A female cross-bred dairy goat suckling its kid

2.2 Mastitis in dairy goats

Mastitis occurs when the mammary gland is inflamed due to any cause. It involves bacteriological, chemical and physical changes in the milk. The most important changes in the milk are the increase of leucocytes, presence of clots and discoloration (Radostits *et al.*, 2000; Radostits *et al.*, 2007). The glandular tissues also change pathologically by swelling with heat, pain and indurations. The occurrence of this disease in goats is

associated with lack of post and pre- milking teat dipping, lack of treatment, unhygienic conditions and poor management (Ali *et al*., 2010).

In order to reduce production losses and tissue damage, there should be early diagnosis and treatment. Control and prevention of mastitis should be emphasized to avoid the high cost of treatment which can sometimes fail (Shearer and Harris, 2003; Radostits *et al.*, 2007). The disease is classified as either clinical or sub-clinical based on pathological findings or observation (Blood and Radostits, 2000; Radostits *et al.*, 2007).

2.2.1 Clinical mastitis

The clinical signs include visual abnormalities in the milk or udder. It is diagnosed through palpation of the udder and use of a strip cup to check for flakes and clots. Usually the udder is painful, hot and red with indurations. The milk is usually discolored with few or many clots. In severe cases there is serum with clumps of fibrin (Radostits *et al.,* 2000; Gitau *et al*., 2011; Gitau *et al.*, 2014).

Clinical mastitis is in addition classified as chronic, sub-acute and per acute. The per acute form is characterized by inflammation of the mammary gland, abnormal milk and also systemic signs which include fever, depression, anorexia and shivering (Radostits *et al.*, 2000; Gitau *et al*., 2011; Gitau *et al.,* 2014). The acute cases are usually painful with sudden onset. The quantity of milk from affected halves is reduced and altered in color. The halves are swollen, red and hot. The milk is watery with clots and flakes. Weakness, depression and fever are observed where there is systemic involvement (Khan and Khan, 2006). This form of mastitis can be a new infection or exacerbations of chronic infections and is mostly caused by *Staphylococcus aureus* and *Staphylococcus agalactiae* (Radostits *et al.,* 2000; Smith, 2002; Gitau *et al*., 2011; Gitau *et al.*, 2014).

In the sub-acute (mildly clinical) cases the affected halves and the milk appear abnormal. The milk is discolored with flakes and clots while the halves are tender and swollen (Shearer and Harris, 2003). The sub-acute mastitis is usually caused by coliforms and *Staphylococcus* (Radostits *et al.,* 2000; Gitau *et al*., 2011; Gitau *et al.,* 2014).

Chronic mastitis shows no clinical signs for long intervals. The mammary glands remain infected for long time and sometimes may periodically cause acute mastitis (Radostits *et al.,* 2000; Gitau *et al*., 2011; Gitau *et al.,* 2014). The somatic cells are chronically elevated and the milk sometimes contains flakes and shreds of fibrin. The milk production is reduced and great economic losses are usually incurred. This form is usually caused by coliforms and *Staphylococci* (Smith, 2002).

2.2.2 Sub clinical mastitis

The clinical signs include the decrease of milk production without any visible changes in the milk or udder together with increase of the milk cellular content. It is diagnosed by estimating the quantity of somatic cells in the milk (Khan and Khan, 2006).

Milk contains white blood cells and epithelial cells in large numbers. Whenever there is infection or injury of the mammary gland, there is tremendous increase in the numbers (million/ml) of the white blood cells (Shearer and Harris, 2003). To diagnose mastitis in cases where there is no inflammation of the mammary gland, the number of white blood cells in a sample of milk is determined. Whenever there is one case of clinical mastitis there are 15-40 times cases of subclinical mastitis (Shearer and Harris, 2003).

Subclinical mastitis affects milk quality, reduces milk yield, is difficult to detect, persists for a longer time and normally occurs before the clinical form. The presence of a large

number of organisms in the milk assists in the spread of the disease (Shearer and Harris, 2003). Subclinical mastitis also poses a threat of transmission of zoonotic bacteria to humans who consume raw milk (Khan and Khan, 2006).

2.3 Etiology of mastitis

There are several organisms that have been isolated from goats with mastitis with the commonest being bacterial infections (Shearer and Harris, 2003). The most common bacteria that have been isolated from goats with mastitis are *Streptococcus spp*., *Staphlococcus spp.*, *E. coli* and *Pasteurella spp*. (Contreras *et al.,* 2007). Other bacteria isolated from goats with mastitis include; *Bacillus spp Proteus spp*. and *Salmonella spp*. (Iqbal *et al.,* 2004). Other less frequent agents include: *Corynebacterium, Pseudomonas, Nocardia, Mycoplasma,* yeast and Caprine arthritis encephalitis virus (Tomita and Hart, 2001).

In a study done by Najeeb *et al.* (2013) the highest bacteria they isolated was *Staphylococcus aureus* (61.64 %) while *Escherichia coli* was (10.96 %) followed by *Streptococcus species* (9.59 %), *Pseudomonas species*, *Bacillus species* (6.85 %, each) and *Corynebacterium species* (4.11 %). *Staphylococcus aureus* had been reported earlier (Ali *et al*., 2010) as the most frequent etiological agent (45.34%) in cases of dairy goat mastitis.

Similar findings were declared by Contreras *et al*. (1995) and Bedidi-Madani *et al*. (1998). In another study by Aydin *et al.* (2009) they isolated 61% *Staphylococci aureus,* 15% *Streptococci species* and 5% *E. coli* from subclinical mastitis cases. A prevalence of *E. coli* infection of 25% was reported in dairy goat mastitis cases by Iqbal *et al*. (2004).

2.3.1 Streptococcal mastitis

The prevalence of streptococcal infection in goats is very low (1-2%) (Contreras *et al.,* 1995), though they tend to result in high somatic cell counts (Hall, 2007). The importance of these bacteria is limited in goats because of the low prevalence (Min *et al.,* 2007). *Streptococcus agalactiae* is the most commonly isolated species followed by *Streptococcus dysagalactiae and Streptococcus uberis. Streptococcus agalactiae* is highly contagious and it mostly causes subclinical mastitis, where it is also able to cause acute clinical mastitis and rarely chronic mastitis (Min *et al.,* 2007).

Transmission occurs from one doe to another during milking through contaminated milking equipment or milker's hands (Radostits *et al.,* 2000; Contreras *et al.,* 2007). *Streptococcus uberis* and *Streptococcus dysagalactiae* are mainly found in the environment where they can survive for long periods and they occasionally cause subclinical mastitis (Smith, 2002). *Streptococcus zooepidemicus* has also been isolated in goats and causes chronic superlative mastitis (Radostits *et al.,* 2000; Contreras *et al.,* 2007).

2.3.2 Staphylococcal mastitis

The *Staphylococcus* species which includes the coagulase-positive *Staphylococcus* (*Staphylococcus aureus)* and coagulase-negative *Staphylococcus* are the highly isolated bacteria that cause mastitis in goats (Shearer, 1992; Contreras *et al.,* 2007**)**. Coagulase positive *Staphylococcus* is mostly associated with clinical mastitis in dairy goats. The main source of these organisms is the udder, the teats and milk from infected glands.

Transmission from one animal to another usually occurs during milking through contaminated milking equipments and milker's hands (Radostits *et al.,* 2000; Radostits *et al.,* 2007). Coagulase-negative *Staphylococcus* comprises a number of different species

which include *Staphylococcus xylosus, Staphylococcus epidermidis*, *Staphylococcus simulans*, *Staphylococcus caprae* and *Staphylococcus chromogenes* (Bergonier *et al.*, 2003; Contreras *et al.,* 2003).

The herd level prevalence of Coagulase-negative *Staphylococcus* is usually between 25-93%, and is isolated mainly from chronic and subclinical infections (Bergonier *et al*., 2003). Coagulase Negative *Staphylococci* are the major causes of subclinical mastitis in dairy goats; the condition is characterized by significant elevation of somatic cells in the milk (Contreras *et al.,* 2003). Clinical mastitis caused by these pathogens has occasionally been reported (Deinhofer and Pernthaner, 1995; Contreras *et al.,* 2007). Coagulase Negative *Staphylococcus* are contagious pathogens found on the skin of goats and human hands and can easily be transmitted during unhygienic milking procedures. Control of staphylococcal mastitis should therefore be through hygienic milking procedures to prevent the transmission from one goat to another (Radostits *et al.,* 2000; Radostits *et al.,* 2007).

2.3.3 Coliform mastitis

Coliforms are mainly environmental organisms which include: *Escherichia coli*, *Enterobactor aerogenes* and *Klebsiella pneumoniae*. Other less-common pathogens include *Pseudomonas Species, Pasteurella multicida* and *Serratia marcescens*. Majority of coliform mastitis are characterized by discolored and watery milk. The goat has depressed appetite; udder halves are swollen and have high fever (Radostits *et al.,* 2000; Contreras *et al.,* 2007). Coliform mastitis is usually clinical, per acute and acute, with systemic involvement. Chronic mastitis has also been reported (Shearer, 1992; Contreras *et al.,* 2007). Transmission occurs at milking, between milking or during dry period when the organisms are transferred from the environment to the animal (Smith, 2002).

2.3.4 Mycoplasma mastitis

The Mycoplasma organisms that cause mastitis in goats include *Mycoplasma mycoides, Mycoplasma putrefaciens*, *Mycoplasma agalactiae* (Radostits *et al.*, 2000; Contreras *et al.*, 2007). In goats, these organisms sometimes cause serious outbreaks of mastitis which are usually characterized by decreased milk production, systemic illness and per acute death in kids (Smith, 2002). *Mycoplasma putrefacians* also causes septicaemia, polyarthritis, pneumonia, and encephalitis, together with high mortality in suckling kids. *Mycoplasma capricolum* has also been reported to cause severe mastitis and infection in kids (Cynthia and Scott, 2011; Contreras *et al.*, 2007).

2.4 Clinical signs of mastitis

Clinical signs are dependent upon host, pathogen and environmental factors (Sharif and Muhammed, 2009). The host factors are; any other disease affecting the goat, number of somatic cells, immunity status, lactation stage and number of parturitions. Pathogen factors are; the inoculums size, virulence of the strain and species of bacteria. The environmental factors include level of hygiene, type of feed and level of management. The clinical signs during the disease are greatly varied in severity (Khan and Khan, 2006).

2.4.1 Clinical mastitis

The signs include physical changes in the milk or udder. The signs and severity of the disease are considerably varied. Clinical cases can be defined as sub-acute (mildly clinical) when symptoms include only minor alterations in the milk of the affected halves such as clots, flakes, or discolored secretion. The half may also be slightly swollen and tender (Shearer and Harris, 2003).

The clinical signs of acute mastitis include, altered and reduced amount of milk produced, sudden onset, swelling, heat and pain in the halve affected. The milk is watery with flakes

and clots. Goats with systemic involvement in acute mastitis appear weak, depressed with fever. In cattle, the most virulent form of acute mastitis can cause death and hence they require urgent medical intervention (Khan and Khan, 2006).

2.4.2 Sub clinical mastitis

The clinical signs include decrease in amount of milk produced and an increase in the number of somatic cells without any physical changes in the milk or udder (Khan and Khan, 2006). Milk has large quantities of white blood cells and epithelial cells. When there is infection or injury of the mammary gland the number of white blood cells increases (millions/ml). In the absence of physical sings in the milk or udder, diagnose of subclinical mastitis is done by measuring the number of white blood cells in a sample of milk (Shearer and Harris, 2003).

The number of epithelial cells in normal milk from goats is more than those in normal milk of cows. The number of somatic cells in the mammary glands of goats is normally increased by sloughing of the epithelial cells into the milk. Sub clinical mastitis compromises the quality of milk. It also acts as a source of infection to other animals in the farm. Usually it decreases milk production, is difficult to detect and persists in herd for a long period (Shearer and Harris, 2003).

2.5 Epidemiology of Clinical and Subclinical Mastitis

The most important factors that determine the occurrence of mastitis are the herd management and geographical locality of the farm (Guidry, 1985; Contreras *et al.*, 2007). Subclinical mastitis has been known to occur even in herds that are well managed with minimal milk yields (Erskine *et al*., 2003).). It has been reported that lactating does are affected by clinical mastitis at a rate of <5% per year (Bergonier *et al.*, 2003).

In Holland after a survey of 300 dairy goat farms, the annual prevalence of clinical mastitis was reported to be 2%. Majority of the farmers did not treat the affected goats but instead were culled (Koop *et al.,* 2009). In another study done in Wilsconsin (USA) the prevalence of clinical mastitis was reported to be 1.4%. Majority of these cases of clinical mastitis were reportedly treated (Koop *et al.,* 2009). Deficiency in selenium has also been reported to be associated with occurrence of mastitis in Spain (Sánchez *et al.,* 2007). It was reported that does fed on diet deficient in selenium had a 15.4% prevalence of mastitis compared to a prevalence of 3.8% in those fed on slow release barium selenite (Sánchez *et al.,* 2007).

Koop *et al.* 2011 reported that subclinical mastitis incidence varies between 15-40% when bacterial cultures of milk samples are used to recover bacteria. Researchers use a threshold of 500,000 somatic cells per ml to measure subclinical mastitis in the goats. The sensitivity of this test ranges from 0.69-0.90 while the specificity ranges from 0.35-0.77 (Koop *et al.,* 2011). In the cow a threshold of 200,000 somatic cells per ml is used to estimate the prevalence of subclinical mastitis. The sensitivity in the cow is 0.75% while the specificity is 0.9% (Schepers *et al.,* 1997; Koop *et al.,* 2011).

In the USA researchers have reported that *Staphylococcus species* were the majority (95.7%) of organisms isolated from milk of dairy goats in which the predominant species was Coagulase Negative *Staphylococcus* (Contreras *et al.,* 1999). Ndegwa (1999) reported that milk samples from small-scale dairy goat farms in Kenya were found to have *Staphylococcus spp.* as the most prevalent bacteria with a prevalence of 78% while the Coagulase Negative *Staphylococcus* had a prevalence of 71%. Foschino *et al.* (2002) reported Coagulase Negative *Staphylococcus* in 90% of milk samples collected from ten

farms in the Bergamo area, Italy. *Staphylococcus aureus* was found in 43% of milk samples in the same study.

In Ethiopia, Gebrewahid *et al.* (2012) reported that the most prevalent pathogen in goats' milk was Coagulase Negative *Staphylococcus* (43.5%). In a study done in South Africa, majority (85.7%) of the udder halve infections were caused by Coagulase Negative *Staphylococcus* while *Staphylococcus aureus* accounted for 14.3% of the udder halves infections (Kyozaire *et al.*, 2005). The Coagulase Negative *Staphylococcus* are the most prevalent organisms detectable on udder skin, inside the streak canal, in mammary glands of dairy goats and on humans hands and can easily be transmitted during unhygienic milking procedures (Kalogridou-Vassiliadou, 1991; Koop *et al.*, 2011). Various Coagulase Negative *Staphylococcus* species are commonly detected in goat milk where they frequently cause subclinical infections persisting for several months (Moroni *et al.*, 2005a). This explains why Coagulase Negative *Staphylococcus* is the most prevalent in dairy goats.

2.6 Mastitis in dairy goats in Kenya

In a study by Ndegwa *et al.* (2001), the rate of infection of dairy goats with subclinical mastitis was found to be 28.7%, 9.8%, and 9.7% according to bacterial culture, CMT and direct leukocyte counts (DLC) respectively. A significant correlation in the results of DLC and those of CMT was reported. The correlation of the two tests was expected as both measures the number of white blood cells in the milk. The results of DLC and CMT are usually altered by the presence of large number of epithelial cells that are continuously sloughed off from the mammary gland of the dairy goats. Therefore the use of these two tests is not recommended for testing the presence of pathogens in the intra-mammary gland (Haenlein, 1987; Hinckeley, 1991). The report by Ndegwa *et al.* (2001) showed that

there was a significant higher prevalence (28.7%) of subclinical mastitis obtained from bacterial isolation as compared to that obtained by DLC and CMT methods. These authors reported no relationship between the presence of bacteria in the milk of goats and the CMT scores.

In another study done by Mbindyo *et al.* (2014), the overall rate of subclinical mastitis was 61% based on CMT while a prevalence of 57% was estimated based on culture results. In that study the most prevalent pathogens were *Staphylococcus species* (41.9%) followed by *Streptococcus species* (8.8%), *Micrococcus* (4%), *E.coli* (3%), *Corynebacterium* (1.3%) and *Pseudomonas* (0.1%). Of the *Staphylococcus*, Coagulase Negative *Staphylococcus* was more prevalent (28.3%), while *Staphylococcus aureus* prevalence was 13.5%.

2.7 Economic losses due to mastitis

Most of the economic losses in the dairy industry are due to mastitis. The economic loss is due to discarded milk, early culling, drug costs, veterinary fees, increased labor, decreased quantity and quality of milk and decreased quality of manufactured milk products (DeGraves and Fetrow, 1993; Miller *et al.,* 1993; Ali *et al.,* 2010).

In the world the losses caused by mastitis in goats is about 10 billion dollars while in cattle, it amounts to about 53 billion dollars annually (Ali *et al.,* 2010). In order to minimize the losses due to mastitis, early diagnoses and treatment is recommended (Sharrif and Muhammed, 2009). In small ruminants the economic loss caused by mastitis is very high (Mota, 2008). Mastitis leads to low production of milk and compromises the quality of final products (Mota, 2008).

In a study done by Carlton and McGavin (1995) the gangrenous type of mastitis was reported to cause the highest economic loss. It has a high mortality, morbidity, and affects

most areas of the udder. It occurs during the kidding season and is very aggressive in nature (Abu-Samra *et al*., 1988).

Different methods are used to estimate the economic loss caused by decrease in milk production in mastitis cases. One of the most important methods is based on milk somatic cell count (Seegers *et al.,* 2003). About 75% of the production losses due to subclinical mastitis are attributed to decreased milk production. Economically, subclinical infections ranks first to clinical mastitis for the reason that losses associated with subclinical infections are widespread and overwhelming. In halves affected with subclinical mastitis, total milk loss is on an average 10 -26 % (Seegers *et al.,* 2003).

Studies done in America on cattle have found that 70% of the economic loss is due to decreased milk production and milk withheld from the market while 30% of the economic loss is due to cost of drugs, veterinary fees, replacement costs and extra labor (Halasa *et al.,* 2007).

2.8 Risk factors associated with mastitis in goats

The risk factors for mastitis are divided into host, management or environmental factors (Sori *et al.,* 2005).

2.8.1 Host factors associated with mastitis

The incidence rate of mastitis has been associated with age of the goat (Boscos *et al.,* 1996; Sharma *et al.,* 2007; Ali *et al.,* 2010). It has been shown that the prevalence of mastitis increases as the age of the goat increases. Higher age (3 years or above) in goats was reported to be significantly associated with caprine mastitis (Sharma *et al.,* 2007; Ali *et al.,* 2010; Razi *et al.,* 2012). Old animals have been exposed to pathogens for a long time as compared to the young animals. This leads to an increased chance of mastitis infection in old animals than in the younger ones (Sharma *et al.,* 2007; Ali *et al.,* 2010;

Razi *et al.,* 2012). Also older animals are under stress and have low immunity caused by high parity and long periods of milk production. This makes them prone to infections including mastitis (Ali *et al.,* 2010).

The risk of mastitis in goats is also associated with the parity of the animal. Boscos *et al.* (1996) and Razi *et al.* (2012) reported that goats in their 5^{th} and 6^{th} parity were more likely to be infected by mastitis than goats in their 1^{st} and 2^{nd} parities. Similar observations were reported by Sánchez *et al.* (1996).

Length of lactation period is also associated with the occurrence of mastitis. Goats with lactation period of 3-4 months have the highest rate of mastitis infection (Razi *et al.,* 2012). Breed of the goat is another factor that determines the occurrence of mastitis in goats. The difference between the breeds may be in part associated with udder conformation, genetic traits and with metabolic, endocrine and immunological differences (Schukken *et al.,* 1990).

Other factors such as level of milk production, stress and nutritional status of the goats influence the rate of infection (Radostitis *et al.,* 2000; Sharif and Muhammed, 2009). The presence of antibodies, high blood leukocyte count together with Peripheral blood leukocyte activity has also been associated with occurrence of mastitis (Radostitis *et al.,* 2000; Sharif and Muhammed, 2009).

The morphology of teat and udder of a dairy goat is a risk factor for mastitis (Klein *et al.,* 2005). There is significant relationship between teat length and udder depth with occurrence of mastitis. The rate of milk floor has positive correlation with the teat morphology (Tancin *et al.,* 2007). Keratin which lines the teat canal acts as a natural barrier for pathogens that cause mastitis. Long teats have therefore more keratin that prevents mastitis infection (Paulrud and Rasmussen, 2004; Klein *et al*., 2005).

Teat lesions compromise the milking procedure, are painful and act as portal of entry of pathogens. The lesions include vesicles, black spot, multiple teats and skin cracks. Teat vesicles, which are due to teat injuries and deformities, are due to poor health management of the udder. They cause damage of the udder and expose the goats to secondary bacterial infection (Radostits *et al.,* 2000; Sharif and Muhammed, 2009).

2.8.2 Management factors associated with mastitis

The type of floor and the farm management system are the most important factors that determine the prevalence of mastitis in dairy goats. There is a close relationship between poor hygiene of barn or goat and high somatic cell count (Barkema *et al.,* 1999; Schreiner and Ruegg, 2003). Goats raised in earthen floors have a higher incidence of mastitis than goats kept in raised slatted floors (Ndegwa *et al.,* 2000; Razi *et al.,* 2012). The udder of goats kept in houses with earthen floors gets contaminated with infectious microbes which are in the dirty wet beddings (Razi *et al.,* 2012).

Poor milking hygiene affects the infection status of the dairy goats (Ndegwa *et al.,* 2000; Razi *et al.,* 2012). Poor milking hygiene increases the rate of infections of both the sub-acute and sub-clinical mastitis. In cases where manure is not removed frequently, there is buildup of infectious agents who later find their way into the teat canal thereby causing mastitis (Ndegwa *et al.,* 2000; Razi *et al.,* 2012).

The use of houses with either concrete or slatted floor to house the goats has been shown to decrease the mastitis infection in goats and hence is a protective factor (Razi *et al.,* 2012). Longer milking intervals has also been shown to increase the risk of mastitis infection. During the prolonged milking intervals there is a high probability of bacteria to enter through the teat orifice and invade the mammary gland. The number of halves with milk leaking is known to increase with prolonged intervals between milking. Leaking of

milk from teat orifice increases the probability of mastitis infection (Schukken *et al.,* 1990; Elbers *et al.,* 1998; Razi *et al.,* 2012). Harmonn (1994) reported that there is a significant change in somatic cell count related to varying inter-milking intervals even in healthy udder halves.

The does that suckle their kids have a high risk of mastitis infection than those does whose kids are bucket fed (Ndegwa et al., 2000; Razi *et al.,* 2012). The kids that suckle their mothers may fail to empty the udder completely leading to colonization by pathogens. Suckling kids also cause injuries on the teats through which infectious organisms gain entry. To reduce mastitis and other diseases infection, restricted suckling has been recommended (Meador and Deyoe, 1991; Razi *et al.,* 2012). The kids are also used to clear any milk left by the milker during hand milking (Meador and Deyoe, 1991; Razi *et al.,* 2012).

Post milking teat disinfection should be applied carefully as it has been shown to be associated with high incidences of mastitis infection (Schukken *et al.,* 1990; Elbers *et al.,* 1998; Barkema *et al.,* 1999; Peeler *et al.,* 2000; Zadoks and Schukken, 2006). It might be that application of post milking teat disinfection results in decreased infections with minor pathogens leading to an increased risk of infection with major pathogens (Lam *et al.,* 1997b; Peeler *et al.,* 2000; Zadoks and Schukken, 2006). This may partly explain this effect.

In the cow at the end of lactation period antibiotic therapy has been reported to be the most effective method of preventing new infections and clearing any existing infections (Elberhart *et al.,* 1979; Peeler *et al.,* 2000; Zadoks and Schukken, 2006). However, quarters that have recovered from *Streptococcus uberis* or *Staphylococcus aureus* mastitis

have a higher rate of new infection than quarters that have no history of previous infection (Zadoks and Schukken, 2006).

2.8.3 Environmental factors associated with mastitis

The occurrence of both clinical and subclinical mastitis is influenced by different environmental factors (Sandholm, 1995; Zadoks and Schukken, 2006). Environmental contamination may come from water, mud, dirt, milker's hands, manure and beddings. The mastitis pathogens that come from the environment include *Streptococcus uberis. Klebsiella pneumonia* and *Escherichia coli*. They use environmental organic matter as their food as such they propagate very well in bedding materials (Sandholm, 1995; Zadoks and Schukken, 2006).

The rate of mastitis infection depends on the number of pathogens on teat orifices and also the population of bacteria in bedding (Hogan and Smith, 1998; Zadoks and Schukken, 2006). *Streptococci* and coliforms have a short lifespan. To reduce environmental mastitis the number of pathogens in the beddings must also be reduced (Hogan and Smith, 1998; Zadoks and Schukken, 2006). The presence of these pathogens on the goat's skin is an indication of environmental contamination. The exposure of the mammary gland to infectious organisms can be reduced through applying a teat cannula at teat orifice to prevent entry of the pathogens or through increase of hygiene in the herd. (Hogan and Smith, 1998; Zadoks and Schukken, 2006).

Wet and warm weather encourage the growth rates of both environmental *Streptococci* and coliforms. The increase of humidity and temperature leads to increase in the number of pathogens in the beddings. In regions that experience both cold and warm weather, the infection patterns depends on the time of the season, with the warm weather having more infections than in cold weather (Hogan and Smith, 1998; Zadoks and Schukken, 2006).

The best bedding that should be used in dairy goats should be from inorganic materials. Washed sand is the best as it has very little nutrients that cannot support bacterial growth. (Hogan and Smith, 1998; Zadoks and Schukken, 2006).

2.9 Diagnosis

2.9.1 Diagnosis of clinical mastitis

Detection of clinical mastitis involves: palpation and physical examination of the udder and visualization of the milk for presence of any abnormalities such as clots, flakes or serous milk (Radostis *et al.,* 2000; Smith, 2002; Radostits *et al.,* 2007). To detect serous milk, flakes and clots a strip cup is used (Blood and Radostis, 2000; Radostits *et al.,* 2007). The presence of discolored milk, flakes and clots are a clear sign of inflammation (Radostits *et al.,* 2000; Radostits *et al.,* 2007).

2.9.2 Diagnosis of subclinical mastitis

Sub-clinical mastitis occurs when the mammary glands are infected but there are no obvious clinical signs both in the udder and in the milk (Blood and Radostits, 2000; Radostits *et al.,* 2007). While it is easy to detect clinical mastitis at farm level, it is difficult to diagnose subclinical mastitis due to lack of diagnostic equipments (Radostits *et al.,* 2007; Persson and Olofsson, 2011).

Milk contains large numbers of white blood cells and epithelial cells. When the mammary gland is infected or injured the white blood cell increases (millions/ml). Due to the absence of visible signs in the udder or milk the number of white blood cells is determined to diagnose subclinical mastitis (Shearer and Harris, 2003). Subclinical mastitis infection can only be diagnosed using indirect methods (Radostits, *et al.,* 2000).

2.9.2.1 California Mastitis Test (CMT)

The CMT is a simple and rapid test that can be applied at the farm. The test is particularly useful in diagnosis of subclinical udder infections. It detects the formation of a gel when deoxyribonucleic acid (DNA) in somatic cells reacts with a detergent. The reaction occurs in a CMT paddle and is graded subjectively as 0, +1, +2, and +3 (Ikram, 1997). The results can be used as a rough estimate of the number of somatic cells in milk (Shearer and Harris, 2003).

Anything that irritates the mammary gland will lead to increase of somatic cells (Smith and Roguinsky, 1997). Decrease in milk production and prolonged days in milking have been reported to increase somatic cells in the milk (East et al., 1987; Wilson et al., 1995). Therefore, CMT is not a definitive test but an indicator test. Bacterial culture should be done on all positive CMT samples in order to confirm the causative organism (Ikram, 1997).

2.9.2.2 Somatic Cell Count (SCC)

The SCC is a useful method of determining the number of leucocytes in the milk. This is done by using an automatic cell counter. The samples can either be analyzed in the farm by using a portable cell counter or in the laboratory. It can also be done through direct microscopic somatic cell count (DMSCC) that requires only simple laboratory equipment and produces results easily (Contreras *et al.,* 1996; Contreras *et al.,* 2007).

2.9.2.3 Electrical conductivity

Electrical conductivity of milk increases during mastitis due to increases in sodium (Na+) and chloride (Cl-) and decreases in potassium (K+) and lactose. Changes in conductivity can be detected by handheld or milk line instrumentation. The data obtained can be

analyzed by computer programs to detect animals with altered electrical conductivity from normal (Petzer *et al*., 2008).

2.9.2.4 Bacteriological analysis

This is a direct method of diagnosing mastitis. Bacteriological analysis is carried out through culturing of milk samples using a standard laboratory method. It can be done on individual halve samples or on composite samples including milk from all halves (Carter *et al.*, 1991; Contreras *et al.*, 2007). In a mastitis control program, the cost of bacteriological culture in the laboratory can be greatly reduced by screening the animals with the indirect tests first and then culturing the positive reactors (Wanjohi *et al.*, 2013).

2.10 Bacterial isolation and identification

Bacterial culture and characterization are carried out following standard methods as described by Sears *et al.* (1993) and Quinn *et al.* (1994). Primary culture is done on 7% sheep Blood Agar and MacConkey agar plates after which they are incubated aerobically at 37°C for 24hrs to 48 hrs. Identification of bacterial isolates on primary culture is made based on colony morphology and hemolytic characteristics on blood agar. They are then sub cultured to produce respective pure cultures, which are Gram stained. Gram stain is performed using procedure as described by Forbes *et al.* (2002) and Bebora *et al.* (2007), after which further biochemical tests and identification is carried out. The isolated organisms are identified to species levels, where possible, using a manual of veterinary laboratory techniques.

The tests done include: oxidase test, catalase test, urease test, citrate utilization test, Voges Proskauer test, Methyl-red test and Indole test, reaction on triple sugar iron agar and on sulphur indole motility medium (Sears *et al.* 1993; Quinn *et al.* 1994; Forbes *et al.* 2002). Mannitol salt agar (MSA) is used to identify *Staphylococcus* and *Micrococcus* species on

the bases of their growth characteristics. Later coagulase, catalase, and oxidase tests are done. *Streptococcus* species are examined according to Christie, Atkins, and Munch-Peterson (CAMP) reaction, growth characteristics on 7% sheep blood agar, sugar fermentation tests and catalase production (Sears *et al.,* 1993; Quinn *et al.,* 1994; Forbes *et al.*, 2002).

Different strains of the same bacteria are then differentiated based on their genotypic and phenotypic differences through typing as described by Sridhar (2006). Phenotypic properties include antigenic, shape, staining, size and biochemical characteristics which can be determined without referring to their genome. Genotypic methods are the study of the microbial DNA, the plasmid and chromosome together with their composition and presence or absence of particular genes (Sridhar, 2006). The phenotype methods used include bio typing, phage typing, bactericide typing, sera typing, antimicrobial susceptibility typing (antibiogram) and protein typing, while the genotyping include plasmid analysis, southern blot analysis and nucleotide analysis (Sridhar, 2006).

2.11 Bacterial antibiotic sensitivity tests

Antibiotic sensitivity testing is important in that it indicates which antimicrobial products would likely be effective and also those that would not likely be effective (Preez, 2000; Contreras *et al.,* 2007). It is performed using disk diffusion method on Mueller-Hinton agar (Oxoid) according to the procedure described by National Committee of Clinical Laboratory Standards (NCCLS, 2006). All isolated bacteria are tested with different antibiotics, including: Tylosine, Co-trimoxazole, Cephalonium, Tetracycline, Cefoperazone, Gentamicin, Kanamycin, Erithromycin, Norfloxacin, Tylmicosin, Ampicillin, Sulphamexazole, Amoxicillin, Penicillin G and Streptomycin (NCCLS, 2006).

The effectiveness of a drug is determined by measuring the diameter of the zone of inhibition around the disc - the larger the diameter, the more effective the drug is considered to be. The diameter is measured by use of calibrated steel ruler. The interpretation of the zone of inhibition is different for each bacteria-antibiotic combination but generally an inhibition zone diameter of ≤14mm scores 'R' for resistant while an inhibition zone diameter of ≥15mm scores 'S' for sensitive (National Committee of Clinical Laboratory Standards –NCCLS, 2006).

2.12 Treatment

The success of treatment of mastitis in does, just like in cows, depends on the efficiency of immunological system, antibiotic susceptibility of etiological agent, clinical manifestation and the cause (Preez, 2000; Contreras *et al.,* 2007). Inflammation of mammary gland causes pathological changes that block access of antibiotics to the bacteria. The other causes of treatment failure include inadequate veterinary service, poor animal husbandry, pharmacokinetic properties of antimicrobial drugs and mastitogenic bacteria related factors (Preez, 2000; Contreras *et al.,* 2007).

Over the past years, there have been developments of drug resistance by bacteria that cause diseases to humans (Witte, 1998; Razi *et al.,* 2012). Due to the smaller diameter of goat teats, intra mammary tubes designed for administration in cattle are often unsuitable for routine use in goats. Currently, antibiotic intra mammary tubes have been of limited success and it may be necessary to design an applicator with a finer nozzle (Younan, 2002). Successful treatment usually depends on the etiological agent, sensitivity results, extent of tissue damage, severity of the infection, choice of drugs, their availability and access to the patient (Radostits *et al.*, 2000; Razi *et al.,* 2012).

Treatment of clinical mastitis is through a therapeutic approach which involves use of systemic antibiotics and anti-inflammatory drugs with regular stripping of the mammary glands (Taufik *et al.*, 2008). Subclinical mastitis treatment is usually done by use of commercially prepared intra mammary antibiotics (Shearer and Harris, 2003). When systemic antibiotics are used to treat mastitis, higher doses are given to ensure enough concentrations get to the udder.

Commonly used drugs for treatment of mastitis include Penicillins at 16500I.U/kg body weight, Oxytetracyclines at 10mg/kg body weight, Tylosine at 12.5/kg body weight, Sulphadimidines 200mg/kg bodyweight, cloxacillin 5mg/kg body weight, amoxicillin plus clavulanic acid 10mg/kg body weight, cephalonium and cefoperazone 10mg/kg body, erythromycin 10mg/kg body weight, tylmicosin 10mg/kg body weight, kanamycin 10mg/kg body weight, and ampicillin 10mg/kg body weight. Administration of dexamethasone 5mg/kg body weight in the mammary gland has been reported to reduce swelling (Radostits *et al.*, 2000; Razi *et al.*, 2012).

2.13 Prevention and control

Mastitis in small ruminants, especially the goat, often persists through the lactation and dry periods, and re-infection is common. Self-cure rates for subclinical mastitis during the dry period are 20% to 60% in the doe (Bergonier *et al.*, 2003; Sharif and Muhammad, 2009). New infections are associated with the first third of lactation, the start of machine milking, and the suckling-to-milking transition (Bergonier *et al.*, 2003; Sharif and Muhammad, 2009). Mastitis control programs should focus on hygiene, the milking system and process, dry-off protocols, treatment and culling. Culling often is the best recommendation for animals with clinical mastitis and for those with subclinical disease

that do not respond to dry therapy and treatment (Bergonier *et al.*, 2003; Smith and Sherman, 2009).

A program for control of mastitis should have information on the type of mastitis affecting the dairy herd and the possible losses (Sandholm, 1995; Sharif and Muhammad, 2009). Initially the health of the udder is assessed and all the lactating animals screened for mastitis (Sandholm, 1995; Sharif and Muhammad, 2009). The lactation period is the most critical phase of the dairy animals as it is when new infections occur. These infections normally occur while milking. Contagious mastitis is controlled by using teat disinfectant before milking, practicing good hygiene milking and dry therapy. To reduce mastitis cases in the herd early diagnosis and treatment is recommended (Sharif and Muhammad, 2009).

Infection by environmental mastitis is controlled by ensuring that the teats are not exposed to bacteria. The does should be provided with dry and clean beddings and their surroundings regularly cleaned to remove any possible contaminants. Additionally environmental *Streptococci* are controlled in dry period by use of antibiotic therapy in both halves (Sharif and Muhammad, 2009).

Milking order should be followed for effective control of environmental mastitis. The does that are infected should be milked last and feed should be provided to all does immediately after milking to ensure that they remain standing for thirty minutes to allow the teat orifice to close (Tomita and Hart, 2001; Sharif and Muhammad, 2009). Culling of chronically infected does should be done to prevent them from spreading the disease to others as it is cheaper to replace them than treat mastitis (Tomita and Hart, 2001; Sharif and Muhammad, 2009).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Ethical Approval

The present study was carried out after approval by the Biosafety, Animal use and Ethics Committee of the Faculty of Veterinary Medicine, University of Nairobi (Appendix I).

3.2 Study Area

The study was conducted in Machakos County, Kenya, from February 2014 to January 2015. The County borders Embu, Muranga and Kiambu to the North and West, Nairobi and Kajiado counties to the West, Makueni County to the South and Kitui County to the East (Figure 3.1). Most areas of the County are semi-arid and have a total acreage of 6,208.20Km^2. It has eight sub-counties including Masinga, Yatta, Matungulu, Kangundo, Kathiani, Mwala, Machakos town and Athi River.

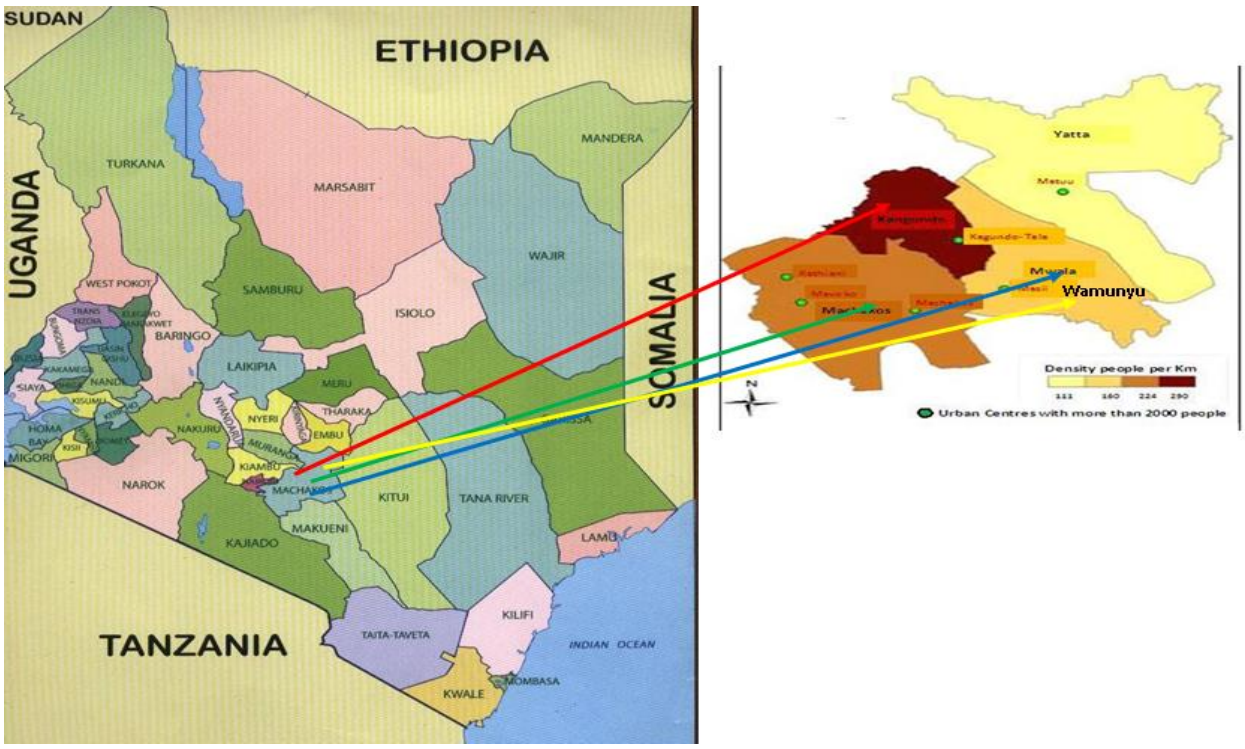

Figure 3.1: Map of Kenya showing the study County of Machakos

Machakos County has two rainfall seasons; long rains (March – May) and short rains (October – December) of over 900mm per annum with temperatures ranging from 22^0C to 30^0C. The County has an estimated total human population of 1,098,600 in 264,500 households, a population density of 188 persons per Km^2 and an annual growth rate of 1.7%. Kangundo sub-county has the highest population density of 565 persons per Km^2 while Masinga sub-county is the least densely populated with 95 persons per Km^2 (KNBS, 2009).

The County has a total of 629,974 goats (KNBS, 2009). The estimated number of dairy goats is 8,214 (Machakos County livestock, 2013). These are either pure or cross-bred German Alpine, Toggenburg, Saanen and Galla. Most dairy goat farmers in the county are smallholders owning an average of 5-8 goats.

3.3 Study design

A cross-sectional survey was conducted to determine the prevalence of mastitis and the associated risk factors in dairy goats in Machakos County, Kenya. Machakos County was selected for the study because of the continued systematic decline of the quantities of milk produced by the dairy goats since their introduction in 2009 (Machakos County livestock report, 2013). It has been suspected that mastitis and its associated risk factors could be a cause.

The Machakos County Director of Veterinary Services (CDVS) availed maps showing the sub-counties and their respective wards. The CDVS also availed the County annual report of 2013 and the results of the national census of 2009 showing both the livestock and human population in the County. The CDVS also gave the conducts of the respective Sub-County Veterinary Officers (SCVO), Sub-County Livestock Production Officers (SCLPO)

and Animal Health Assistants (AHA) in the respective Sub-Counties and wards that were later used to identify households with lactating dairy goats.

3.4 Sample size determination

Sample size was determined using the formula by Dohoo *et al.* (2003):

$n= (Z^2\alpha pq)/L^2$,where n is the required sample size, *Zα* is the value of Z that provides 95% confidence intervals (1.96), p is *a priori* estimate of prevalence of mastitis in goats which from previous studies was 28.6% (Ndegwa *et al.*, 2000), L is the precision of the estimate at 5%, q is 1-p.

$n= Z^2_{\alpha}p\ (1-p)/L^2 = (1.96)^2 0.286\times 0.714/\ (0.05)^2 = 313.78$

A sample size of 320 was adopted.

3.5 Identification and selection of the study goats

The study goats were lactating dairy goats of Toggenburg, German alpine, Galla, Saanen and cross- breeds, managed either under improved or traditional husbandry practices. The goats were either kept in zero-grazing system, semi-zero grazing system, tethering or free range. In the semi-zero grazing system, the goats were fed with grass cut from the farms and sometimes they were grazed in the open fields. Another source of feed was crop residues especially in the dry seasons and post-harvest period.

Farmers had different houses for the goats. Some houses had earthen floors while others had raised stall with slatted floor. The farmers acquired the dairy goats by buying from other farmers in a subsidized price. There are also local microfinance institutions which provided them with loans to purchase the dairy goats from other areas of Kenya. The goats also varied in ages, parities and stages in lactation.

Four wards with the highest density of dairy goats in Machakos County were purposively selected. These wards were Matungulu west ward (Matungulu Sub County), Kiima kimwe/Muvuti ward (Machakos town Sub County), Wamunyu/Yathui Ward (Mwala Sub county) and Mwala/Makutano ward (Mwala sub county) (Machakos County livestock report, 2013). Each of these four wards had an average population of dairy goats of 1100.

A total of 280 households owning lactating dairy goats and from within the four wards were randomly selected for the study. A maximum of two lactating goats were selected from each household for the study. Since the population of dairy goats in the four study wards was the same, eighty lactating does were randomly selected from each of the four wards to make a sample size of 320 lactating goats.

The objectives of the study were explained to the farmers and permission to take part in the study sought. Questionnaires (Appendix II) were administered via personal interviews to those who agreed to take part in the study. The goats were examined (Appendix III) and milk samples taken from them.

3.6 Data collection

Data were collected through administration of questionnaires, physical examination of the goats' teats and udder, and laboratory analysis of milk samples.

3.6.1 Household interviews using questionnaires

A questionnaire (Appendix II) was administered to household heads to collect information on management practices. The questionnaire data included data such as type of doe (milking/suckling), parity, production in litres, feed/grazing system, size of litter, housing practiced, lactation stage, breed, lesions on udder or teats, study site, rate of manure removal and hygiene milking.

3.6.2 Physical examination of the goats

Physical examination of the goats was conducted (Appendix III). A detailed visual inspection and systemic palpation of udder and teats of the lactating does was done. Visible lesions on the teat and udder were recorded. The lesions of interest included chapped cracked skin, injuries, wounds, teat end hyperkeratosis, supernumerary teats, black spot, suckling damage, fly bites, vesicles, warts, scars, allergic reactions, photosensitization, chemical damage, abrasions and cuts.

Teat length was measured by calibrated steel ruler and was taken as the distance from the base of the teat to the end of teat. Inspection of the udder included visual examination of the posterior of does to record any changes in symmetry and size. The position of the udder halves were recorded and any abnormal physical changes noted. The abnormal appearance included edema, fibrosis, presence of multiple teats and fibrosis.

3.6.3 Collection of milk samples

The goats were first restrained and the udder washed with clean water. The teats were dried with disposable paper towel and disinfected with 70% alcohol. Using aseptic methods, milk samples were collected from each teat of all the 320 lactating dairy goats regardless of whether they had clinical mastitis or not.

After discarding the first strips of milk, ten mls from each halve was collected into labeled sterile sample bottles. The bottles were then capped and kept in cool boxes with ice packs at 4^0C and transported within 24 hrs to the Department of Public Health, Pharmacology and Toxicology, University of Nairobi for laboratory analysis.

3.6.4 Examination of does for clinical mastitis

The udder of each doe was palpated and visualized to check for any changes in consistency, size and temperature. A strip cup was used to check for any abnormalities such as clots, flakes, serous or discolored milk.

3.6.5 Treatment of clinical cases

During sampling, goats found to have clinical mastitis were treated with broad-spectrum antibiotics. After culturing, identification and sensitivity tests were complete the goats were treated with the appropriate antibiotics.

3.7 Laboratory analysis of milk samples

3.7.1 California Mastitis test (CMT)

Milk samples from udder halves of apparently healthy does were screened for subclinical mastitis infection using the CMT according to the procedures and the interpretation by Quinn *et al.* (1994). Two mls of milk was put in sterile mastitis paddle wells. Equal volume of the CMT reagent was added and the mixture shaken gently. Gel formation was recorded as a positive result while lack of gel formation was recorded as a negative result. Additionally the results were recorded in four categories; 0, +1, +2, and +3. Scores that were $\geq$+ 2 was considered positive while those which were 0 and +1 were considered negative (Quinn *et al.*, 1994). Interpretation of the results was as follows; 0 = no reaction, +1= Distinct thickening during rotation, but no gel, +2 = slight formation of gel which follows the rotating plate very slowly and +3 = solid formation of gel that adheres to the base of the plate. The milk samples with obvious signs of clinical mastitis were not subjected to CMT.

3.7.2 Bacterial culture

A standard of 0.01 ml of milk sediment was inoculated by streaking onto the surface of 5% sheep blood agar plates and MaCconkey agar (MA) plates (Carter *et al.*, 1991) and incubated at 37^0C for 24-48 hrs. The growth of microorganisms on the plates was determined after the incubation period. Cultures with bacterial growth were recorded positive while those without growth were recorded negative. Pure cultures were further obtained by sub-culturing part of typical and well isolated colony on a corresponding medium (5% sheep blood agar and MaCconkey) and incubated further at 37ºC aerobically for 24 hours. Mixed growths were then sub cultured onto fresh media of same type to obtain pure colonies.

3.7.3 Bacterial isolation and identification

The bacterial growths were studied macroscopically for abundance, colonial morphology and their hemolytic properties (*Staphylococcus* and *Streptococcus* were differentiated on the blood agar on the basis of their different hemolytic properties). Biochemical tests were done to identify the isolates. The bacteria were identified using standard procedures and features (Carter *et al.,* 1991)**.** Gram stain procedures were performed according to the method described by Quinn *et al*. (1999), Forbes *et al*. (2002) and Bebora *et al*. (2007).

To differentiate *Staphylococcus* and *Streptococcus spp,* catalase reaction was performed on all Gram positive isolates employing the rapid slide technique described by Cheesbrough (1985). A drop of 3% hydrogen peroxide was placed on a slide, organism was added and mixed and observed for bubbling to confirm the presence of catalase enzyme. Catalase negative reaction indicated presence of *Streptococcus* species whereas catalase positive indicated *Staphylococcus* species.

Coagulase test (Appendix IV) was carried out to differentiate *Staphylococcus aureus* from other *Staphylococcus* species. *Staphylococcus aureus* is coagulase positive while coagulase-negative *Staphylococci* are negative. The CAMP (Christie, Atkins and Munch-Petersen) test (Appendix V) and growth in MacConkey agar plate was carried out to differentiate *Streptococcus agalactiae* from other mastitis causing *Streptococcus* (*Streptococcus agalactiae* potentiates *Staphylococcus aureus* hemolysin leading to complete or Beta (β) haemolysis of the red blood cells on Bovine blood Agar – a positive CAMP test) (Sears *et al.,* 1993; Quinn *et al.,* 1994; Forbes *et al.,* 2002). *Streptococci agalactia* was identified by testing Catalase-negative *Streptococci* with Bacitracin. *Streptococci agalactia* tests negative (Sears *et al.,* 1993; Quinn *et al.,* 1994; Forbes *et al.,* 2002).

Gram-negative isolates (*Enterobacteriaceae, Klebsiella, Citrobacter, E.Coli, Proteus and enterobacter*) were sub-cultured on MacConkey agar from blood agar to differentiate them on their ability to ferment lactose (lactose fermenters) and (non-lactose fermenters). The lactose fermenters are *Klebsiella, Citrobacter, E.Coli or Enterobacter* while the non-lactose fermenter is *Proteus*. The motility of the lactose fermenters organisms was tested by growth on semi solid soft agar. The motility was indicated by growth of the organisms away from the stab line. Those that were motile were classified as *E.coli, Citrobacter* or *Enterobacter. Klebsiella* is non-motile.

In addition Triple sugar Iron (TSI) Agar, IMViC test (Indole, Methyl red, Voges-Proskauer and Citrate utilization tests) and oxidase reaction tests were done (Sears *et al.,* 1993; Quinn *et al.,* 1994; Forbes *et al.,* 2002). Those that tested positive in Indole and Methyl red test were either *E.Coli* or *Citrobacter*. The Citrate test differentiated the *E.Coli* and *Citrobacter. Citrobacter* is Citrate positive while *E.Coli* is citrate negative (Table 3.1).

Table 3.1: Summary of tests done on Gram Negative bacteria isolated in dairy goat milk in Machakos County, Kenya 2014

Test/ Organism	LF(+ve), NLF(-ve)	Motility test	Indole test	Methyl test	Citrate test	IMVIC test
Klebsiella	+ve	-ve	eliminated	eliminated	eliminated	Eliminated
Proteus	-ve	eliminated	eliminated	eliminated	eliminated	Eliminated
E. Coli	+ve	+ve	+ve	+ve	-ve	Eliminated
Citrobacter	+ve	+ve	+ve	+ve	+ve	-+-+
Enterobacter	+ve	+ve	-ve	-ve	Eliminated	Eliminated

NB; (1) Motility was tested on semi solid soft sulphur agar

(2) "Eliminated"- Any organism that tested (-ve) was not included in the subsequent tests

Key; LF= Lactose fermenters, NLF=Non lactose fermenters

3.8 Antimicrobial sensitivity tests

3.8.1 Preparation of organisms for sensitivity tests

The organisms were cultured separately in triple sodium azide medium at 37^0C for 24 hours. After growth, 3 colonies for each organism were picked and placed into 9mls normal saline in a test tube. The mixture was shaken using the vortex machine. The turbidity of the mixture was compared with McFarland standard 10^{-5}.

3.8.2 Sensitivity tests

Sensitivity test was done using the disk diffusion method on Mueller-Hinton agar as described by National Committee of Clinical Laboratory Standards (2006). Sterile cotton swabs were used to transfer diluted bacterial suspension onto Mueller-Hinton agar plates. The swabs were rubbed on the whole agar surface to seed the bacteria uniformly.

Paper discs impregnated with eight locally available drugs (ampicillin, sulphamexazole, gentamycin, co-trimoxazole, tetracycline, kanamycin, norfloxacin and streptomycin) were used as in Multodisk®. They were applied using sterile forceps on the surface of Himedia Mueller Hinton agar which was earlier impregnated uniformly with the bacteria under test, and then incubated overnight at 37°C.

The diameter of inhibition zone around the disc was measured to determine the effectiveness of a drug (a drug with a large diameter comparative to others was considered more effective). Classification of micro-organisms into sensitive and resistant was according to the guidelines given in the manual developed by Stephen *et al.* (2005) of the National Committee for Clinical Laboratory standards (2006). Also the interpretation of the zone of inhibition was different for each bacteria-antibiotic combination but generally an inhibition zone diameter of ≤14mm scored 'R' for resistant while an inhibition zone diameter of ≥15mm scored 'S' for susceptible (Appendices VI-VIII).

3.9 Data handling and analysis

Data were entered in a Microsoft Excel 2008 spreadsheet and exported to both Instat® and Stata® for statistical analyses. Descriptive statistics including frequency tables, graphs, means and their standard deviations were generated using the same softwares. Prevalence of both clinical and subclinical mastitis in dairy goats in Machakos County was calculated as described by Thrushfield (2005) (Appendix IX).

Chi-square (χ^2) statistic was used to test for associations between the potential risk factors (explanatory variables) and occurrence of mastitis (outcome variable). In all chi-square test applications, level of $p<0.05$ was considered statistically significant. Univariate analysis was additionally done to screen for risk factors potentially associated with occurrence of mastitis. These included type of doe (milking/suckling), parity, milk

production in litres, feed/grazing system, litter size, type of housing, stage of lactation, breed, study site, presence of lesions on teat or udder, rate of manure removal and milking hygiene. Variables with a p value of ≤ 0.1 were considered significant in the univariate analysis and were included in the multiple logistic regression procedure where p-values of less than 0.05 were considered significant. The odds ratio (OR) was used to determine the strength of any associations identified in the multivariate logistic regression procedure. Kappa statistic (Dohoo *et al.,* 2003) (Appendix X) was used to test for the agreement between the results of the California Mastitis Test (CMT) and bacterial culture.

CHAPTER FOUR: RESULTS

4.1 Response rate

Out of the 280 households visited to sample 320 goats, none declined to participate in the study. This gave a response rate of 100%.

4.2 Characteristics of survey households

4.2.1 Number, gender and age of the goat farmers

All the farms recruited for this study were small scale. A total of 280 goat farms participated in the study out of which 320 goats were sampled. Most (85.7%; 240/280) of the farmers had a single lactating goat and 40 farmers had two lactating goats at the time of the survey. Matungulu west ward, had majority (26.8%; 75/280) of the dairy goat farmers, while Wamunyu/Yathui ward had the least (23.2%; 65/280) number of farmers (Table 4.1). Majority (95%; 266/280) of the dairy goat farmers were 31 years of age and above (Table 4.2). There were more female famers in all the age categories than there were male farmers. Overall female farmers constituted 77.5% (217/280) of the dairy goat farmers (Table 4.2).

Table 4.1: Number of dairy goat farmers surveyed in Machakos County, Kenya 2014

Ward	No of farmers	Proportion (%)
Wamunyu/yathui	65	23.2
Kiima kimwe/muvuti	67	24.0
Matungulu west	75	26.8
Mwala/makutano	73	26.0
Total	280	100

Table 4.2: Sex and age distribution of dairy goat farmers surveyed in Machakos County, Kenya 2014

Sex	Age (years)				
	20-30 No (%)	31-40 No (%)	41-50 No (%)	>50 No (%)	Total No (%)
Male	5 (1.8)	27 (9.7)	18 (6.4)	13 (4.6)	63 (22.5)
Female	9 (3.2)	67 (23.9)	81 (29)	60 (21.4)	217 (77.5)
Total	14 (5)	94 (33.6)	99 (35.4)	73 (26)	280 (100)

No= Number

4.2.2 Land acreage

Land sizes ranged from less than four acres to more than 10 acres. Kiima Kimwe/Muvuti ward had the highest proportion (22%) of small farms (<4 acres) while Mwala/Makutano ward had the highest (8%) of farms larger than 10 acres (Table 4.3).

Table 4.3: Land acreage in the study wards, separately and combined in Machakos County, Kenya 2014

Land size (acres)	Ward								Total n= 280	
	Wamunyu/ Yathui: n=65		Kiima Kimwe /Muvuti: n=67		Matungulu west n=75		Mwala/Makutano n=73			
	No	%	No	%	No	%	No	%	No	%
1-4 acres	12	4	60	22	38	14	9	3	119	43
5-10acres	38	14	5	2	29	10	40	14	112	40
> 10acres	15	5	2	1	8	3	24	8	49	17

4.2.3 Other livestock kept by study households

A variety of livestock were kept by the dairy goat farmers as displayed in Table 4.4. The most common livestock were cattle and poultry. Therefore goats were the commonest species kept by all (280) survey farmers.

Table 4.4: Other livestock kept by the 280 surveyed dairy goat farmers in Machakos County, Kenya 2014

Ward	No of Livestock farmers				
	Cattle	Sheep	Poultry	Rabbits	Pigs
Wamunyu/Yathui	45	7	62	4	-
Kiima Kimwe	51	6	65	2	-
Matungulu West	41	3	69	8	2
Mwala/Makutano	58	12	73	5	-
Total	195	28	269	19	2

4.3 Characteristics of the study goats

4.3.1: Breeds of the study dairy goats

Of the total 320 dairy goats sampled for mastitis testing, the most commonly kept breed was Toggenberg (50.6%; 162/320). Other breeds reared included the German alpine (25%; 80/320), Crosses, Galla and the Saanen (Table 4.5). The least common breed in the study was Saanen with only one goat sampled each in Matungulu west and in Mwala/Makutano wards, respectively (Table 4.5). Cross breeds were found in all the study wards. Galla goats were sampled in all wards except in Matungulu west ward. In Wamunyu/Yathui ward, the German Alpine was the most common while in all the other wards Toggenberg was the most common (Table 4.5).

Table 4.5: Distribution of dairy goats by breeds and ward in Machakos County, Kenya 2014

Breed	Ward				
	Wamunyu/Yathui	Kiima Kimwe	Matungulu west	Mwala/Makutano	Total
German alpine	35	20	12	13	80
Toggenberg	19	39	54	50	162
Galla	5	6	-	2	13
Crosses	21	15	13	14	63
Saanen	-	-	1	1	2
Total	80	80	80	80	320

4.3.2. Age of the study dairy goats

About three-quarters (74%; 237/320) of the lactating goats were between 1.5 years and six years. A small proportion (4.7%; 15/320) was less than 1.5 years (Table 4.6). All the sampled goats used a buck for breeding. A total of 82 bucks were used for breeding. Most (66%; 212/320) of the goats were served by a Toggenberg buck. Only 3% (10/320) of the study goats were served by a Galla buck.

Table 4.6: Age of the study dairy goats in Machakos County, Kenya 2014

Breed	Age (Years)				
	<1.5	1.5-3	3-6	>6	No (%)
German Alpine	4	26	33	17	80 (25)
Toggenberg	8	53	67	34	162 (50.6)
Galla	1	4	5	4	13 (4.1)
Cross	2	21	26	13	63 (19.7)
Saanen	-	1	1	-	2 (0.6)
Total (%)	15 (4.7)	105 (32)	132 (41)	68 (21)	320 (100)

4.3.3 Stage of lactation of the study dairy goats

The average length of lactation of the study goats was three months. Majority (65%; 208/320) of the study goats had been in lactation for more than two months, 35% (112/320) in early lactation, 37.2% (119/320) in mid lactation and 27.8% in late lactation by the time of the survey (Table 4.7).

Table 4.7: Stage of lactation of the study dairy goats

Stage of lactation	Number	Proportion (%)
Early in lactation (≤2months)	112	35.0
Mid in lactation (>2-4months)	119	37.20
Late in lactation (>4months)	89	27.80
Total	320	100

4.3.4 Parity and pregnancy status

At the time of study a high percentage (77%; 245/320) of the study goats had a parity of one or two, 11% (35/320) had a parity of 3-4 and 12% (40/320) had parity of five and above (Table 4.8). A small percentage (20%; 65/320) of the study goats was pregnant at the time of the survey.

Table 4.8: Parity of the dairy goats in Machakos County, Kenya 2014

Parity	Number	Proportion (%)
≤2	245	77
3-4	35	11
≥5	40	12
Total	320	100

4.4 Housing

Of the 320 goats, 86.5% (277/320) were housed and the rest were tethered in the compound. Majority (88%; 244/277) were housed in goat pens with raised slatted floor (Table 4.9). The type of floor of the houses varied from wooden plunks (65%; 180/277), to natural stones (0.7%; 2/277), murram (23.8%; 66/277), sisal stems (8%; 22/277) and concrete (2.5%; 7/277). Manure was reportedly removed from where the goats slept once a day (46.9%; 150/320) and after a week (53.1%; 170/320) (Table 4.9). Nearly all goats (98%; 315/320) did not use beddings, and of the five with beddings, use of a sack was the most common (80%; 4/5). An example of a goat house is shown in appendix XI.

Table 4.9: Housing status of 320 survey dairy goats in Machakos County, Kenya 2014

Housing of the goats		Number	Proportion (%)
Housed	Yes	277	86.5
	No	43	13.5
Type of housing	Pen with raised slatted floor	244	88
	Brick house	25	9
	Stone house	8	3
Type of floor	Timber	180	65
	Murram	66	23.8
	Sisal stems	22	8.0
	Concrete	7	2.5
	Natural stones	2	0.7
Manure removal and cleaning	Once per day	150	46.9
	>once per week	170	53.1
Use of beddings	Yes	5	1.6
	No	315	98.4

4.5 Farming systems and feeding

The two commonly practiced farming systems by the farmers were semi-zero grazing (38.9%; 109/280) and free range (37.5%; 105/280). Only a few farmers (9.7%; 27/280) practiced zero-grazing and tethering (13.9%; 39/280) (Table 4.10). The farmers fed their goats on a variety of feeds including local grass (41%; 115/280), shrubs (22.5%; 63/280), crop residues (17.8%; 50/280), napier grass (9%; 25/280), sweet potato vines (1.2%; 3/280) and Lucerne (8.4%; 24/280) (Table 4.11). Almost half (49.3%: 129/280) of the surveyed farmers complained of lack of feed as a major constraint to keeping goats.

Lack of feed was reportedly severe during the dry season. This was reported by almost all (99.4%: 278/280) of the interviewed farmers. The use of supplements was uncommon, being reported to be used by only 20.9% (59/280) of the farmers interviewed (Table 4.11).

Table 4.10: Farming systems practiced by 280 farmers of dairy goats in Machakos County, Kenya, 2014

Farming system	Number	Proportion (%)
Zero grazing	27	9.7
Semi zero grazing	109	38.9
Tethering	39	13.9
Free range	105	37.5

Table 4.11: Feeding of survey goats in Machakos County, Kenya, 2014.

Feeding of goats		No of farmers	Proportion (%)
Type of feed	Napier grass	25	9
	Lucerne	24	8.4
	Shrubs	63	22.5
	Crop residues	50	17.8
	Local grass	115	41
	Sweet potato vines	3	1.2
Adequate feed	Yes	151	54.1
	No	129	45.9
Inadequate feed during	Dry season	278	99.4
	Rainy season	2	0.6
Supplements	Yes	59	20.9
	No	221	79.1

4.6 Milking technique, milk production and hygiene

There were only two milking techniques practiced by the farmers- pulling of teats (75.7%; 212/280) and squeezing (24.3%; 68/280). Majority (82.1%; 230/280) of the farmers milked their goats twice a day and only a small proportion (1.4%; 4/280) milked their goats thrice in a day (Table 4.12). A large proportion (40.3%; 113/280) of the farmers reported that their goats produced two litres of milk per day. Only 10% (28/280) of farmers reportedly had goats that produced four litres of milk or more per day (Table 4.12). Almost all (99%; 277/280) the farmers allowed their goats to suckle their kids. Only 1% (3/280) of the farmers bucket fed the kids. Over three-quarters of the farmers (78.6%; 220/280) allowed the kids to suckle twice a day. As far as milking hygiene was concerned, almost all (98.2%; 275/280) the farmers washed their hands and goat teats before milking. About a third (32.8%; 92/280) of the farmers used teat disinfection and paper towels while the rest (67.1%; 188/280) did not use (Table 4.13). None of the 280 farmers treated their goats with antibiotics during their dry periods.

Table 4.12: Milk production of dairy goats in Machakos County, Kenya, 2014

Milking technique and milk production		Frequency	Proportion (%)
Milking technique practiced on the goats	Squeezing	68	24.3
	Pulling	212	75.7
Frequency of milking per day	Once	46	16.4
	Twice	230	82.1
	Thrice	4	1.4
Milk production per day (litres)	1	105	37.5
	2	113	40.3
	3	34	12.1
	≥ 4	28	10.0

Table 4.13: Milking hygiene practices of dairy goats by farmers in Machakos County, Kenya 2014

Milking hygiene practices	Level	No of respondents	Proportion (%)
Wash hands and teats before milking	Yes	275	98.4
	No	5	1.6
Teat disinfection and use of paper towels on goats	Yes	92	32.8
	No	188	67.2
Use of antibiotic dry therapy on goats	Yes	0	0
	No	280	100

4.7 Marketing and utilization of milk

A high proportion (72.5%; 203/280) of the farmers consumed the milk produced at home and only (27.5%; 77/280) sold the milk. Most of the farmers (74%; 57/77) sold the milk to their neighbors and the rest (26%; 20/77) in the neighborhood markets. The price of milk varied from Ksh 40 to over Ksh110 per litre (Table 4.14). Almost all (95%; 266/280) the farmers interviewed were not satisfied with the prices of milk offered.

Table 4.14: Marketing of milk from dairy goats in Machakos County, Kenya, 2014.

Milk marketing and utilization	Level	Frequency	Proportion (%)
Milk utilization	Consumed	203	72.5
	Sold	77	27.5
Milk marketing	Neighbors	57	74
	Nearest market	20	26
Price of milk per litre (Ksh)	Ksh 40-70	38	49.4
	Ksh 71-110	32	41.6
	Ksh >110	7	9.1
Price satification	Yes	14	5
	No	266	95

4.8 Constraints faced by dairy goat farmers

The farmers reportedly faced a variety of constraints in dairy goat production. The vast majority (43.6%; 122/280) reported lack of feeds as their greatest constraint (Table 4.15). Another constraint was the high cost of mineral supplements reported by 69 of the 280 (24.6%) survey farmers. Other minor constraints experienced are shown in Table 4.15.

Table 4.15: Constraints faced by dairy goat farmers in Machakos County, Kenya 2014

Challenges	Number of farmers	Proportion (%)
High cost of feed	122	43.6
High cost of mineral supplements	69	24.6
Diseases	26	9.3
High cost of treatment	19	6.8
Lack of training in goat production	18	6.4
Poor and lack of milk market	10	3.6
Water scarcity	5	1.8
Theft of goats	4	1.4
High cost of drugs(dewormers)	2	0.7
Lack of qualified veterinary staff	1	0.4

4.9 Common diseases and conditions affecting dairy goats and extension services

A variety of goat diseases were reported. The most commonly reported diseases were worm infestation (53.6%; 150/280) and diarrhea (34.3%; 96/280). Other reported diseases included Pneumonia, Mastitis, Foot rot, eye infections, Mites, Abscess, Orf and Bloat (Table 4.16). Professional veterinary services were reportedly available to the Machakos County dairy farmers. Majority (58.1%; 162/280) of the farmers had the services of animal health assistants (AHAs) while others (30.9%; 87/280) had the services of a paravet (Table 4.17). Very few (5.6%; 16/280) farmers sought the services of a veterinary officer. A few farmers (5.3%; 15/280) treated their sick goats. Only 5.1% (15/280%) of the farmers reported a sick goat at the time of survey. Six of 280 (2.1%) farmers had goats with mastitis at the time of the survey. Only 5.6% (16/280) of the farmers reportedly had treated their goats against mastitis in the past (Table 4.17).

Table 4.16: Diseases and conditions affecting dairy goats in Machakos County, Kenya 2014

Disease	No of respondents	Proportion (%)
Worm infestation	150	53.6
Diarrhea	96	34.3
Foot rot	12	4.4
Bloat	8	2.8
Mastitis	6	2.2
Mites	3	0.9
Orf	2	0.6
Abscess	1	0.3
Eye infections	1	0.3
Pneumonia	1	0.3

Table 4.17: Extension services offered to dairy farmers in Machakos County, Kenya, 2014

Extension services	Level	No of farmers	Proportion (%)
Who treats the goats	VO	16	5.6
	AHA	162	58.1
	Paravets	87	30.9
	Self	15	5.3
Goat currently sick?	Yes	15	5.1
	No	265	94.9
If sick what is the disease?	Orf	1	0.4
	Diarrhea	6	2.1
	Mites	1	0.4
	Mastitis	6	2.1
	Pneumonia	1	0.4
	Eye infection	1	0.4
Goat treated against mastitis in the past	Yes	16	5.6
	No	264	94.4

Key: VO= Veterinary officer

AHA= Animal Health Assistant

4.10 Physical examination

4.10.1 Length of teats

A majority (69.7%; 223/320) of the goats had teat length of >3cm and the rest a length of ≤3cm.The latter were goats that had kidded once or twice.

4.10.2 Lesions on teats and udder

Only 11% (35/320) of the goats had lesions on the teats and udder. These included wounds (3%; 9/320), fibrosis (2%; 7/320), supernumerary teats (2%; 7/320), injuries (1.5%; 5/320%), edema (0.9%; 3/320). A few (1.3%; 4/320) of the teats had evidence of scarification indicating a healed wound (Plate 4.1).

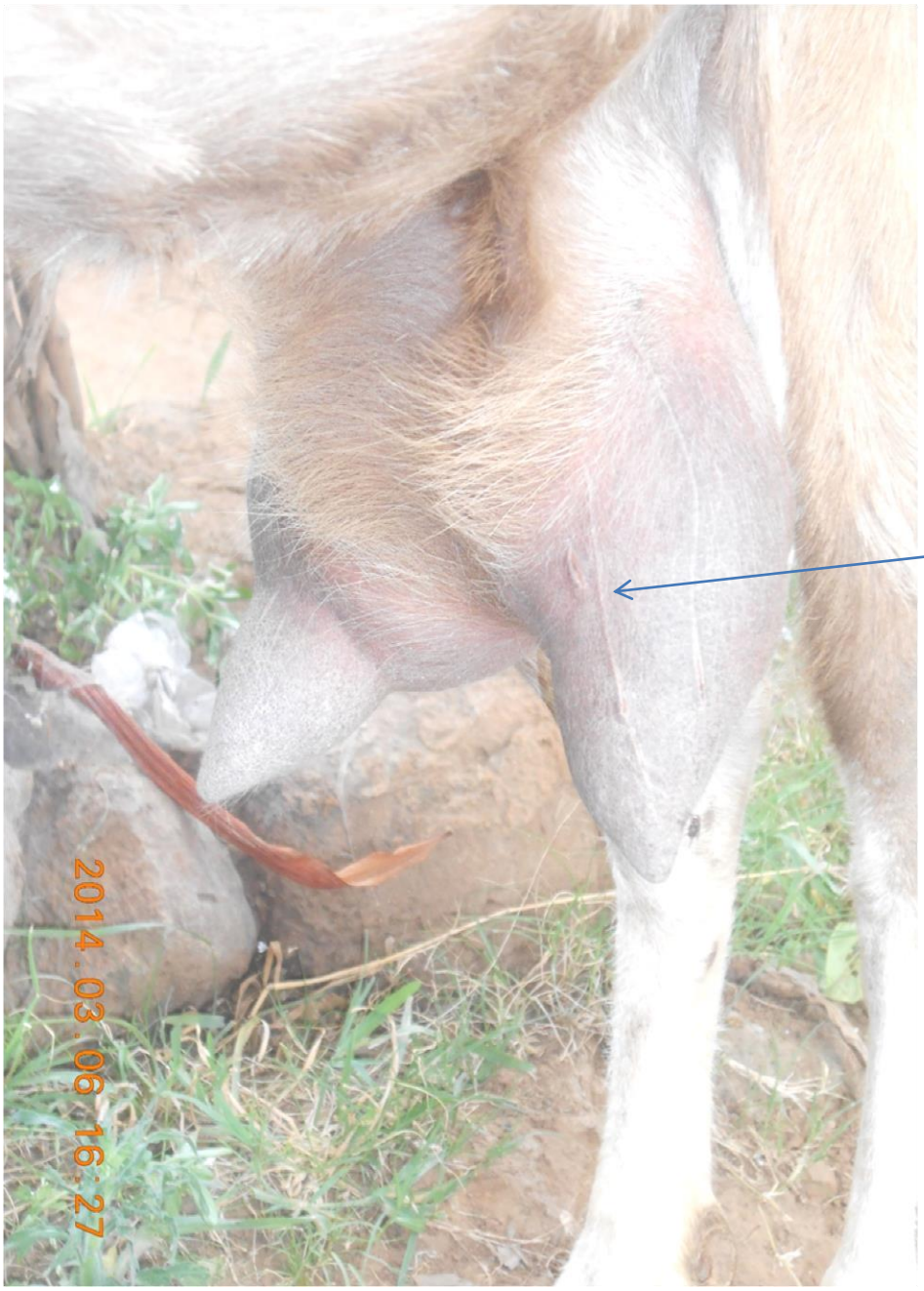

Plate 4.1: A scar on a teat of dairy goat in Machakos County, Kenya, 2014

4.11 Prevalence of clinical mastitis

Only six cases of clinical mastitis were recorded during the study for a prevalence of 1.9% (6/320). Both the left and right udder halves of the cases were affected. The cases were distributed almost equally in the four study wards.

4.12 Laboratory tests

4.12.1 Prevalence of subclinical mastitis by California Mastitis Test (CMT)

A total of 314 (320 minus 6 with clinical mastitis) apparently healthy goats were tested for subclinical mastitis using the California Mastitis Test (CMT). The prevalence of sub clinical mastitis ranged from 25.6% (20/78) in Yathui/Wamunyu ward to 35.4% (28/79) in Matungulu West ward (Table 4.18). Overall, the prevalence was 30.3% (95/314). However, the prevalence by ward was not significantly ($P<0.05$) different (Table 4.18). Both the left half udder and the right half udder were equally affected with subclinical mastitis according to the CMT.

Table 4.18: California Mastitis Test results of milk samples of dairy goats in four wards of Machakos County, Kenya, 2014

Ward	No of goats	No positive	Prevalence (%)	P-Value
Yathui/Wamunyu ward	78	20	25.6	0.61
Kiima kimwe/Muvuti ward	78	23	29.5	
Matungulu West ward	79	28	35.4	
Mwala/Makutano ward	79	24	30.4	
Total	314	95	30.3	

4.12.2 Prevalence of sub clinical mastitis by bacterial culture

Of the 314 apparently healthy goats tested for subclinical mastitis on bacterial culture, 47 tested positive giving an overall prevalence of 15% (47/314). There were slight differences (statistically non significant) in the prevalence between the wards as shown in Table 4.19. Both halves of the udder were equally affected.

Table 4.19: Bacterial culture results of milk samples of dairy goats in four wards of Machakos County, Kenya 2014

Ward	No of goats	Positive	Prevalence (%)	P- Value
Yathui/Wamunyu ward	78	13	16.6	**0.697**
Kiima kimwe/Muvuti ward	78	9	11.5	
Matungulu west	79	11	14.0	
wardMwala/Makutano ward	79	14	17.7	
Total	314	47	15.0	

4.12.3 Comparison of CMT and bacterial culture results for subclinical mastitis

Among the 172 CMT positive milk samples, 28.5% (49/172) of them yielded bacterial growth while 71.5% (123/172) were culture negative. Only 0.7% (3/456) of the CMT negative samples were culture positive (Table 4.20). The observed agreement was 79.94%, while the agreement expected by chance was 68.87%. A Kappa statistic of 0.3556 was obtained indicating a moderate agreement between CMT and bacterial culture in the diagnosis of subclinical mastitis.

Table 4.20: Comparison of CMT and bacterial culture in the diagnosis of sub clinical mastitis in dairy goats of Machakos County, Kenya 2014

CMT	Bacterial Culture		
	+ve	-ve	Total
+ve	49	123	172
-ve	3	453	456
Total	52	576	628

Observed agreement P_O = (49+453)/628 = 79.94%,

Agreement expected by chance P_C = {(172×52)/628 + (456×576)/628}/628 = 68.87%,

Kappa (*K*) = (79.94% – 68.87%) / (1-68.87%) = 11.07% / 31.13% = 0.3556

4.12.4 Species of bacteria isolated

A variety of species of bacteria were isolated in 640 milk samples. Of these only 62 (9.7%) were bacteria positive. The most frequently isolated bacteria were Coagulase negative *Staphylococci* (5.6%; 36/640). Other bacteria isolated included coagulase positive *Staphylococci* (*Staphylococcus aureus), Streptococcus epididymis, Streptococcus agalactiae* and *Citrobacter* (Table 4.21).

Table 4.21: Species of bacteria isolated in goat milk in Machakos County, Kenya 2014

Bacteria Species	No isolated	Proportion (%)
Staphylococcus aureus	16	2.5
Coagulase Negative *Staphylococcus*	36	5.6
Streptococcus Epididymis	5	0.8
Streptococcus agalactiae	3	0.5
Citrobacter	2	0.3
Total	62	9.7

4.12.5 Antimicrobial sensitivity tests

The 62 bacterial isolates were tested for sensitivity to various antimicrobials as shown in Table 4.22. *Staphylococci aureus* isolates were found to be sensitive to Gentamycin (94%), Norfloxacin (94%) and Kanamycin (88%). They were resistant to tetracycline (38%), Sulphamexazole (38%) and Co-trimoxazole (31%), among others (Table 4.22).

Coagulase Negative *Staphylococci*isolates were sensitive to Ampicillin, Kanamycin and Gentamycin (97%) and Norfloxacin (81%). They were resistant to tetracycline (58%), cotrimoxazole (56%) and Streptomycin (50%) (Table 4.22). *Streptococci epididymis* isolates were sensitive to Gentamycin and Norfloxacin (100%). They were resistant to Tetracycline (60%). *Streptococcus agalactiae* were sensitive to Ampicillin and Kanamycin (100%). They were resistant to Sulphamexazole (100%), Cotrimoxazole and Tetracycline (67%) (Table 4.22). Citrobacter was sensitive to Ampicillin, Streptomycin, Kanamycin, Gentamycin and Norfloxacin (100%) and resistant to Sulphamexazole (100%), among others. The antimicrobial sensitivity profiles of different isolates in the study wards are given in appendices XII-XV. Plate 4.2 shows results of antimicrobial sensitivity.

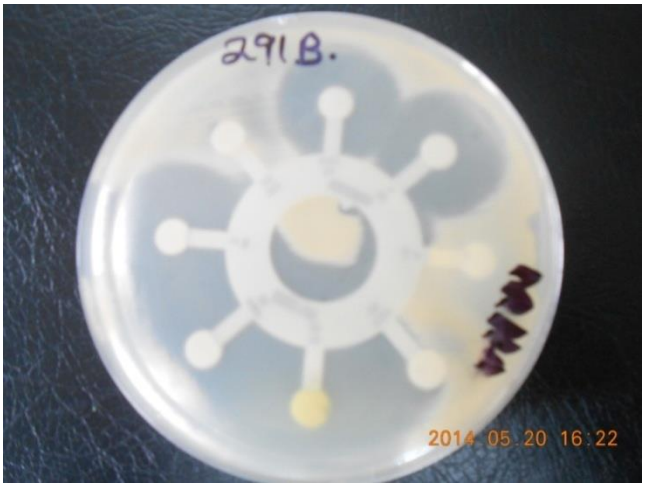

Plate 4.2: Antibiotic sensitivity results of *Staphylococcus* spp isolate

Table 4.22: Antimicrobial sensitivity patterns for organisms isolated in goat's milk in Machakos County, Kenya 2014

Bacterial Species (Number of isolates)	Antimicrobial sensitivity(+/-)							
	Ampi	Tetra	Cotri	Strep	Kana	Gent	Sulph	Norf
Staphylococcus aureus(16)	12/4	10/6	11/5	12/4	14/2	15/1	10/6	15/1
Coagulase Negative *Staphylococcus*(36)	35/1	15/21	16/20	18/18	35/1	35/1	13/23	29/7
Streptococcus epididymis(5)	3/2	2/3	4/1	3/2	3/2	5/0	3/2	5/0
Streptococcus agalactiae(3)	3/0	1/2	½	2/1	3/0	2/1	0/3	2/1
Citrobacter(2)	2/0	1/1	1/1	2/0	2/0	2/0	0/2	2/0

Key; += Sensitive, - = Resistant, Ampi = Ampicillin, Tetra = Tetracycline, Cotri = Cotrimoxazole, Strep = Streptomycin, Kana = Kanamycin, Gent = Gentamycin, Sulph = Sulphamethaxazole, Norf = Norfloxacin

4.12.6 Level of the isolates resistance to commonly used antibiotics in Machakos County

Resistance of the isolates to almost all the tested antimicrobials was common. Overall, the isolates were resistant to sulphadimidine (58.1%), tetracycline (53.2%), cotrimoxazole (46.8%) and streptomycin (40.3%), among others (Table 4.23).

Table 4.23: Level of the isolates resistance to commonly used antimicrobials in Machakos County, Kenya 2014

Antimicrobials	No. of resistant isolates(n=62)	Proportions (%)
Ampicillin 25mg	7	11.3
Tetracycline 25mg	33	53.2
Cotrimoxazole 25mg	29	46.8
Streptomycin 10mg	25	40.3
Kanamycin 30mg	5	8.1
Gentamycin 10mg	3	4.8
Sulphadimidine 200mg	36	58.1
Norfloxacin 5mg	9	14.5

4.12.7 Multidrug resistance among bacteria isolated from mastitis milk

Multidrug resistance was found among 50 isolates (80.6%; 50/62). Most (83%; 30/36) of the Coagulaes Negative Staphyloccocus and all (100%; 8/8) of the Streptococcus and 100% (2/2) of the Citrobacter isolates were resistant to two or more drugs. Slightly more than half (62.5%; 10/16) of the Staphylococcus aureus isolates were multidrug resistance (Table 4.24).

Table 4.24: Multidrug resistance among bacteria isolated from milk of dairy goats in Machakos County

Bacterial isolates	No of resistant drugs					
	0	1	2	3	4	5
Staphylococcus aureus (n=16)	2	4	5	5	0	0
Coagulaes Negative *Staphyloccocus* (n=36)	3	3	9	14	6	1
Streptococci (n=8)	0	0	3	3	2	0
Citrobacter (n=2)	0	0	2	0	0	0
Overall (n=62)	5	7	19	22	8	1

4.13 Risk factors for mastitis in dairy goats in Machakos County, Kenya

A number of explanatory variables were assessed for their potential association with the occurrence of mastitis in dairy goats. The association of mastitis with these potential risk factors was first investigated by univariate logistic analyses (Appendix XVI) where the significant variables ($p \leq 0.1$) were poor milking hygiene (0.03), parity >4 (0.043), Late stage of lactation (0.031), infrequent manure removal (0.024) and lesions on teats and udder (0.0099).

In the multiple logistic regression procedure (Appendix XVII), the five significant variables in univariate analysis that had p-values of less than 0.05 were {milking hygiene (0.029), parity >4 (0.037), late stage of lactation (0.026), infrequent manure removal (0.025) and lesions on teats and udder (0.0099)}.

Prevalence of mastitis in homesteads where good milking hygiene was not practiced was 19.4% compared to a prevalence of 9.7% in homesteads where good milking hygiene was observed. The difference was statistically significant ($P<0.05$) (Appendix XVII). Goats in homesteads where good milking hygiene was not observed were 2.2 times (OR=2.2, P=0.029) more likely to develop mastitis relative to goats in homesteads where good milking hygiene was observed.

Parity was also positively associated with development of mastitis. Indeed there was a gradual increase in mastitis prevalence with increasing parity; prevalence of 13.9% for parity ≤2, prevalence of 17.1% for parity 3-4 and prevalence of 30% for parity >4. Thus, higher parity was significantly associated with occurrence of mastitis (OR=2.6, P=0.037) (Appendix XVII). Similarly, late stage of lactation was significantly associated with occurrence of mastitis as displayed in appendix XVII. Goats that were late in lactation (>4months) were 2.2 times (OR=2.2, P=0.026) more likely to develop mastitis relative to goats in early lactation (≤2 months).

Frequency of removal of manure from goat houses was another factor associated with occurrence of mastitis. Goats in houses where manure was removed weekly were about 2 times (OR=2.03, P=0.025) more likely to develop mastitis than those in houses where manure was removed daily (Appendix XVII).

The prevalence of mastitis in goats with lesions on teats and udders was 25.7% compared to a prevalence of 15.1% in those without. The difference was significant (OR=2.73, P=0.0099). Thus, there was a positive association between presence of lesions on teats and udders and occurrence of mastitis (Appendix XVII).

CHAPTER FIVE: DISCUSSION

5.1 Discussion

In this study dairy goat farming was found to be practiced by small scale farmers of both sexes. However, there were more females (77.5%) than males (22.5%). These results are in agreement with the results of Ogola *et al.* (2010) who reported that goat farming in Kenya was practiced more by females (87%) than males (13%). However, the results were in contrast to those reported by Mbindyo *et al.* (2014) who found more male goat farmers than females in the Mt. Kenya area. Umunna and Olafadehen (2014) also reported more male dairy goat farmers (90%) than females in a study conducted in Nigeria. The reason why there were more female dairy goat farmers in Machakos County could probably have been due to the presence of many microfinance institutions that prefer to provide loans to female farmers to start small scale businesses such as dairy goat farming.

Other than dairy goats, the farmers also kept other species of livestock including cattle, sheep, poultry, rabbits and pigs. This was an indication of the farmers' understanding of the need for diversification of their economic activities. In a study conducted in the Mt. Kenya area Mbindyo *et al.* (2014) found a similar pattern of livestock ownership. However, in the southern savannah region of Nigeria, dairy goat farmers never mixed them with other livestock species (Umunna and Olafadehen, 2014).

The most preferred breeds of dairy goats were the Toggenburg and the German alpine. These results are in agreement with the study by Ogola *et al.* (2010) in the Coast, Rift Valley and Western Kenya where the Toggenberg was the most preferred breed. However, in the semi-arid area of Mwingi in Eastern Kenya, the Galla x Toggenburg cross was the most common presumably because of its better adaptability to the harsh climatic conditions (Ndeke *et al.,* 2015).

Almost all the goats (86.5%) in this study were housed in goat pens with raised slatted floor. Such floors would be ideal for removal of goat droppings. Mbindyo *et al.* (2014) working in the Mt. Kenya area also reported a similar practice of housing goats. These results are however, in sharp contrast to the findings by Umunna and Olafadehen (2014) in Nigeria where goats were kept in pens with earthen floors.

In the current study, removal of manure was done equally on a daily basis (47%) and on weekly basis (53%). These findings were consistent with those of Akraim *et al.* (2010) in Libya where manure removal was done on daily basis (45%) and on weekly basis (55%). However, in a study carried out in Tanzania, removal of manure was entirely done on a daily basis (Swai *et al.,* 2008). Regular and more frequent removal of manure would create a clean environment thus reducing subsequent chances of bacterial accumulation and udder infections.

Most of the homesteads visited had their goats on semi-zero (39.1%) and free range (37.5%) grazing systems. In their study in Mt. Kenya region, Mbindyo *et al.* (2014) reported that all their study goats were zero grazed. This was attributed to the small parcels of land in the region compared to the much larger acreage in Machakos County. Although the farmers in Machakos County complained of a lack of feeds especially in the dry season as a major constraint, there was a wide diversity of feeds available for the goats including, grass, tree shrubs, crop residues and nappier grass. These results were comparable to those of Ogola *et al.* (2010) and Kinyanjui *et al.* (2010) who made a similar observation with regard to goat feeds in various regions of Kenya.

Majority of the goats from the study produced two litres of milk or less while only a few (10%) produced four litres and more of milk. This pattern of milk production was similar to that reported in the Mount Kenya region (Mbindyo *et al.,* 2014) where majority of the

study goats produced two litres of milk. The amount of milk produced in the current study was however, higher than that reported for crossbreeds in Tanzania (Mtenga and Kifaro, 1992) but lower than the amount of milk produced in some dairy goat herds in Nigeria (Donklin and Boyazoglu, 2000) of 2.5 litres per day. The differences in milk production in different regions could have been due to differences in breeds, feeding and even the weather (Ogola *et al*., 2010; Sulo *et al*., 2011).

Although the dairy industry in Kenya has been commercialized, there appears to be very little trading in goat milk in Machakos County with most of the milk (72.5%) being consumed within the homesteads. These results are consistent with the findings in other parts of Kenya by Ogola *et al*. (2010), Sulo *et al*. (2011), Kinyanjui *et al.* (2010) and Mbindyo *et al.* (2014) that most goat milk was consumed locally at home. The goat milk industry in Kenya is relatively new and probably with time it will become more established when the public realizes the benefits of goat milk.

The farmers cited various constraints they faced in dairy goat farming including high cost of feed, high cost of minerals, high cost of goats treatment, poor milk market and goat theft. These findings are not unique within Machakos County as similar observations have been reported in Nigeria (Umunna and Olafadehen, 2014). When the farmers in the current study talked of high cost of feeds, they meant commercial feeds which they do not need during the rainy season when grass and tree shrubs are plenty.

Diseases that were reportedly the most prevalent were worm infestations (54%) and diarrhea (34%). These results differ from the finding in Nigeria (Umunna and Olafadehen, 2014) where tick-borne diseases (38%) and diarrhea (23%) were reportedly most prevalent in dairy goats. It was possible that worm control (deworming) was poor in Machakos County compared to the Nigeria study. On the other hand, tick control (no tickborne

disease reported) appeared to have been better in the Machakos study compared to the Nigeria study.

In this study, the prevalence of clinical mastitis (1.9%) in dairy goats was low. This could be due to the fact that, the examination of the goats for clinical mastitis was done during the dry season. Low prevalence of clinical mastitis during dry season has been reported in other studies in Bangladesh (Rahman *et al.,* 2009) in India (Joshi and Gokale, 2006) and in Ethiopia by Dego and Tareke (2003). Other studies where low prevalence of clinical mastitis has been reported includes in New South Wales (<1%) (Ryan and Greenwood, 1990), in Spain (2%) (Contreras *et al.,* 1997) and in Ethiopia (2.4%) (Wakwoya *et al.,* 2006).

The low prevalence of clinical mastitis in the current study may also be attributed to the clean environment where the goats were housed. Most farmers frequently removed manure from the goats' houses thus ensuring a clean environment and less bacterial contamination. However, these results are in contrast to results of other studies where, slightly higher prevalence proportions of mastitis ranging from 5%-10% were reported in Bangladesh (Islam *et al.,* 2011; Sarker and Samad, 2011), Spain (Contreras *et al.,* 2007) and Nigeria (Ameh *et al.,* 1993).

The prevalence of subclinical mastitis based on CMT was 30.5% and 15% based on bacterial culture. This difference may have been due to a high rate of false positives in the CMT. This explains the moderate Kappa statistic of 0.3556 obtained between the two tests. Similar results were declared by Mulei (1999) in a study conducted in Kenya, where he reported a prevalence of subclinical mastitis of 34% based on CMT and 23% based on bacterial culture. Megersa *et al.* (2010) and Gebrewahid *et al*. (2012) in studies conducted in Ethiopia reported similar prevalence of subclinical mastitis of 15% and 18%,

respectively based on bacterial culture. Higher rates of subclinical mastitis have been reported in the USA (27%) (McDougall *et al.,* 2002), in Kenya (57%) (Mbindyo *et al.,* 2014), in Palestine (52%) (Adwan *et al.,* 2005*),* in Tanzania (51.5%) (Swai *et al.,* 2008), in Kenya (28.7%) (Ndegwa *et al.,* 2000) and in Tanzania (76.7%) (Mbilu, 2007).

These differences of low and high prevalence proportions of subclinical mastitis may be a reflection of different management practices. In addition, it is possible that the herds with high prevalence of subclinical mastitis may have been large herds which have been shown to be positively associated with not only mastitis, but other infectious diseases (Thrushfield, 2008). In the current study in Machakos County, the herd sizes were small (average six goats per homestead).

In this study only 28.5% of the CMT positive samples yielded bacteria on culture. Similar results of CMT positive and bacterial culture negative milk samples have been declared in Kenya (Ndegwa *et al.,* 2001; Mbindyo *et al.,* 2014) and in Ethiopia (Wakwoya *et al.,* 2006). The CMT positive and culture-negative samples could be partly explained by the fact that the udder could have been injured at the time of sampling and therefore recovering from infection or that the infection was not due to a bacterial pathogen. It could also be due to an organism such as *Mycoplasmas*, which requires special media and cannot be identified using routine bacterial isolation techniques (Menzies and Ramanoon, 2001).

Positive CMT could also be due to the production of cytoplamic particles into the milk resulting to a positive CMT without the presence of bacteria in the udder (Haenlein, 1987; Hinckeley, 1991). A small proportion (0.7%) of CMT negative milk samples yielded bacterial growth on culture. This result was consistent with reports in Kenya by Mbindyo *et al.* (2014) who isolated bacteria from 0.6% of CMT negative milk samples, in Ethiopia

where Wakwoya *et al.* (2006) isolated bacteria from 30.8% of CMT negative milk samples and in Kenya Ndegwa *et al.* (2001) isolated bacteria from 22.5% of CMT negative milk samples and further observed that these bacteria may cause latent infection that may not stimulate detectable increase in somatic cell counts, thus a negative CMT.

The most prevalent bacteria causing mastitis in dairy goats in Machakos County was *Staphylococcus* species (83.9%). This bacterium is found widely distributed on animal skin, and it is a contagious pathogen that can be transmitted from doe to doe especially in unhygienic milking procedures (Menzies and Ramanoon, 2001). Also *Streptococcus* species were frequently (12.9%) isolated. Of the *Staphylococcus* species isolated, coagulase negative *Staphylococcus* was the most prevalent (58.1%) followed by coagulase positive *Staphylococcus* (25.8%). Similar findings were reported in Ethiopia by Gebrewahid *et al.* (2012) who isolated 44.7% coagulase negative *Staphylococcus*, 27.7% *Staphylococcus aureus*, and 10.6% *Streptococcus.* Similar isolation frequencies of these bacteria have been reported in the USA (38.2%), Spain (70.0%) and Kenya (60.3%) (White and Hinckley, 1999; Sanchez *et al*., 1999; Ndegwa *et al*., 2001).

Globally *Staphylococci* species are the most prevalent and important organisms that cause mastitis (Menzies and Ramanoon, 2001). They are contagious in nature and are usually transmitted through unhygienic milking methods (Menzies and Ramanoon, 2001). In this study majority of the subclinical and clinical cases of mastitis were due to *Staphylococcus* species infection.

This isolation pattern has also been reported earlier by Rahman *et al.* (2009) and Anyam and Adekeye (1995) in studies done in Bangladesh and Nigeria, respectively. These bacteria are ubiquitous in nature and would easily infect udders especially in dirty environments. The isolation of *S. aureus* is a cause for concern because the bacteria is not

only of veterinary interest but represents a direct threat to human health considering that *S. aureus* can produce heat stable enterotoxins that are not inactivated during pasteurization of milk or production of milk products and can provoke food intoxication (Menzies and Ramanoon, 2001).

The organisms isolated in this study were sensitive to a number of antimicrobial agents. Similar results have been declared in Kenya (Ndgewa, 1999; Mbindyo *et al.,* 2014) who reported similar sensitivity patterns of bacteria isolated from milk of dairy goats. The findings are also in agreement with studies by Wakwoya *et al.* (2006) in Ethiopia who reported that majority of coagulase positive *Staphylococcus* (92.5%), CNS (88.2%), *Corynebacterium* (91.6%), were susceptible to the antimicrobials tested.

Most of the bacterial isolates were multidrug resistance to tetracyclines, sulphamexazole, streptomycin and co-trimoxazole. This was in accordance with results by Ndegwa (1999) and Mbindyo *et al.* (2014) in Kenya who reported resistance of bacteria isolated from goat milk to tetracycline and streptomycin.

Further afield, multidrug resistance to streptomycin and amoxicillin of milk bacterial isolates was reported in Bangladesh (Sarker *et al.,* 2011), while resistance to penicillin G and streptomycin has been reported in Pakistan by Ali *et al.* (2010). Results of this study were also consistent with the reports of Egwu *et al.* (1994) which indicated the presence of drug resistance to bacterial pathogens, including coliforms and *Streptococci* isolated from mastitic goats in Nigeria. These results also agree with findings by Malinowski *et al.* (2008) in Poland who reported that most Coagulase Positive *Staphylococcus* species developed multiple resistances to most antibiotics used.

In the current study the multidrug resistance could be due to the fact that the four drugs were commonly used for treatment of the goats when sick including mastitis in Machakos County and were usually under dosed by the farmers and unqualified persons.

There was an association between increased parity and the occurrence of mastitis in goats in Machakos County. Similar results were declared in Italy by Moroni *et al.* (2005b) who reported that goats in their third and fourth parities were more prone to mastitis infection than goats in their first or second parities. Sanchez *et al.* (1999) and Mbindyo *et al*. (2014) reported a similar infection pattern. However, these results are in contrast to findings by Gebrewahid *et al*. (2012) in Ethiopia who found no association between occurrence of mastitis and parity.

Late stage of lactation was also found to be associated with the occurrence of mastitis. These findings are in agreement with the results by Mbilu (2007) and Moroni *et al*. (2005b) who concluded that later stages of lactation had more infection than earlier lactation stages but are in contrast with findings by Gebrewahid *et al*. (2012), Mbindyo *et al.* (2014), Ndegwa *et al.* (2001) and Taufik *et al.* (2008) who found no association between the occurrence of mastitis and the stage of lactation. The design of the current study was such that any significant differences between exposed (late in lactation) and non-exposed (early in lactation) would be detected.

Poor milking hygiene and occurrence of mastitis were also found to be associated. Mbilu (2007), Mbindyo *et al.* (2014) and Ndegwa *et al.* (2001) also reported a similar observation. This is not surprising since it makes biological sense that poor milking hygiene would increase the risk of udder and teat infection.

The results of this study showed that the frequencies of manure removal was positively associated with the occurrence of mastitis; the less the frequency of manure removal, the

higher the risk of mastitis. Higher frequency of manure removal would leave a clean environment thus reducing the risk of mastitis. This finding was consistent with that of Bergonier *et al.* (2003) who reported high prevalence of mastitis at drying-off or at parturition in relation with environmental contamination due to infrequent manure removal in dairy goats' houses and their surroundings.

Another factor that was positively associated with mastitis was the presence of lesions on teats or udder. This finding was not unexpected since injuries to the teats and udders would provide a portal of entry of microorganisms thus causing infection. This finding was in agreement with that of Mekibib *et al*. (2009) in Ethiopia and Demelash *et al*. (2005) in southern Ethiopia who reported that cows with injured teats were more likely to be infected by mastitis causing organisms than those cows with no teat injury. These findings were however in contrast with that by Swai *et al.* (2008) in Tanzania who reported no association between occurrence of mastitis and presence of lesions on teats or udder of dairy goats.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The following conclusions can be drawn from the study.

- Mastitis was found in the dairy goats of Machakos County, Kenya. The prevalence of clinical mastitis was lower than the prevalence of subclinical mastitis.
- The bacteria that caused mastitis in the study area were Coagulase positive *Staphylococci*, Coagulase negative *Staphylococci*, *Streptococcus epididymis*, *Streptococcus agalactiae* and *Citrobacter*.
- The isolated organisms were found to be highly sensitive to Gentamycin, Kanamicin, Ampicillin and Norfloxacin. They were found to be generally resistant to Tetracycline, Cotrimoxazole, Streptomycin and Sulphamethaxazole.
- Most of the bacterial isolates exhibited multidrug resistance to the antibiotics used. All the *Citrobacter* and *Streptococci* isolates were multidrug resistant while Coagulase negative *Staphylococus* and *Staphylococcus aureus* isolates had a low level of multidrug resistance.
- The risk factors for mastitis in the study area included parity of more than two kidding, late stage in lactation, poor milking hygiene, removal of manure after a week from the goat houses and presence of lesions on the teats or udder of the goats.

6.2 Recommendations

- Farmers should be trained on the control of mastitis in their farms through use of milking hygiene, housing hygiene, post milking teat dipping, dry off therapy and culling of chronically infected goats.
- Farmers should be advised to make sure any mastitis case noticed is treated promptly to avoid spread to other goats.
- Farmers should be advised to be more observant when their lactating goats are in the late lactation stage or are in their third and above parity as this is when mastitis is likely to occur.
- Farmers should be advised not to treat mastitis cases themselves but to call qualified persons so as to avoid under dosing and subsequent development of antimicrobial resistance.
- Daily and periodic removal of manure from the goat houses should be a routine exercise and should be accompanied by cleaning of the environment surrounding the dairy goats.
- All lesions on the teats or udder which are due to injuries should be treated at once to avoid development of mastitis.
- Veterinary extension should be improved by employing more extension officers and facilitating them to reach as many farmers as possible.

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APPENDICES

APPENDIX I: LETTER OF APPROVAL BY FACULTY ANIMAL BIOSAFETY COMMITTEE

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

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Dr Laban N. Makau
c/o Dept of PHPT

16.05.2014

Dear Dr Makau,

RE: Approval of Proposal by Biosafety, Animal use and Ethics committee

Estimating the prevalence of mastitis in dairy goats in Machakos County

By Makau Ngunga Laban J56/80615/2012

We refer to the above proposal that you submitted to our committee. We have now reviewed your proposal and have noted that your work basically involves obtaining milk from Dairy goats in the locality proposed and no experimental work on the animals. Furthermore, we have noted that appropriate biosafety measures will be observed when handling and disposing of biological materials.

We therefore approve your study as per your proposal.

Rodi O. Ojoo BVM, M.Sc, Ph.D.
Chairman,
Biosafety, Animal Use and Ethics Committee,
Faculty of Veterinary Medicine.

APPENDIX II: QUESTIONARE ON DAIRY GOATS AND FARMERS

Dr. Laban Ngunga Makau

Department of Public Health, Pharmacology and Toxicolgy

Faculty of Veterinary Medicine, University of Nairobi

PART A; BACKGROUND INFORMATION

1. Name of ward;_____
2. Gender of farmer. 1=female,

   2=male
3. Age of farmer. 1=20-30yrs,

   2=31-40yrs,

   3=41-50yrs,

   4=>50yrs
4. Breed of dairy goat. 1= Germany alpine,

   2= Toggenburg,

   3= Galla,

   4=Cross,

   5=others, specify_____
5. Number of dairy goats. 1= 1-3,

   2= 4-6,

   3=>7
6. Other livestock kept and their numbers (i) Cattle_____

   (ii) Sheep_____

   (iii) Poultry_____

   (iv) Rabbit_____

   (v) Others, specify_____
7. Size of the farm in acres_____
8. Duration of dairy goat farming_____

PART B; BREEDING

1. Number of lactating does.1=1,

   2=2,

   3=3,

   4=4.

   5=>4

2. Age of lactating doe 1= <36months,

   2=36-48 months,

   3= 4-6years,

   4= >6years

3. Stage of lactation 1= Early (1-2 months),

   2=mid (2-4months),

   3=Late (> 4months).

4. Parity 1= Few <3,

   2= Moderate 4-6,

   3= many >6.

5. Kidding date_____

6. Breeding method; 1= A.I

   2= Buck

7. If buck, who is the owner of the buck;1=My own,

   2=Communal

   3=another farmer who charges

8. Signs of heat in does; 1=Bleating,

   2= Mounting others,

   3= Clear vaginal discharge,

   4=others, specify_____

9. Date of last service_____

10. Has the doe been showing signs of heat since last service; 1=yes, 2= No

11. Is the doe currently pregnant? 1=Yes, 2= No,

12. If yes (in 11) indicate the duration of the pregnancy; 1=1-2 months

2=>2-3months

3=>3-4months

4=>4months

PART C; HOUSING

1. Are the goats housed? 1=Yes,

2= No

2. If housed indicate type of housing. 1=Goat pen with raised slatted floor

2= Goat pen without raised slatted floor,

3=other, specify_____

3. Type of floor; 1=Concrete,

2=Murram,

3=wooden plunks

4=others, specify_____

4. If not housed where are they kept at night? 1= Tethered in the open,

2= Fence of thorny tree branches,

3= others, specify_____

5. Frequency of manure removal from the pens or from where kept at night.

1= Once per day

2=once every 3days,

3=once every week,

4=others, specify_____

6. Do you use beddings; 1= yes,

   2= No

7. If yes, what type of bedding; 1= maize straws,

   2=Grass,

   3=others, specify_____

PART D; FEEDING

1. Type of grazing system. 1=zero grazing,

   2=semi zero grazing,

   3=tethering,

   4=free range system

2. Type of feed given to the goats; 1=Napier grass,

   2= Lucerne,

   3= shrubs,

   4= crop residues,

   5= Local grass

   6=others, specify_____

3. Do you think they get adequate feed; 1=yes,

   2=No

4. If no, what times of the year; 1=dry season,

   2=rainy season.

5. Do you supplement? 1=yes,

   2=no

6. If yes, what type of supplement(s) 1=Concentrates

   2=Minerals

   3=others (specify) _____

PART E; MILK PRODUCTION AND HYGIENE

1. Type of milking technique used; 1=squeezing teats,
   2=pulling teats.
2. What is the frequency of milking per day? 1=Once
   2=Twice
   3=Thrice
3. Do you disinfect the teats after milking? 1=yes,
   2=no
4. If yes which disinfectant do you use? _____
5. Do you practice antibiotic dry therapy; 1= Yes
   2=No
6. Current milk production per day; 1= 500mls-1 lt
   2= >1 lt-2lts
   3= >2 lts-3lts
   4=>3lts-4lts
   5=>4lts
7. Generally compare the current milk production with the previous milk production of all your goats since you started dairy goat production ; 1=improved, 2=dropped
8. If production has improved or dropped in (7) indicate by what percentage;1=1%-25%
   2=>25%-50%
   3=>50%-75%
   4=>75-100%
   5=>100%

9. If production has improved or dropped in (7) give three reasons for each;

   (i) Improved (a) _____

   (b)_____

   (c)_____

   (ii) Dropped (a) _____

   (b)_____

   (c)_____

10. How are the kids fed? 1=Suckle

    2= Bucket fed

11. If suckled indicate the frequency per day; 1= Once

    2= Twice

    3= Thrice

PART F; DISEASES AND EXTENSION SERVICES

1. Who treats your goats; 1=V.O,

   2=AHA,

   3=paravets,

   4=self,

   5=others specify_____

2. Are the services adequate; 1=Yes,

   2=No

3. If no, what do you recommend_____

4. What are the common goat diseases prevalent in your farm; 1=Pneumonia

   2=mastitis,

   3=foot rot,

   4=Diarrhea

   5=worms,

   6=others, specify

5. Is the goat currently suffering from any disease; 1= Yes,

   2= No

6. If yes, which disease;_____

7. What are the clinical signs of mastitis?,1=bloody milk with clots,

   2=swollen teats/udder,

   3=firm/hard udder,

   4=others, specify

8. Have you treated any of your goats against mastitis; 1=yes,

   2=No

9. If yes when was the date of last treatment_____

10. Do you milk goat when suffering from mastitis; 1=yes,

2=No

11. If yes what do you do with the milk; 1=discard,

2=consume,

3=sell,

4=others, specify

PART G; MARKETING OF MILK

1. How is the milk used; 1= consumed,

2=sold

2. If sold where? 1=neighbors,

2=nearest market,

3=others, specify_____

3. Do you sell all the milk? 1=yes,

2= No.

4. If no what proportion is sold per day? _____

5. Are you satisfied with the marketing of the milk; 1=yes,

2= No

6. Cost of milk per litre; 1=40-50

2=51-70,

3=71-90,

4=91-110,

5=>110.

7. Give three most important problems/constraints you encounter in your dairy goat enterprise (in order of priority)

APPENDIX III: PHYSICAL EXAMINATION OF DAIRY GOATS

1. Length of the teat 1= short <2cm,

   2=medium 2-4cm,

   3= long >4cm

2. Indicate the results of teat ends examination on the following

	Left side	Right side
Wounds		
Scars		
Warts		
Patent orifice		
Ease of milking		

3. Indicate the results of udder halves examination on the following

	Left side	Right side
Injury		
relative size and symmetry		
Fibrosis		
Supernumerary teats		
Edema		
Other defects		

APPENDIX IV: COAGULASE TEST

Plasma of 1-in-6 dilution is placed in saline (0.85% NaCl). 1 ml volumes of the diluted plasma are placed in small tubes. Several isolated colonies of test organism are emulsified in 1 ml of diluted rabbit plasma to give a milky suspension which is incubated at 35^{o}C in ambient air or in water bath for 4 hours. This is examined at 1, 2 and 4 hour for clot formation by tilting the tube through 90°**.** Negative tubes are left at room temperature overnight and re-examined. (This step is essential, for some strains of *S. aureus*, including many MRSA, which produce a delayed clot which is rapidly lyses at 37°C by the organism's staphylokinase. Coagulase positive results; any degree of clot formation thus, *Staphylococcus aureus***.** Coagulase Negative: No clot (plasma remains wholly liquid) thus coagulase negative *Staphylococcus*

APPENDIX V: CAMP TEST

The standard CAMP test depend on the elaboration of two toxins during growth to form a typical arrowhead or flame-shaped clearing at the junction of the two organisms when they are placed perpendicular to each other. An inoculating loop is used to streak a beta-lysin-producing Staphylococcus aureus (ATCC25923) in a straight line across the center of a sheep blood agar plate. The test organism is streaked in a straight line perpendicular to the S. aureus leaving 1cm space between the two streaks. (Multiple organisms can be tested on a single plate if they are 3 to 4mm apart). The plate is incubated at 37 degree Celsius in ambient air for 18-24 hours. Positive results: Enhanced hemolysis is indicated by an arrow head-shaped zone of beta hemolysis at the junction of the two organisms. Negative results: No enhancement of hemolysis.

APPENDIX VI: INHIBITION ZONE DIAMETER INTERPRETATION STANDARDS FOR STAPHYLOCOCCUS SPECIES

Drug name (Dose strength)	Zone of inhibition diameter (mm)	
	Resistant (mm)	Sensitive (mm)
Ampicillin (25 mg)	≤ 16	≥ 17
Tetracycline(25 mg)	≤ 18	≥ 19
Co-trimoxazole (25mg)	≤ 15	≥ 16
Streptomycin (10mg)	≤ 14	≥ 15
Kanamycin (30mg)	≤ 17	≥ 18
Gentamycin (10 mg)	≤ 14	≥ 15
Sulphamexazole (200mg)	≤ 16	≥ 17
Norfloxacin (5mg)	≤ 22	≥ 23

Source: NCCLS, 2006

APPENDIX VII: INHIBITION ZONE DIAMETER INTERPRETATION STANDARDS FOR STREPTOCCOCUS SPECIES

Drug name (Dose strength)	Zone of inhibition diameter (mm)	
	Resistant (mm)	Sensitive (mm)
Ampicillin (10 mg)	≤ 16	≥ 17
Tetracycline (30 mg)	≤ 22	≥ 23
Co-trimoxazole (25mg)	≤ 15	≥ 16
Streptomycin (10mg)	≤ 14	≥ 15
Kanamycin (30mg)	≤ 22	≥ 23
Gentamycin (10 mg)	≤ 22	≥ 23
Sulphamexazole (300mg)	≤ 22	≥ 23
Norfloxacin (5mg)	≤ 17	≥ 18

Source: NCCLS, 2006

APPENDIX VIII: INHIBITION ZONE DIAMETER INTERPRETATION STANDARDS FOR CITROBACTER SPECIES

Drug name (Dose strength)	Zone of inhibition diameter (mm)	
	Resistant (mm)	Sensitive (mm)
Ampicillin (10 mg)	≤ 16	≥ 17
Tetracycline (30 mg)	≤ 18	≥ 19
Co-trimoxazole (25mg)	≤ 16	≥ 17
Streptomycin (10mg)	≤ 14	≥ 15
Kanamycin (30mg)	≤ 17	≥ 18
Gentamycin (10 mg)	≤ 15	≥ 16
Sulphamexazole (300mg)	≤ 17	≥ 18
Norfloxacin (5mg)	≤ 17	≥ 18

Source: NCCLS, 2006

APPENDIX IX: CALCULATION OF PREVALENCE RATES BY THRUSHFIELD 2005

Prevalence is the proportion of persons in a population who have a particular disease or attribute at a specified point in time or over a specified period of time.

Prevalence = (All new and pre-existing cases during a given time period) /

Population during the same time period.

APPENDIX X: KAPPA STATISTICS

Test 1	Test 2 +ve	-ve	Total
+ve	A	B	R1
-ve	C	D	R2
Total	C1	C2	N

Observed agreement PO = (A+D)/N

Agreement expected by chance PC = {(R1C1)/N + (R2C2)/N}/N

Kappa (*K*) measures agreement beyond what would be expected by chance:

$K = (P_O - P_C) / (1-P_C)$.

APPENDIX XI: A DAIRY GOAT FARMER OUTSIDE HER GOAT HOUSE IN MACHAKOS COUNTY, KENYA, 2014

APPENDIX XII: ANTIMICROBIAL SENSITIVITY PATTERNS OF CITROBACTER (N=2) ISOLATED FROM DAIRY GOATS IN MACHAKOS COUNTY, KENYA 2014.

Isolate No	Ward	Antibiotics							
		Ampi	Tetra	Cotri	Strep	Kana	Gent	Sulph	Norf
1	KIIM	S	R	S	S	S	S	R	S
2	KIIM	S	S	R	S	S	S	R	S

Key: KIIM=Kiima Kimwe/Muvuti, Ampi=Ampicllin, Tetra=Tetracycline, Cotri=Cotrimoxazole, Strep=Streptomycin, Kana=Kanamycin, Gent=Gentamycin, Sulph=Sulphamexazole, Norf=Norflaxacin, S=Sensitive, R=Resistant.

APPENDIX XIII: ANTIMICROBIAL SENSITIVITY PATTERNS OF STREPTOCOCCI (N=8) ISOLATED FROM DAIRY GOATS IN MACHAKOS COUNTY, KENYA 2014.

Isolate No	Ward	Antibiotics							
		Ampi	Tetra	Cotri	Strep	Kana	Gent	Sulph	Norf
1	WAM	S	R	S	R	S	R	S	R
2	WAM	R	S	S	S	R	S	R	S
3	KIIM	R	R	R	S	S	S	S	S
4	KIIM	S	S	S	R	S	S	R	R
5	MATU	S	S	R	S	R	S	S	S
6	MATU	S	R	S	S	S	S	R	S
7	MWL	S	S	R	R	S	R	R	S
8	MWL	S	R	S	S	S	S	R	S

Key: WAM= Wamunyu/Yathui, KIIM=Kiima Kimwe/Muvuti, MATU=Matungulu west, MWL=Mwala/Makutano, S=Sensitive, R=Resistant, Ampi=Ampicllin, Tetra=Tetracycline, Cotri=Cotrimoxazole, Strep=Streptomycin, Kana=Kanamycin, Gent=Gentamycin, Sulph=Sulphamexazole, Norf=Norflaxacin

APPENDIX XIV: ANTIMICROBIAL SENSITIVITY PATTERNS OF COAGULASE POSITIVE STAPHYLOCOCCI (N=16) ISOLATED FROM DAIRY GOATS IN MACHAKOS COUNTY, KENYA 2014.

Isolate No	Ward	Antibiotics							
		Ampi	Tetra	Cotri	Strep	Kana	Gent	Sulph	Norf
1	WAM	H	S	S	S	S	S	R	S
2	WAM	R	R	S	S	S	R	S	S
3	WAM	S	S	R	R	S	S	S	S
4	WAM	S	S	S	S	S	S	S	S
5	WAM	S	R	R	S	S	S	R	S
6	WAM	S	S	S	S	S	S	S	S
7	WAM	R	S	S	R	S	S	R	S
8	WAM	S	R	S	S	S	S	S	S
9	KIIM	S	R	R	S	S	S	R	S
10	KIIM	R	S	S	S	S	S	R	S
11	KIIM	S	R	R	S	S	S	S	S
12	KIIM	S	S	S	R	S	S	S	R
13	KIIM	S	S	S	S	R	S	S	S
14	KIIM	S	R	R	S	S	S	R	S
15	MATU	S	S	S	R	S	S	S	S
16	MATU	R	S	S	S	R	S	S	S

Key: WAM= Wamunyu/Yathui, KIIM=Kiima Kimwe/Muvuti, MATU=Matungulu west, S=Sensitive, R=Resistant, Ampi=Ampicllin, Tetra=Tetracycline, Cotri=Cotrimoxazole, Strep=Streptomycin, Kana=Kanamycin, Gent=Gentamycin, Sulph=Sulphamexazole, Norf=Norflaxacin

APPENDIX XV: ANTIMICROBIAL SENSITIVITY PATTERNS OF COAGULASE NEGATIVE STAPHYLOCOCCI (CNS) (N=36) ISOLATED FROM DAIRY GOATS IN MACHAKOS COUNTY, KENYA 2014.

Isolate No	Ward	Antibiotics							
		Ampi	Tetra	Cotri	Strep	Kana	Gent	Sulph	Norf
1	WAM	S	S	S	S	S	S	S	S
2	WAM	S	S	R	R	S	S	S	R
3	WAM	S	S	S	R	S	S	R	S
4	WAM	S	R	S	R	S	S	R	S
5	WAM	S	S	S	S	S	S	S	S
6	WAM	S	R	R	R	S	S	R	S
7	KIIM	S	S	S	R	S	S	S	S
8	KIIM	R	R	S	R	S	S	S	S
9	KIIM	S	S	R	S	S	S	R	S
10	KIIM	S	R	R	S	S	S	S	S
11	MATU	S	S	R	S	S	S	S	S
12	MATU	S	R	R	R	S	S	R	R
13	MATU	S	R	S	S	S	R	R	S
14	MATU	S	R	R	S	S	S	S	S
15	MATU	S	R	S	R	S	S	R	S
16	MATU	S	S	R	S	S	S	R	S
17	MATU	S	S	S	S	S	S	R	R
18	MATU	S	R	R	R	S	S	R	S
19	MATU	S	S	S	S	S	S	S	S
20	MATU	S	R	R	R	S	S	R	S
21	MWL	S	R	R	R	S	S	S	S
22	MWL	S	S	R	S	S	S	R	R
23	MWL	S	R	R	S	S	S	R	S
24	MWL	S	S	S	R	S	S	R	S
25	MWL	S	R	R	S	S	S	R	S
26	MWL	S	S	S	R	S	S	R	R
27	MWL	S	R	R	R	S	S	R	S
28	MWL	S	R	S	R	S	S	S	S
29	MWL	S	R	R	S	S	S	R	R
30	MWL	S	R	R	S	S	S	R	S
31	MWL	S	R	R	R	S	S	R	S
32	MWL	S	S	R	S	S	S	R	S
33	MWL	S	R	S	R	R	S	S	S
34	MWL	S	R	S	R	S	S	R	S
35	MWL	S	S	R	S	S	S	R	R
36	MWL	S	R	S	S	S	S	S	S

Key: WAM= Wamunyu/Yathui, KIIM=Kiima Kimwe/Muvuti, MATU=Matungulu west, MWL=Mwala/Makutano, S=Sensitive, R=Resistant, Ampi=Ampicllin, Tetra=Tetracycline, Cotri=Cotrimoxazole, Strep=Streptomycin, Kana=Kanamycin, Gent=Gentamycin, Sulph=Sulphamexazole, Norf=Norflaxacin

APPENDIX XVI: UNIVARIATE LOGISTIC ANALYSIS OF POTENTIAL RISK FACTORS FOR MASTITIS IN DAIRY GOATS IN MACHAKOS COUNTY, KENYA 2014

Risk factor	Level	Mastitis +ve	Mastitis -ve	Prevalence (%)	P-value
Milking hygiene	Not practiced Practiced	42 10	175 93	19.40 9.7	0.034
Manure removal	>week Daily	35 17	135 133	20.6 11.33	0.024
Parity	>4 kidding 3-4 kidding ≤2 kidding	12 6 34	28 29 211	30 17.1 13.9	0.043
Pregnant	Yes No	14 38	51 217	21.5 14.9	0.19
Stage of lactation	Late in lactation (>4months) Mid in lactation (>2-4months) Early in lactation (≤2months)	22 18 12	67 101 100	24.7 15.1 10.7	0.031
Breed	German Alpine Toggenberg Galla Cross Saanen	14 26 2 10 -	66 136 11 53 2	17.5 16.0 15.4 15.8 -	0.99
Lesions on teats and udders	Present Absent	9 43	23 245	25.7 15.1	0.0099
Length of teats	≤3cm >3cm	14 38	83 185	14.4 17.0	0.56
Study site (Wards)	Wamunyu/Yathui Kiima/Kimwe Matungulu West Mwala/Makutano	14 11 12 15	66 69 68 65	17.5 13.75 15.0 18.0	0.82

APPENDIX XVII: MULTIVARIATE LOGISTIC REGRESSION MODEL FOR RISK FACTORS SIGNIFICANT (P≤ 0.1) IN UNIVARIATE MODEL

Risk factor	Level	Mastitis		Prevalence (%)	P- value	OR
		+ve	-ve			
Milking hygiene	Not practiced	42	175	19.40	0.029	2.20
	Practiced	10	93	9.7		
Manure removal	>week	35	135	20.6	0.025	2.03
	Daily	17	133	11.33		
Parity	>4 kidding	12	28	30	0.037	2.60
	3-4 kidding	6	29	17.1		
	≤2 kidding	34	211	13.9		
Stage of lactation	Late in lactation (>4months)	22	67	24.7	0.026	2.20
	Mid in lactation (>2-4months)	18	101	15.1		
	Early in lactation (≤2months)	12	100	10.7		
Lesions on teats and udders	Present	9	23	25.7	0.0099	2.73
	Absent	43	245	15.1		