PATHOLOGY AND HAEMATO-BIOCHEMICAL CHANGES AND ECONOMIC IMPACT IN GOATS FEEDING ON *OPUNTIA STRICTA* AND COMMUNITY PERCEPTION OF THE PLANT IN LAIKIPIA COUNTY, KENYA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT FOR THE DEGREE OF MASTERS CLINICAL PATHOLOGY AND LABORATORY DIAGNOSIS IN THE DEPARTMENT OF VETERINARY PATHOLOGY, MICROBIOLOGY AND PARASITOLOGY IN THE UNIVERSITY OF NAIROBI

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DECLARATION

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

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DEDICATION

This thesis is dedicated to:

My dear wife Gladys Makena and our entire family for prayers, encouragement and support throughout this study.

My late father M'Ncebere and mother Grace Ciomwirabua who were always determined to see that I succeed in education.

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LIST OF ABBREVIATIONS AND ACRONYMS

ALP	Alkaline phosphatase
ALT	Alanine aminotransferase
AST	Aspartate aminotransferase
BD	Becton Dickinson
GS	Graduate school
BUN	Blood Urea Nitrogen
CIDP	County Integrated Development Plan
CPK	Creatine kinase
CSD	Clinical Studies Department
EDTA	Ethylene diamine tetra acetic acid
GIT	Gastrointestinal tract
Hct	Haematocrit
IUCN	International Union for Conservation of Nature
KAP	Knowledge, Attitude and Practices
K_2EDTA	Dipotassium ethylene diamine tetra acetic acid
KNBS	Kenya National Bureau of Statistics
MCV	Mean Corpuscular Volume
MCH	Mean Corpuscular Haemoglobin
MCHC	Mean Corpuscular Haemoglobin Concentration
MPV	Mean Platelet Volume
PDW	Platelet Distribution Width

PSS	Portosystemic shunts
RBC	Red Blood Cells
RDW	Red Cell Distribution Width
RVIL	Regional Veterinary Investigation laboratory
THR	Thrombocytes
TP	Total Proteins
VPMP	Veterinary Pathology, Microbiology and Parasitology
WBC	White Blood Cells

ABSTRACT

Opuntia stricta variety *stricta (O. stricta)*, a plant with thorns and spines has invaded northern part of Laikipia County, Kenya and reduced prime grazing land and pastures. Its cladodes (the green flat paddle-shaped stem segments) and fruits are protected by thorns and small spines called glochids. This study was carried out in Laikipia North Sub-county, Laikipia County between October 2018 and February 2019. The objectives were to determine haemato-biochemical changes and pathology and economic impacts in goats consuming *O. stricta* and the community perception of the plant and its risk factors. A semi-structured questionnaire was used to determine knowledge, attitude and practices and risk factors associated with *O. stricta.* Most of farmers knew *O. stricta* as "Olmatundai" in Maasai language and had lived with it for the last sixty years. Respondents specified that *O. stricta* grows in both dry and rainy seasons and that goat mainly feeds on its fruits. Farmers know that the plant causes emaciation, deaths, blindness, injuries on the lips and mouth, skin and muscles. They observed that proliferation of *O. stricta* in the area has displaced people, decreased the grazing land, limited peoples' movements from their residences, increased human-wildlife conflicts and impoverished them through mortalities of livestock. Eighteen (18) goats whose health was affected by feeding on the plant (sick goats) were purchased from three locations that were invaded by this cactus. Six goats that were clinically healthy (controls) were purchased from two *O. stricta* free ranches in the study area. Blood samples for haematology and biochemistry were taken from the two groups and analyzed. Animals were humanely killed and postmortem examination conducted. Goats that had progressively fed on *O. stricta* had the following external lesions: thorn and spine injury-associated blindness (38.9%); septic ulcerative wounds on the lips and mouth (94.4%) or tongue (83.3%); *Opuntia stricta* spines and thorns piercing the ear lobes and various parts of the skin

(100%); abscesses at various locations (22.2%); emaciation (100%) that led to death. Internally, *O. stricta* thorns and spines were embedded on the subcutaneous tissues, muscles, rumen, reticulum and abomasum mucosa. Mucosa of abomasum had thick folds; edema and hemorrhage, and in some cases severe septic abscesses; and foreign body granulomas in the tunica mucosa and tunica submucosa. Foreign body granulomas occurred in the ears, lips and tongue. Affected goats had microcytic regenerative anemia that was associated with iron deficiency; neutrophilia and lymphopenia that are consistent with severe inflammation. Low levels of albumin, alkaline phosphatase, aspartate aminotransferase, alanine aminotransferase, blood urea nitrogen and creatinine occurred in all goats that were affected by the plant. Low carcass and organ weights, and reduced muscle and fat cover occurred in all sick goats. Focal inflammation and necrosis of skeletal and smooth muscles that occurred in sick goats happened consistently with increased levels of creatine kinase in plasma. Emaciation of the sick goats was attributed to malnutrition caused by reduced feed intake due to severe injuries by *O. stricta* spines in the gastrointestinal tract. The occasioned death of livestock and loss of body weight (emaciation) as a result of consumption of the *O. stricta* caused enormous economic losses to pastoral communities in the study area. Costs of treatment of *O. stricta* related conditions, frequent condemnations of whole carcasses and organs added to the losses. Consumption of *O. stricta* caused severe irreversible damage to gastrointestinal system especially the oral cavity and abomasum. Injuries to organs reflected on alterations in blood parameters of goats. The study showed that no treatment or intervention measures can reverse the damage caused by many thorns and spines penetrating into body systems of goats consuming *O. stricta*. Measures to control this invasive plant in Laikipia north should be instituted in order to minimize losses in livestock production and the associated impacts on lives and livelihoods of the people in the area.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

Herbivores in pastoral production system entirely derive their nutritional requirements for survival from the forage they eat. Conversely vegetation has changed with time and developed defensive structures to safeguard their sustained life and continued existence (Van Soest, 2018). Gradual weapons battle amid foliage and herbivores do exist and plants have developed prickles, bristles, and spikes as a form of resistances against herbivores which feeds on them particularly in dry regions (Halpern *et al*., 2007; Halpern *et al*., 2011). Consequently, herbivores are prone to gastrointestinal injuries from the forage they eat.

Illness of an animal feeding spiky plant can be linked to injuries on the mouth and other parts of the gastrointestinal tract (GIT) and the consequences of this are problems of grasping, chewing or allowing it into the stomach and subsequently digestion and absorption of the nutrients (Barker *et al*., 1993). Any pathological condition affecting anatomical structures and functions and physiological functions of the digestive system severely affects food movement, breakdown and uptake of the required nutrients by the animal.

Opuntia stricta variety *stricta* (Haw.) is one of the thorny and prickly plants (CABI, 2017) that have invaded northern part of Laikipia County in Kenya in recent past, resulting to reduction in prime grazing land and access to grass (Strum *et al*., 2015; Shackleton *et al*., 2017). The cladodes and fruits of the spiny *Opuntia* spp. are protected by small spines called glochids. Both spineless and spiny *Opuntia* spp. are widely used in many countries of the world especially in Arid and Semi-Arid zones as forage, fodder and animal nutrition. In the countries where spiny

Opuntia spp. is farmed as forage, it is subjected to propane or paraffin flame to remove spines before animals are fed on them (Mondragón-Jacobo and Pérez-González, 2001).

In Laikipia north rangeland, mostly during the drought, livestock feed on the ripened spiny fruits of *O. stricta* together with thorns and spines. In the process glochids attach and penetrate the lips, buccal cavity, stomach and intestines of the animals and initiate development of abscesses at injured sites. Consequently, animals develop body weight loss (cachexia), drop milk yield, become blind and then die (Shackleton *et al*., 2017).

Most studies done on *Opuntia* spp. are on their nutrition benefits and medicinal values in both animals and humans (Barbera *et al*., 1995; Nobel, P.S., 2002; Kim, *et al*., 2012). There are no studies done on the harm caused by spiny *Opuntia* spp. when animals feed on it with thorns and spines, as happens naturally in the rangelands.

This study was therefore carried out to determine haemato-biochemical changes and pathology in goats consuming spiny *Opuntia stricta* variety *stricta* in Laikipia County. Economic impacts of *O. stricta* on livestock and Knowledge, attitude and practices on this plant in the affected community were assessed.

1.2 Problem statement

Goats have been eating fruits of *O. stricta* in Laikipia north Sub-County especially during the dry periods, due to reduced availability of grass and other types of forage as a result of its invasion of the prime grazing land (Strum *et al*., 2015; Shackleton *et al*., 2017). Glochids on the fruits gets attached on the lips, buccal cavity, stomach, intestines, eyes and skin of the animals. The affected animals become blind, lame, emaciated and finally die. Progressive deaths of goats and other

livestock species caused by consumption of this plant have impacted negatively on the social economics and livelihoods of pastoralists in the county, gradually increasing their vulnerability. Constant loss of the sole source of livelihood is likely to increase the current state of insecurity in Laikipia County and beyond, in terms of livestock rustling and other forms of criminal acts.

By the time this study was being carried out, over one quarter of goat population in the study area were exposed to *O. stricta* and three quarters were at high risk of *O. stricta* as it was being spread at a very fast rate by wildlife, livestock and human activities (Fig. 1). Even though farmers in the study area have been losing livestock because of this plant for some years, nothing has been done on the ground to save the situation. This is because the harmful effects of *O. stricta* in livestock after consumption are not fully known.

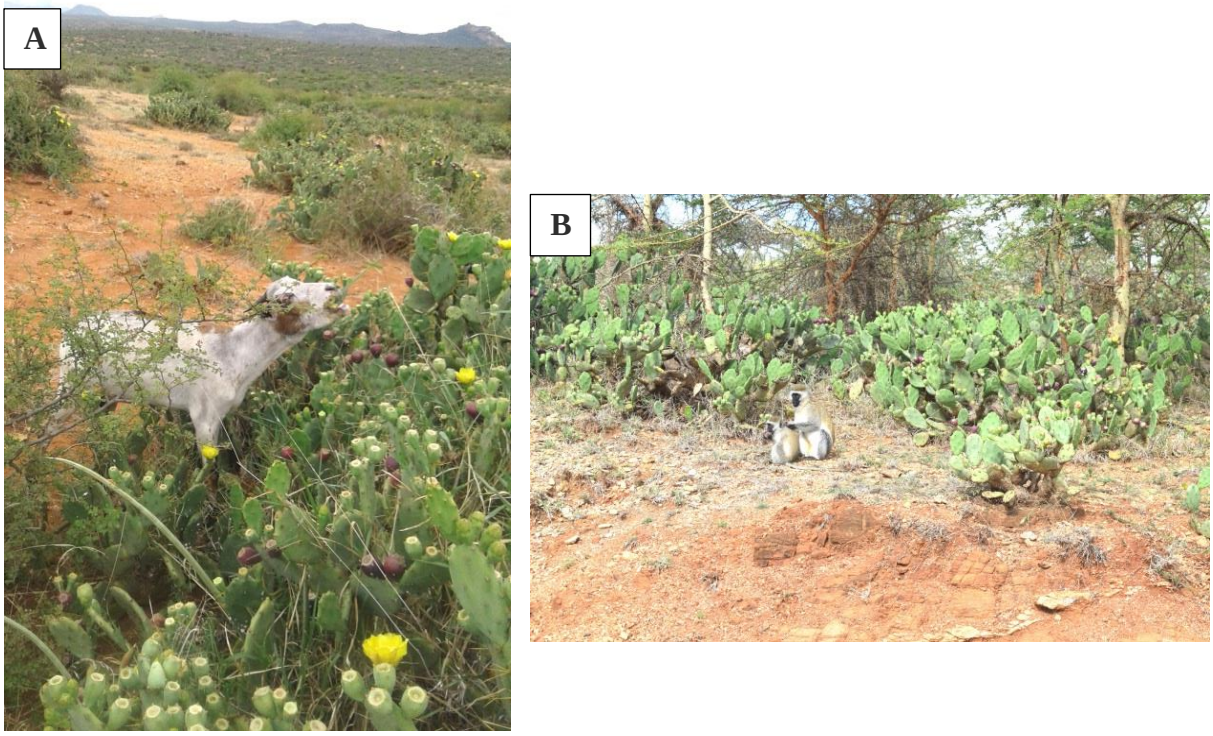


Figure 1: Goat browsing (A) and Baboons eating (B) ripened *Opuntia stricta* fruits in Laikipia north

1.3 Study justification

There are no previous studies in Kenya on the effects of *O. stricta* in livestock; yet, the plant causes significant economic losses to pastoral farmers in dry lands. The causes of progressive loss of body condition and subsequent death of goats consuming *O. stricta* fruits have not been determined before, making it difficult to institute meaningful intervention measures. This study reveals the specific injuries caused by *O. stricta* and explains the actual causes of wasting and subsequent deaths of affected animals. There are no prior studies on knowledge, attitudes and practices of communities that bear the losses associated with *O. stricta*, yet such studies are

important in participatory implementation of measures to mitigate losses caused by the plant. An understanding of the losses attributed to the plant will influence the choice of strategies to reduce losses caused by the plant and encourage stakeholders to participate in interventions to control *O. stricta* in pastoral zones. Control of this plant will redeem the invaded grazing areas and minimize conflicts over pastures.

1.4 Study objectives

1.4.1 Overall objective

To determine haemato-biochemical parameters and pathology and economic impacts in goats consuming *Opuntia stricta* variety *stricta* and knowledge, attitude and practices and risk factors associated with the plant in Laikipia County, Kenya.

1.4.2 Specific objectives

Specific objectives of the study were: -

1. To determine the knowledge, attitude and practices and risk factors associated with *O. stricta* in Laikipia County.

2. To determine haematological and biochemical parameters of goats feeding on *O. stricta* in Laikipia County.

3. To determine pathological lesions and their distribution in body organs of goats feeding on *O. stricta* in Laikipia County.

4. To determine economic impact of *O. stricta* on the livestock in Laikipia county

1.5 Study hypothesis

$H_{o:}$ Consumption of fruits of *O. stricta* does not cause pathology or alter haematological and biochemical parameters of goats leading to ill-health and death; has no economic impact on the livestock and community in the *O. stricta* affected area have no knowledge of the plant and the risk factors associated with it.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Goats are one of the 155 ruminant species in the world and one of the six domesticated ruminants; others being cattle, sheep, buffaloes, reindeer and yaks (Van Soest, 2018). They are kept mainly for meat, milk, fiber and skin production (Dove, 2010). The approximate goat population worldwide is about 921 million (Devendra and Liang, 2012). Estimated livestock population in Laikipia County is 340,914 sheep, 282,734 goats and 189,685 heads of cattle. In Laikipia North Sub-county which is the study area, livestock population are: 120,416 goats, 86,452 sheep and 39,417 heads of cattle (KNBS, 2009). Goat population is the largest among domestic ruminants in the sub county (120,416) (KNBS, 2009) and pastoralists consider them as Automated Teller Machine Card (ATM card) because they do exchange them at any time of the day with money for their livelihood. Small East African goats, Galla goats and their crosses are the main breeds of goats kept in Laikipia north Sub County.

The high and medium potential land constitutes 20.5% of the total Laikipia County's land area while the remaining 79.5% is low potential hence unsuitable for crop farming (Laikipia CIDP, 2014). Over 80% of people depend on livestock distributed as follows: Large-scale ranching 37%, pastoralists (32%) and smallholder farming (21%); 5% of the land is fully centered to wildlife and tourism (Butynski and de Jong, 2014). Pastoralism is practiced in the communal group ranches predominantly owned by the Mukogondo Maasai, in the gazetted Mukogodo forest. Community group ranches are characterized by land degradation caused by overgrazing and associated invasion by *O. stricta*.

Good health of goats depends on the availability of adequate forage and functional digestive system. An effective and functional gastrointestinal tract of goats is directly related to the total energy used for their production (Silanikove, 2000). Lesions in the mouth and esophageal regions account for important losses in production and financial returns from the affected animals (Pugh and Baird, 2012). The ulcerative lesions on Gastrointestinal tract (GIT) that develops after goats have consumed *O. stricta* cause severe loss of body condition and reduce its value in terms of money at market price and the quality and value of dressed carcass at slaughter.

2.2 Forage

Forage is 'eatable portions of vegetation, excluding removed seeds, which can make available food for foraging faunae or that can be reaped and given to animals as food (Givens *et al.,* 2000). Plant eating animals requires vegetation for nutrition, and in reaction vegetation have fortifications against herbivorous attackers. For this reason, vegetation has changed with time and developed defensive structures to safeguard life and continued existence. Plant eating animals in contrast have advanced ways to overwhelm these fortifications (Van Soest, 2018). Spikes, pointed prominences or processes and tickles are amongst the weapons which plants have developed with time to defend themselves from herbivores. In addition, spikes also shelter a range of diseases causing microorganisms that are hazardous to plant eating animals than the aching they cause through the physical injuries (Halpern *et al.,* 2007). The sharp defensive organs of the plants introduce a number of disease-causing microorganisms into the body systems of the animals in a type of biological warfare (Lev-Yadun and Halpern, 2008). Therefore, besides mechanical injuries inflicted to the animals by thorns on the forage, microorganisms harbored on these prickles are introduced on the inflicted wounds resulting to

infected lesions (Halpern *et al.,* 2007). Introduction of both aerobic and anaerobic microorganisms into the body of herbivores by these thorns (Lev-Yadun and Halpern, 2008) may result in disease conditions such as gas gangrene, anthrax and dermatitis (Halpern *et al.*, 2007). Cacti in the genus *Opuntia* are farmed and widely used as forage in many countries of the world. Some species of this cactus plant have thorns and spines which causes injuries on the herbivores foraging on them (Mondragón-Jacobo and Pérez-González, 2001; Nobel, 2002). *Opuntia stricta* variety *stricta* (Haw.) is one of the thorny and spiny cacti in this genus (CABI, 2017) and its cladodes and fruits are foraged naturally by livestock and wild animals.

2.2.1 *Opuntia* species as forage, fodder and animal nutrition

The use of *Opuntia* spp. as a source of nourishment for people, livestock and wild animals has been very significant in the dry and partially dry areas of many countries such as northern Mexico for many hundreds of years. It has been utilized as feed for cattle, sheep and goats and is an ancient custom in the country (Mondragón-Jacobo and Pérez-González, 2001). Some studies indicate that inclusion of *Opuntia* spp. in the nutrition of sheep and goats makes better the grade of meat (Barbera *et al*., 1995). In most intensive beef and dairy production systems, many *Opuntia* species are utilized as forage (Mondragón-Jacobo and Pérez-González, 2001). During the dry periods *Opuntia* species which are farmed as fruits and forage helps a lot to save lives of people and animals the same way and they are important source of energy, water and vitamins. Even though they are mostly utilized for cows, *Opuntia* spp. has also been utilized as feed for pigs (Mondragón-Jacobo and Pérez-González, 2001).

The use of various *Opuntia* spp. as forage, fodder and source of animal nutrition has made it possible to have important reserve of feeds for livestock in acute dry seasons. This has made the

worth of the *Opuntia* spp. as forage to nearly exceed its worth as a fruit plant. *Opuntia ficus-indica* is mostly grown as a fodder and utilized in many countries in the world as forage. Most of these species have spikes and they have to be treated before use as animal feeds. Some of these species such as *Opuntia mycrodasys* (also called thorny pear causes blindness) are injurious to animals but still they are eaten when the other types are rare (Mondragón-Jacobo and Pérez-González, 2001). Fruits from *Opuntia* spp. are valued nutrition supply for faunae and are freely consumed when accessible. Greater than sixty percent of animal species that forage at platyopuntia eats the fruits. Fruits and seeds are the main basis of charm to customers. All the mammalian species that forage at *Opuntia* systems also consumes blossoms and berries when they get them **(**Nobel, 2002).

The common species of *Opuntia* utilized to provide feed for goats in countries such as in northern Mexico comprise *Opuntia leucotricha, O.streptacantha, O.robusta, O.cantabrigiensis, O. rastrera, O.lindheimeri, O.imbricata, O.microdasys* and *O.leptocaulis.* All of these species have many firm, big spikes and barbed bristle *(ahuates*), which can be a source of severe harms to eyes and mouth of livestock nourishing on them. However, these *Opuntia* spp. are subjected to propane or paraffin flame in order to remove bristles of the entire plants before the animals are allowed to feed on them (Mondragón-Jacobo and Pérez-González, 2001). Scorching off the bristles is therefore very important when feeding the *Opuntia* species that have spines such as *O. stricta* to cattle, sheep and goats to avoid eyes, mouth and gastrointestinal injuries. In the rangelands; livestock feeds on the different species of *Opuntia in situ* together with their spines and this causes great harm on their digestive systems resulting to varied pathological lesions along gastrointestinal tract and blindness. This problem is not seen in the spineless species of *Opuntia* such as the *Opuntia ficus-indica*. When animals forage on spiny *Opuntia* spp. naturally

in the field, spines cause septic inflammatory lesions (Nobel, 2002). The spikes and barbed bristle on the berries become fixed in the digestive system of an animal bringing about inflammation, protuberance and sores on the fleshy parts of the upper and lower lips, mouth, tongues and buccal cavity. Frequently the wounds inflicted by thorns and spines are invaded by disease causing microorganisms resulting to demise of the animal (Shackleton *et al*., 2017).

2.2.2 *Opuntia stricta* variety *stricta*

Opuntia stricta variety *stricta* (Haw.) belongs to the family *Cactaceae*, genus *Opuntia* and species *O.stricta* (CABI, 2017). *O. stricta* has been selected as amongst 100 of the "World's Worst" invaders by the International Union for Conservation of Nature (IUCN) Invasive Species specialist group. It is also recorded as a toxic wild plant in South Africa and in most Australian states (BioNET-EAFRINET, 2011). In Laikipia North, recurrent drought, overstocking and poor rangeland management in communally owned ranches has resulted in land degradation and depletion of rangeland grass and other range plants and tree species which are livestock feeds. These degraded rangelands have been invaded and covered by drought resistant *O.stricta* variety *stricta* which both livestock and wildlife in the area feeds on mostly during the drought seasons as an alternative feed. Constant overgrazing by the pastoralists within the county and from the neighbouring counties of Baringo, Samburu and Isiolo, coupled with the alterations in land usage especially from pastoralism to settlements has created a favorable environmental for the cactus to thrive (Strum *et al.,* 2015). When goats and other livestock species feed on the ripened spiny fruits of *O.stricta* variety *stricta*; they develops ulcerative oral lesions and abscesses along GIT; become blind, emaciated and reduce milk yield and then die (Shackleton *et al.,* 2017).

Pathology, haematological, biochemical changes and economic losses associated with the effects of spiny *O. stricta* in goats feeding on this cactus naturally in the wild is not documented. This makes it difficult to institute meaningful intervention measures to mitigate losses caused by this plant. In addition, determination of knowledge, attitudes and practices of communities that bear the losses associated with *O. stricta*, is crucial in participatory implementation of measures to mitigate losses caused by this cactus. A clear understanding of the losses attributed to *O. stricta* is very important in influencing the choice of strategies to reduce losses caused by the plant and also to encourage stakeholders to participate in interventions to control *O. stricta* in pastoral zones.

CHAPTER THREE

3.0 COMMUNITY PERCEPTION OF *OPUNTIA STRICTA* VARIETY *STRICTA* IN LAIKIPIA COUNTY, KENYA

3.1 Introduction

Opuntia stricta variety *stricta* has invaded northern part of Laikipia County in the recent past and reduced prime grazing land (Strum *et al.*, 2015; Shackleton *et al*., 2017). Coverage of the grazing areas by the *O. stricta* has resulted to extinction of rangeland grasses and other range plants which were livestock feeds. This situation has been worsened by recurrent and prolonged droughts in the area due to climatic change. Consequently, goats and other livestock species have resulted to feeding on *O. stricta* as an alternative and the only feed available. As goats and other livestock species feed on the ripened spiny fruits of *O. stricta*, they develop ulcerative oral lesions and abscesses along GIT; become blind, emaciated and drop milk yield and then die (Shackleton *et al.*, 2017). Farmers in the *O. stricta* invaded locations have been losing goats and other livestock species which are their sole source of livelihood due to the effects of this plant. This scenario has impacted negative socioeconomic status and increased their vulnerability. The objective of this study was to determine the knowledge of farmers on *O. stricta* var. *stricta* and how they have been coping with it since it invaded their land couple of years ago. Economic losses and harmful effects in goats which are associated with the plant were also assessed.

3.2 Materials and Methods

3.3 Study site

The study was carried out in Laikipia North Sub-county, Laikipia County, Kenya between October 2018 and February 2019. Laikipia County covers an area of 9,462 km^2 and lies between latitudes 0º 18" and 0 º 51" North and between longitude 36º 11" and 37º 24' East. It borders Samburu County to the North, Isiolo County to the North East, Meru County to the East, Nyeri County to the South East, Nyandarua and Nakuru Counties to the South West and Baringo County to the West (Laikipia CIDP, 2014) (Fig. 2). The County is divided into three Sub-Counties namely Laikipia North, Laikipia East and Laikipia West. Laikipia North is purely pastoral zone while the other two Sub-counties are Agro-pastoral zones (Fig. 3).

3.4 Climatic conditions

The county experiences a relief rainfall due to its altitude and location. The annual average rainfall varies between 400mm and 750mm though higher annual rainfall totals are observed on the areas bordering the slopes of Mt. Kenya and the Aberdare ranges. The annual mean temperature of the county ranges between 16º C and 26º C (Laikipia CIDP, 2014).

3.5 Ecological conditions

The vegetation is primarily grassland, bush land, woodland, and dry forest. Wildlife and undulating landscapes are key features in the county (Laikipia CIDP, 2014).

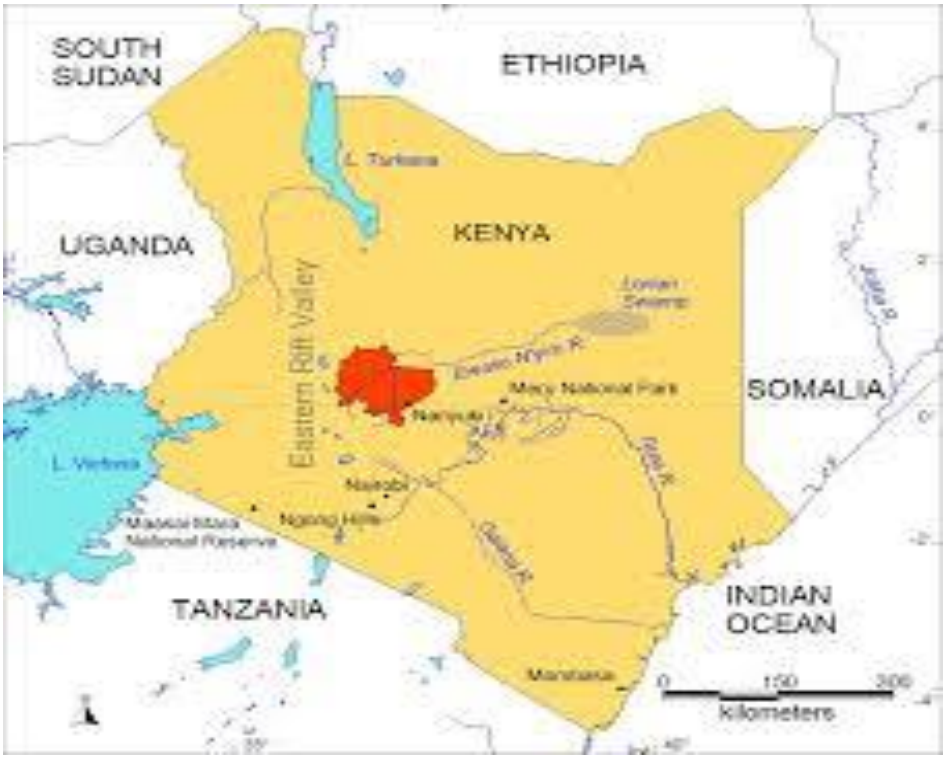


Figure 2: Map of Kenya showing position of Laikipia County (Highlighted in red) (https://laikipia.go.ke/county-maps/)

3.6 Study design

3.6.1 Design for Community Perception of *Opuntia Stricta*

Three locations of Laikipia north namely Mumonyont, Makurian and Ilpolei which have been invaded by *O. stricta* were targeted. The three locations border each other. Dol dol town which is in Mukogodo location is where *O. stricta* was introduced first as a living fence and then spread to cover the three locations (Fig. 3).

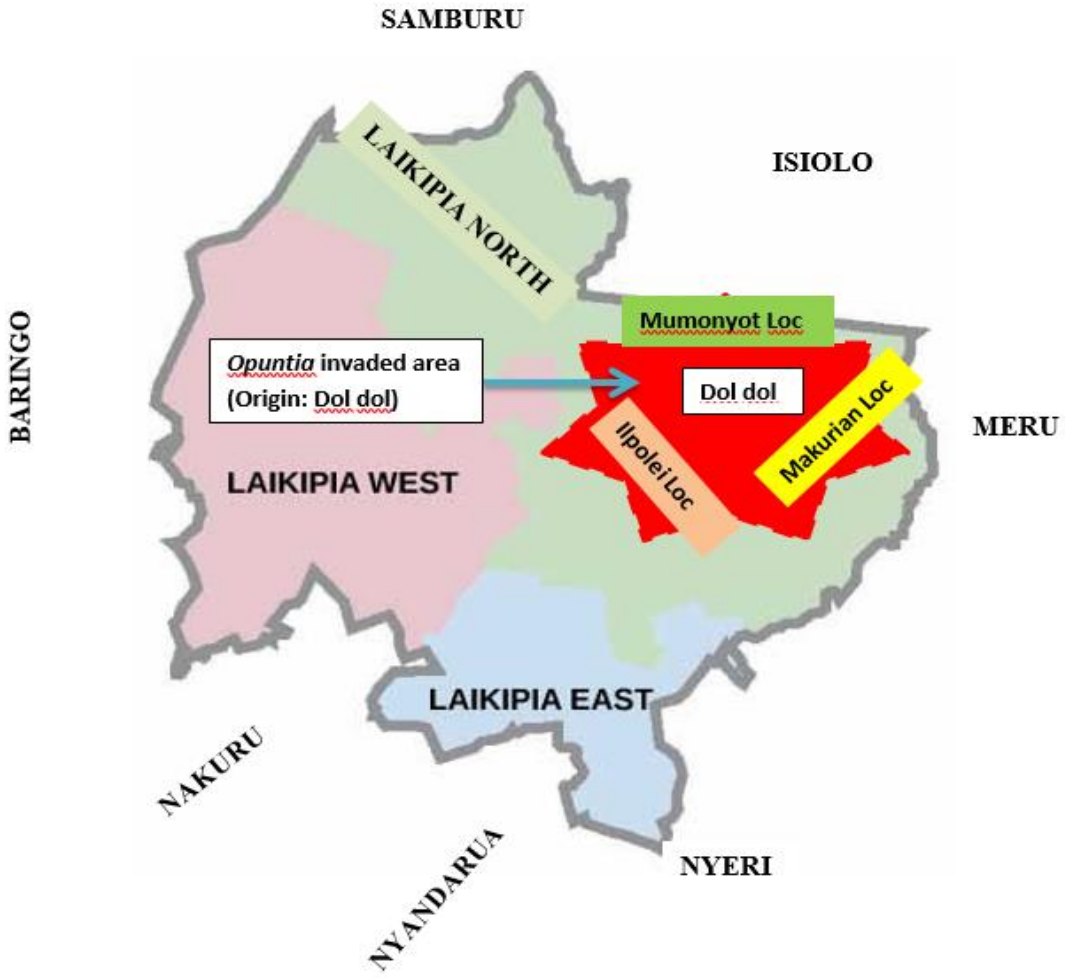


Figure 3: Map of Laikipia County showing three locations invaded by *Opuntia stricta* (https://laikipia.go.ke/county-maps/)

A semi-structured questionnaire (appendix 1) was used as a research instrument to determine knowledge, attitude and practices (KAP), economic impacts and risk factors associated with *O. stricta* variety *stricta*. One hundred-sixteen (116) household owners from the three locations were randomly selected and interviewed.

3.6.2 Questionnaire administration

The objective of this study was to determine whether farmers knew *O. stricta* var. *stricta* and its impacts in their midst, how they have been coping with it from the time the plant invaded their land and what were their views concerning this cactus in future. After preparation of the questionnaire, the sub county veterinary field officers working in Laikipia north were trained on how to administer them. The questionnaires were made up of close-ended listing and some open-ended questions with five main sections. These sections included: (1) Background information (Demographic data of respondents), (2) Information of the household, (3) Knowledge about *O. stricta*, (4) Economic losses of livestock due to deaths and treatment, and (5) Economic losses of livestock due to production and reproduction. The questionnaires were pre-tested prior to administration and some questions in some sections were adjusted accordingly.

Important aspects such as livestock species and numbers kept by respondents, livestock feeds available in the area, reasons for animals consuming *O. stricta* fruits, animal species affected and the age groups were covered. Other information was body parts of animals affected after an animal has consumed the plant, clinical signs the respondents associated with an animal that had consumed *O. stricta* and action taken after clinical signs appeared. The total number of animals each respondent had lost in the past one year; cost of each animal species at the local livestock market and their general opinion on the plant were also covered.

Simple random probability method of sampling was used. Questionnaire administrators were dropped by the vehicle every five (5) kilometers apart in the area of study where they randomly administered the questionnaires. This ensured that there was no bias in the selection of the households. One hundred and sixteen (116) households from Mumonyont, Makurian and Ilpolei

locations were randomly sampled and the heads of the households interviewed (Fig. 4). Where the household heads were absent, their spouses or any other suitable persons (son, daughter or worker) were interviewed instead. The interviews were done in the local Maasai language or Kiswahili and the local administration (Chiefs, assistant chiefs and community leaders) assisted in interpretations in their mother tongue during the interviews. Respondents were asked to answer questions on the knowledge of *O. stricta*, its benefits and harmful effects in both livestock and humans and economic losses associated with livestock's loss of body condition and deaths after consumption of the plant. This information was used to assess economic losses and harmful effects of *O. stricta* variety *stricta* in goats and other livestock species. Global positioning system (GPS) coordinates; questionnaires and observational data were recorded per household.

3.7 Data analysis

Questionnaire data from 116 households was coded, entered into Microsoft Excel, cleaned, verified and validated. The data was then imported into Statistical Package for Social Sciences (SPSS) version 22 for analysis. Data was summarized by use of descriptive statistics. Chi-square statistics significant of $p<0.05$ was used to test relationships between different categorical variables.

3.8 Results

3.8.1 Demographic data

Interviewees freely and willingly gave the information about the effects of *O. stricta* since they viewed it as menace (very disastrous plant) in their midst which should be eradicated in order for them to survive in the area. Most of the households (88.8%) were owned by males (Fig. 5).

Figure 4: Household owner interview during questionnaire administration in *Opuntia stricta* invaded area

Many male respondents (34.0%) were in 31 – 40 years of age category while most of the female respondents (38.5%) were above 55 years. However, this was not significant ($\chi^2 = 1.909$, df = 3, p = 0.591). The main occupation of the majority of respondents (81.9%) was farming with

occupation distribution among males being 79.6% farming, 6.8% business, 9.7% salaried and 3.9% casual laborers mainly sand harvesting in dry river beds (Fig. 6). The occupation of all female respondents (100%) was farming. The responsibility of day today management decisions about the animals was upon the livestock owner (91.4%) even though most of them (51.9%) had no formal education. Spouses (4.3%), sons (3.4%) and workers (1%) also participated in management decision of animals.

More females' respondents (63.8%) were interviewed compared to males (36.2%). This was because in "Maasai" tradition, females' remains at home as the males go out to look after their livestock. Most people interviewed (39.66%) were in 18-30 years' age group, followed by 31-40, 41-50, and above 50 years at 23.28%, 19.83% and 17.24% respectively (Fig. 7). Respondents with tertiary level of education were only males in 18 – 30 years' age category. There was much difference between the education level of the household head and the education levels of the person responsible for day today management decisions of the animals. This difference was significant ($\chi^2 = 299.132$, df = 9, p = 0.001).

Similar difference was observed between the education level of the household head and the interviewee which was also significant ($\chi^2 = 116.262$, df = 9, p = 0.001). Between interviewee and the person responsible for the management of livestock, their education levels also had much difference and significant ($\chi^2 = 121.904$, df = 9, p = 0.001).

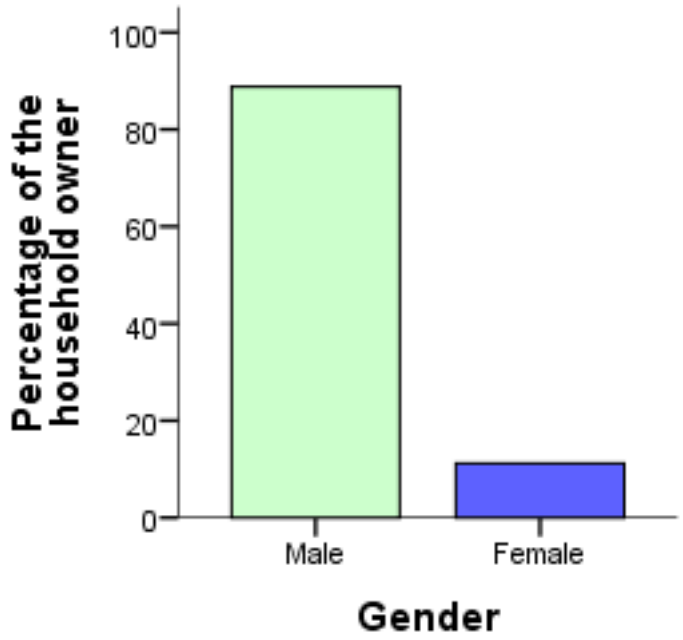


Figure 5: The percentage of the household owners by gender in *Opuntia stricta* invaded sites in Laikipia

Among 36.2% male respondents, their relationship with the household head was that 85.7% were the owners, 11.9% sons and 2.4% workers. Among the 63.8% female respondents, their relationship with the household head was that 81.1% were spouses, 17.6% were owners, and 1.4% daughters. There was a strong and significant relationship between interviewee and the livestock owner (χ^2 = 74.649, df = 4, p = 0.001).

3.8.2 Information about the household

In 116 households visited 74.6% had cattle, 94.7% sheep, 98.2% goats and 13.2% camel (Fig. 8). The main reasons for keeping livestock were: subsistence (88.8%), business (6.9%), culture (2.6%) and prestige/hobby (1.7%) (Fig.9). Female respondents indicated business and subsistence as the only reason for keeping livestock.

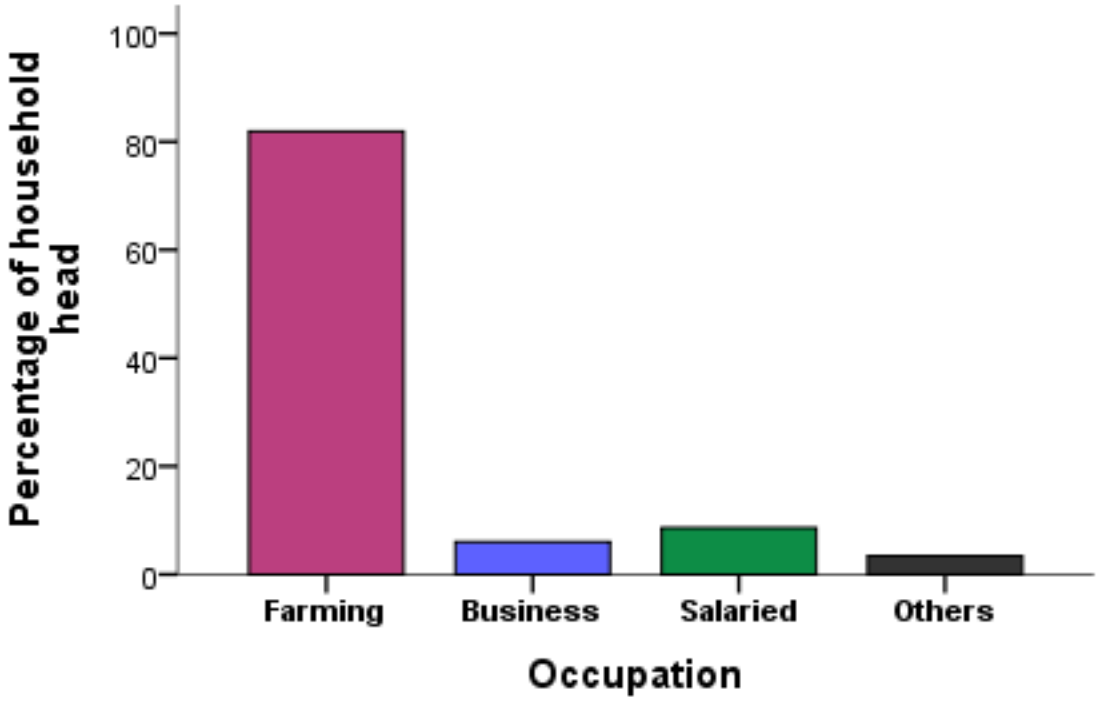


Figure 6: The main occupation of the household head in *Opuntia stricta* sites in Laikipia

The male headed households had higher number of animals than the female headed households. For the male headed households' mean of animals kept were: Cattle 9.87; sheep 29.71; goats 32.90 and camels 1.62. For the female headed households' mean of the animals kept were: cattle 3.54; sheep 12.77; goats 12.77. All female headed households had no camels. The persons with higher education level kept more animals than those with less education level. Thus, people with tertiary education level had more animals than those with secondary education in that order down the line.

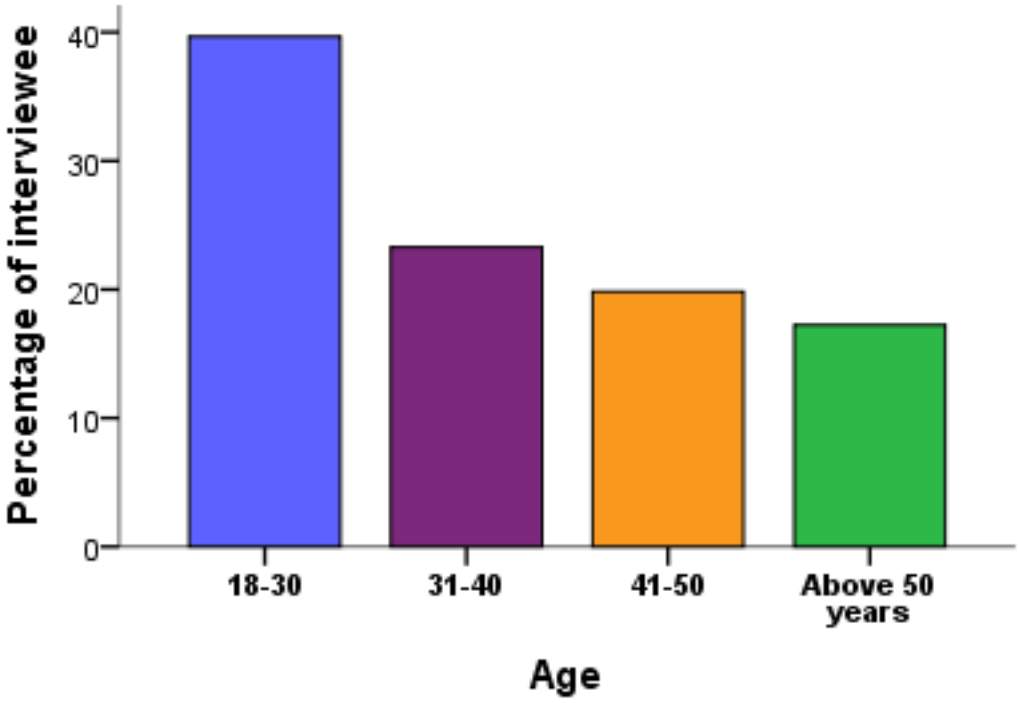


Figure 7: Percentage of interviewees by age groups in *Opuntia stricta* invaded sites of Laikipia

Grass and foliage were not available (100%) during dry periods while *O. stricta* (100%) and acacia (66.4%) were available in the same period (Fig. 10). In rainy season *O. stricta* was available (100%) as goat feeds, followed by grass and acacia (98.3%) and foliage 7.8% (Fig. 11). In the area invaded by *O. stricta*, extension services on veterinary and livestock production were not offered (56%). Only (44%) of the respondents said they get veterinary services. Veterinary services offered were: vaccination (98%), deworming (51%), availing of drugs (7.8%), treatment of clinical cases (3.9%) and availing of feed supplements during drought periods (2%). Training of stakeholders on livestock management was not done at all.

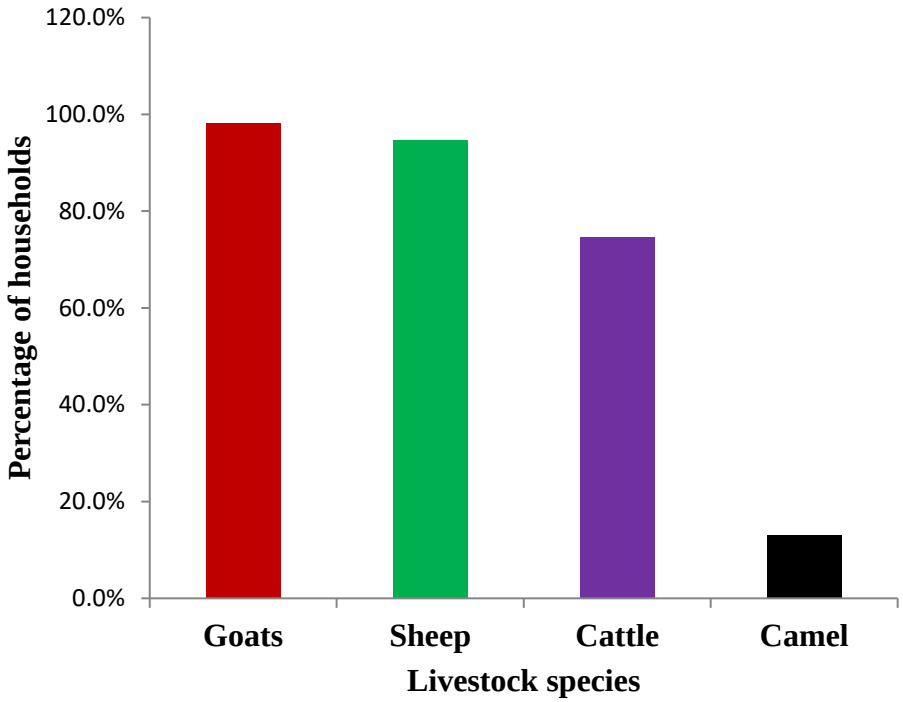


Figure 8: Livestock species kept per household in *Opuntia stricta* invaded areas of Laikipia

3.8.3 Knowledge about *Opuntia stricta*

All 116 respondents (100%) said they knew *O. stricta* variety *stricta* with its local "Maasai" name varying from "Olmatundai" (89.7%), "Ormatundai" (4.3%), "Rukurasi" (2.6%), "Ilmatunda" (1.7%), "Limatunda" and "Kikwei" 0.9% each (Fig. 12). The respondents had lived with the plant for the last sixty (60) years (Fig. 13). According to 95.69% and 97.41% of the respondents respectively, *O. stricta* was not beneficial to livestock and humans. The stated benefits to livestock were that *O. stricta* is the only source of feed during dry period (2.6%), it offers shade for grass growth (1%), and camel feed (1%).

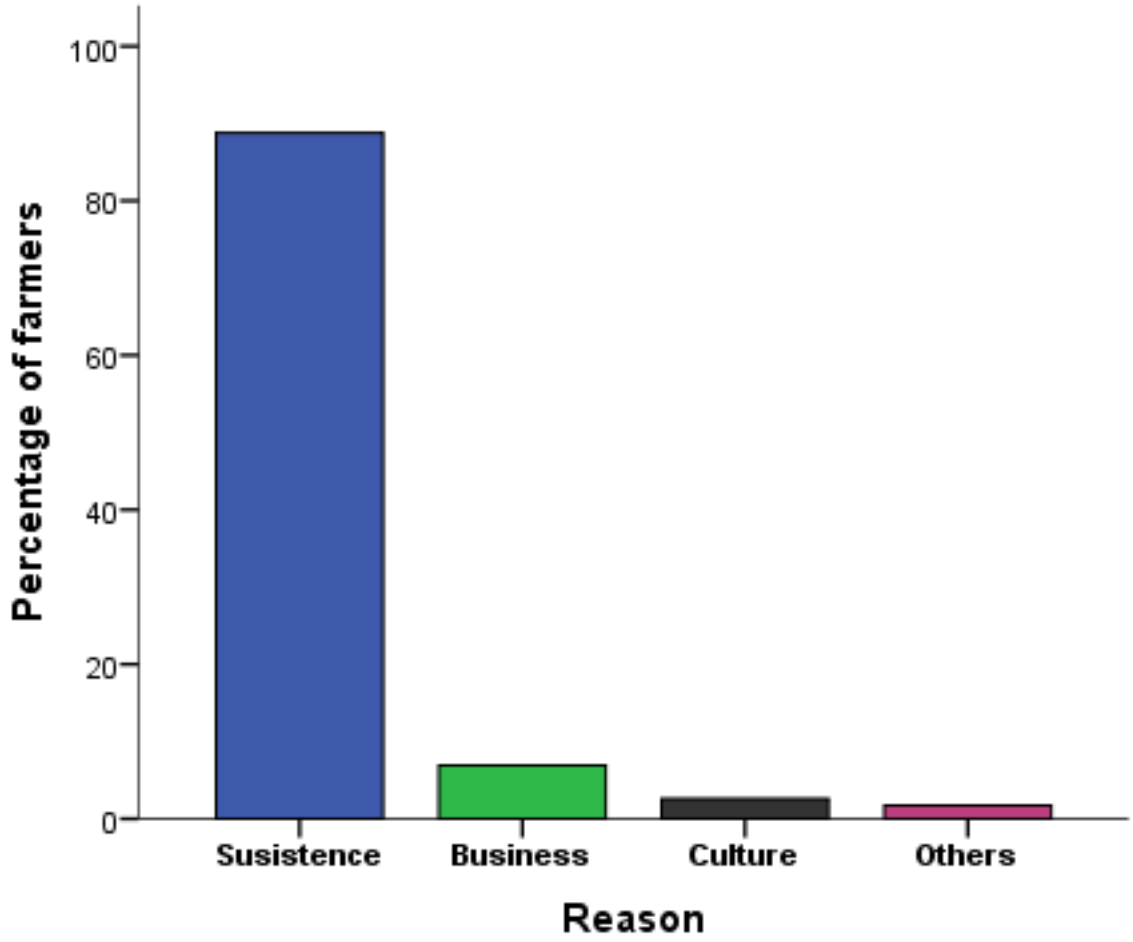


Figure 9: Main reasons for keeping livestock in Laikipia north

Stated benefits to humans included: *O. stricta* fruits are processed to produce juice and wine which are sold for income to people (1%), Children eats fruits (1%) and protection of the tree growth (1%). Nevertheless, all respondents (100%) said *O. stricta* have harmful effects to both livestock and humans.

Stated harmful effects of *O. stricta* on livestock were: causes blindness (93.9%), injuries on the lips and mouth (76.5%), death of livestock (59.1%), emaciation (35.7%) and injuries on the skin

and muscles (28.7%) (Fig.14). Harmful effects in humans include: causes wounds on the skin (84.1%), causes eye injuries and blindness (60.1%), and causes severe diarrhea to humans especially children consume fruits (41.6%) (Fig. 15).

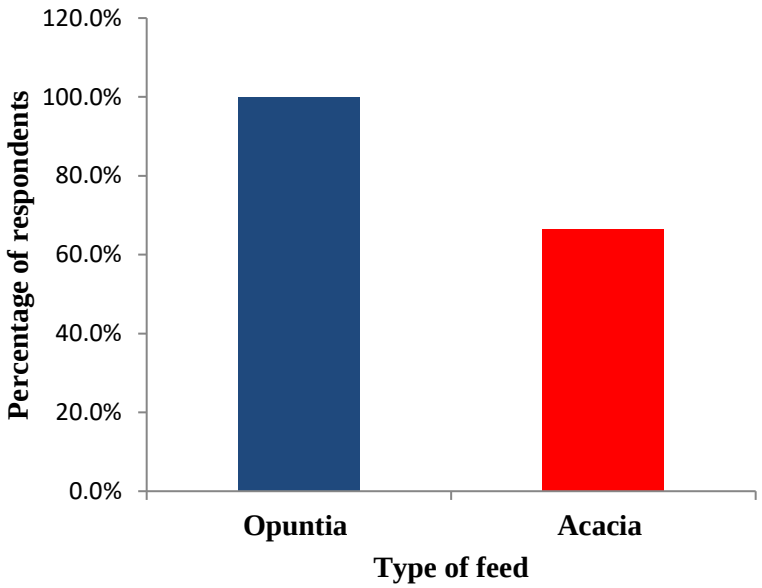


Figure 10: Livestock feeds available during dry season in Laikipia north

According to respondents, parts of the *O. stricta* eaten by animals are: fruit (100%), leaves (43.1%), flowers (16.4%), and stem (11.2%). All respondents (100%) said roots are not eaten at all (Fig. 16). Respondents recorded that *O. stricta* is eaten by animals, in dry and rainy seasons (56%); while 44% stated that it is eaten only during the dry season. Respondents indicated that animals eat *O. stricta* in all seasons (dry and rainy seasons) because they like the plant (52.59%) and in dry season because it was the only feed available (46.55%); 0.86% of the respondents said they did not know the reason why animals would eat the plant in both or other season (Fig. 17). Those who said that animals eat fruits of *O. stricta* in both seasons commented that animals

becomes accustomed to eating the fruits once they start eating them and so they eats them throughout.

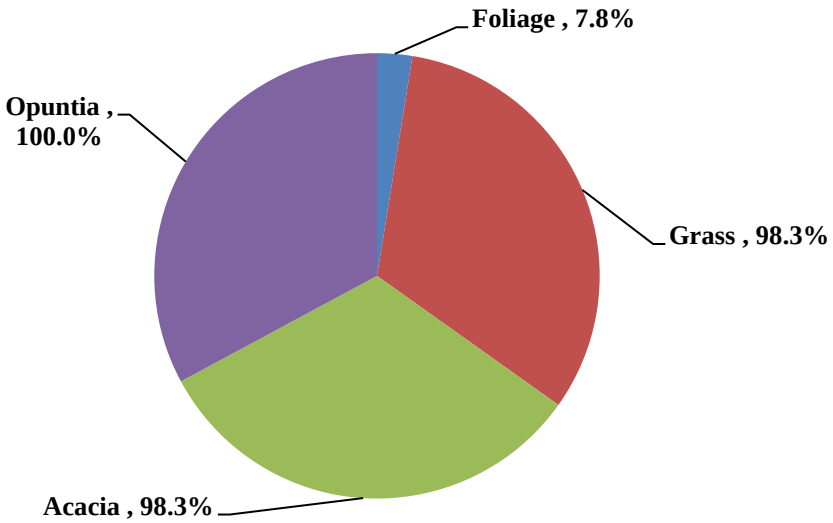


Figure 11: Livestock feeds available during rainy season in Laikipia north

The animal species mostly affected/harmed by *O. stricta* are: sheep (77.6%), goats (72.4%), cattle (26.7%) and camels (5.2%) (Fig.18). Respondents stated that the sex of animal mostly affected by consumption of *O. stricta* is: both males and females (89.7%) and only females (10.3%) of the respondents. The age groups of sheep mostly affected are: 54.7% adults ($1^1/_2$ - 4 years), all age groups of sheep affected the same way (35.4%) and only old sheep (above $4^1/_2$ years) (27.4%). Adult goats ($1^1/_2$ - 4 years) were mostly affected (54.8%); all age groups of goats affected the same way (35.7%) and only old goats (above $4^1/_2$ years) (27.8%) of the respondents. Similar to sheep, all respondents (100%) said young goats (day 1 old to 1 year) are not affected by *O. stricta*.

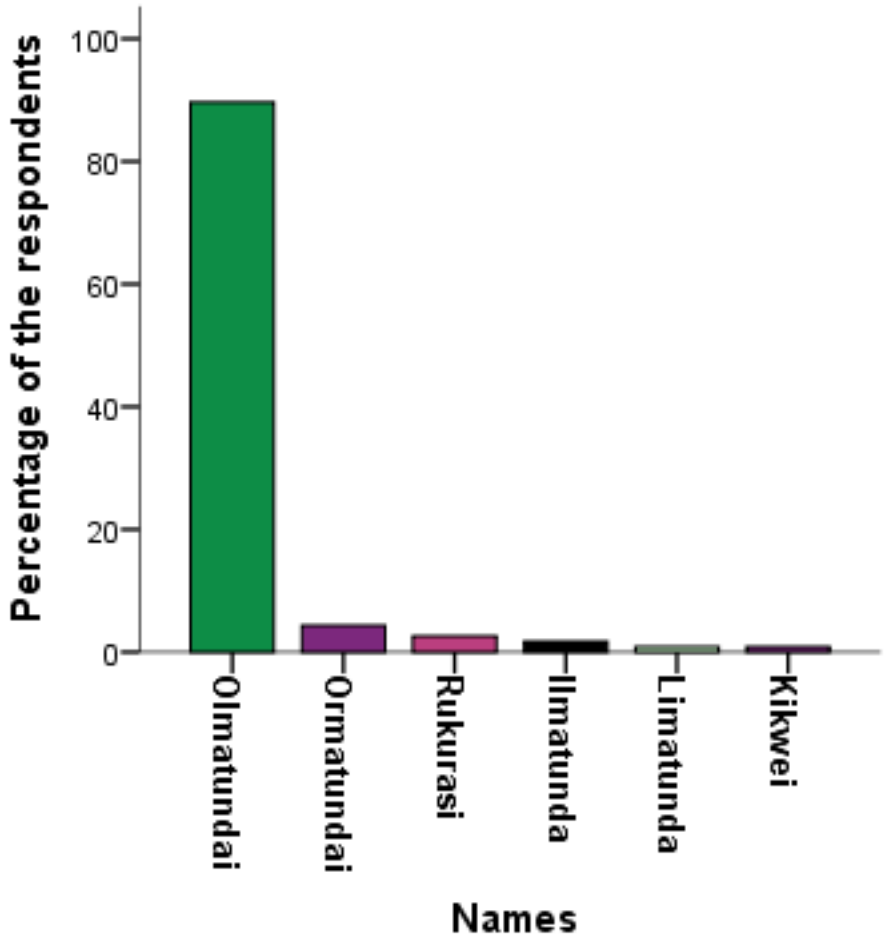


Figure 12: Local names given to *Opuntia stricta* in Laikipia

The age groups of cattle affected were: 2 – 5 years (55.6%), old cattle above 6 years (34.3%) and all age groups of cattle (31.3%). All respondents (100%) said young sheep and goats (day 1 old to 1 year) and young cattle (day 1 old to $1^1/_2$ years) are not affected by the *O. stricta*. Respondents reported that adult camels (3 – 8 years) are affected (57.1%), while (38.1%) said that all age groups of camel are affected the same way and that young camels (day 1 old to $2^1/_2$ years) are least affected (4.8%). All respondents (100%) stated that old camels (above 9 years) are not affected by *O. stricta*, no matter how much they eat it.

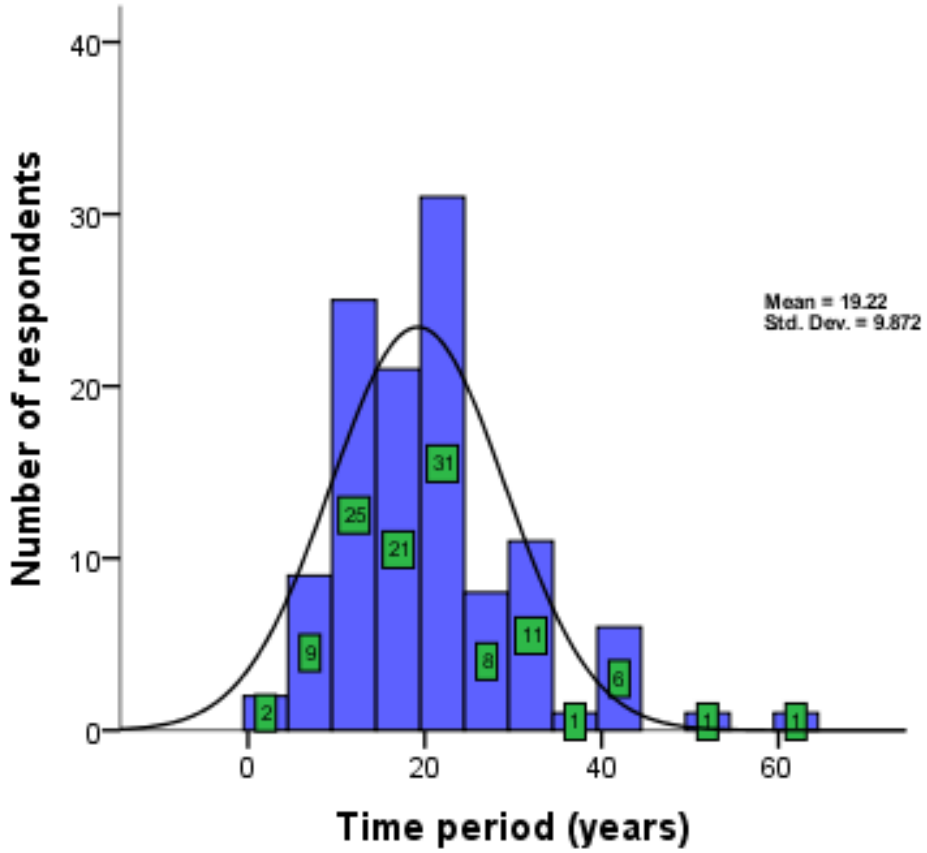


Figure 13: Period of time respondents had known *Opuntia stricta* in Laikipia

Old chicken (1%) of the respondents are also affected by *O. stricta* if they continuously eat the fruits. Although majority of the households had donkeys, owners observed that donkeys do not consume *O. stricta* and therefore they are not affected by this cactus.

Respondents associated the following clinical signs with an animal that had eaten *O. stricta*: blindness (100%), injuries in the mouth (99.1%), loss of body condition (98.3%) and lack of appetite (89.7%). Other signs included: salivation (19.8%), lameness (18.1%), reddish diarrhea (7.8%), decreased milk production (6.9%), skin injuries (6%), red urine (3.4%), foul smell from the mouth (1.7%), arthritis (1.7%), failure to close mouth (0.9%), reddened mouth (0.9%), spines

on the skin (0.9%), swelling of the stomach (0.9%), infertility (0.9%), teeth coming off (0.9%) and teat injuries (0.9%) (Fig. 19). The first clinical signs to appear after an animal has eaten *O. stricta* (Fig. 20) were as follows: Injuries in the mouth (54.1%), loss of body condition (35.8%), lack of appetite (3.7%), red urine (2.8%), blindness (1.8%) and salivation (1.8%). The next sets of clinical signs reported by 57% of the respondents were blindness and injuries in the mouth (31.8%). Others included: salivation (2.8%), lameness (2.8%) and reddish diarrhea (2.8%), loss of body condition (0.9%), red urine (0.9%) and spines on the skin (0.9%). Time taken for clinical signs to appear was reported as few weeks by 56% of the respondents, few months (31.9%) and few days (12.1%) after an animal has eaten *O. stricta* (Fig. 21). Respondents (98.3%) said they had slaughtered animals affected by *O. stricta* and the same number (98.3%) agreed that the slaughtered animals had some abnormalities in the entire GIT (Fig. 22). Respondents reported that most of the times eyes were blind; wounds occurred on the lips and mouth and numerous spines localized on different parts of GIT making the offal inedible.

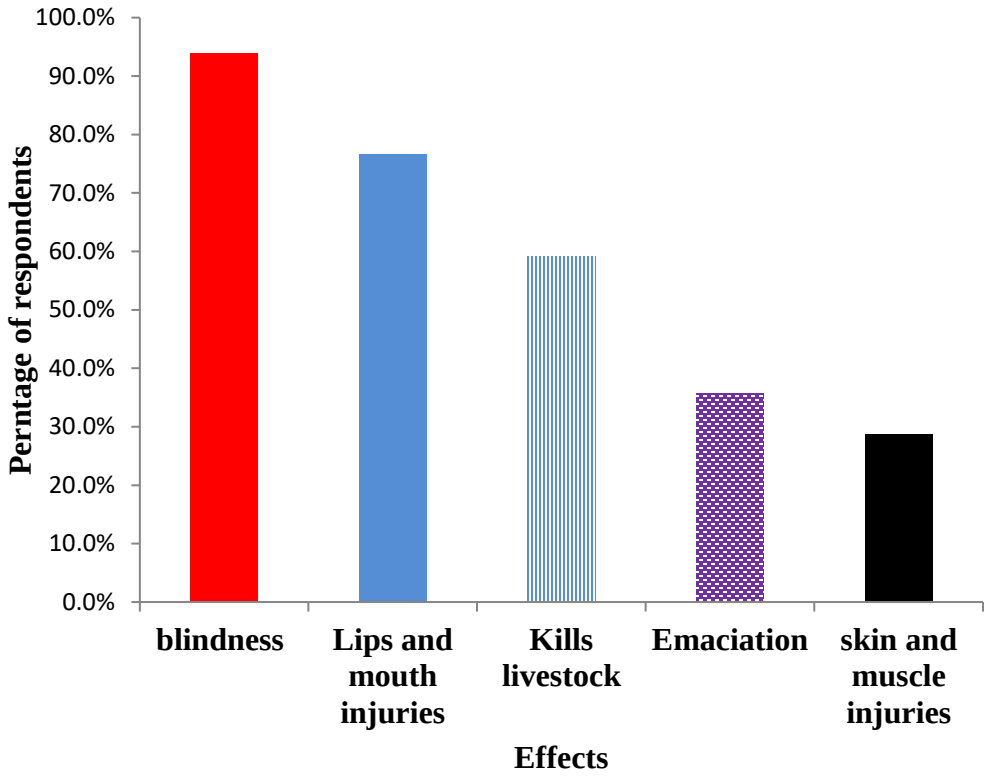


Figure 14: Reasons why *Opuntia stricta* is considered to be harmful to livestock

All respondents (100%) reported that once an animal was affected by consumption of *O. stricta*, it died no matter what interventions measures were tried to reverse the condition (either by use of homemade therapy or drugs from agro-veterinary outlets). The period of time taken by animals to die after they presented with clinical signs, differed from one animal species to the other although 1 – 5 months period was reported by most respondents as follows: Sheep (87.6%), goats (83.3%) and cattle (59%). Camels were reported to die in 1 – 2 years (42.9%) and 1 – 5 months (28.8%).

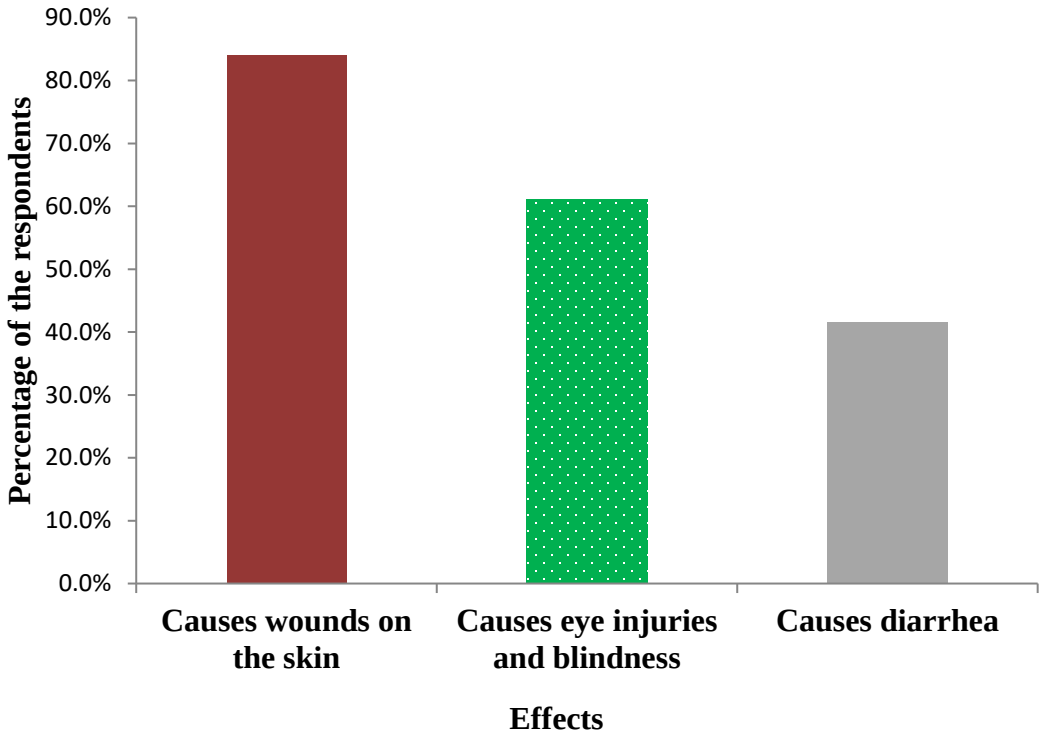


Figure 15: Reasons why *Opuntia stricta* is considered to be harmful to humans

3.8.4 Economic losses due to deaths and treatment

Respondents took different actions on their animals after they presented clinical signs associated with eating of *O. stricta*. The actions were: self-treatment of their livestock (53.4%), cull for slaughter (44.8%) and seek veterinary intervention (1.7%) (Fig. 23). For those who self-treated, (66.1%) bought drugs from agro-veterinary outlets, (48.4%) used homemade therapy and (3.2%) used herbal plants (Fig. 24). The homemade therapy was used to wash or was applied on the wounds inflicted by the *O. stricta* thorns and spines.

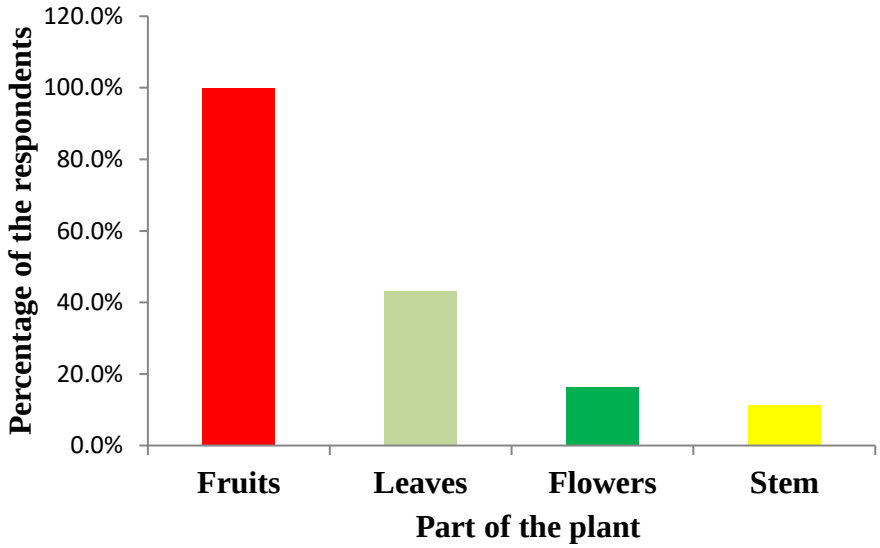


Figure 16: Different parts of *Opuntia stricta* eaten by animals

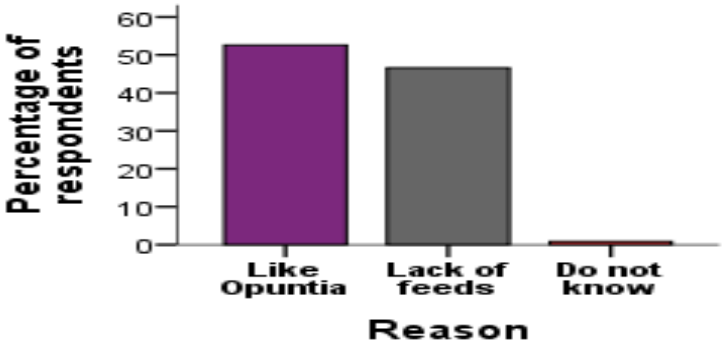


Figure 17: Reasons why animals eat *Opuntia stricta*

Homemade therapies used in self-treatment of livestock affected by *O. stricta* are: Warm salty water "Magadi" (87.5%); application of sugar on the eyes (3.1%), Contents of Dalambi plant (3.1%), Mixture of kerosene, sugar, water, detergent Omo® and salt (3.1%) and contents of Loisuk plant (3.1%) (Fig. 25). Drugs from agro-veterinary outlets used are: Oxytetracycline injection (57.1%), Oxytetracycline eye powder (11.9%), adamycine injection (9.5%), Penstrep

injection (4.8%), Oxytetracycline and tylosin injection (2.4%), Oxytetracycline injection and eye powder (2.4%), Oxytetracycline, Penstrep and tylosin injections (2.4%), Noromectin injection (2.4%), Oxytetracycline injection and albendazole (2.4%), levafas (2.4%), Penstrep injection and levamisole (2.4%) (Fig. 26). Even though all the above treatment regimens are massively used, all those who self-treat (100%) said it does not work at all and eventually the treated animals die.

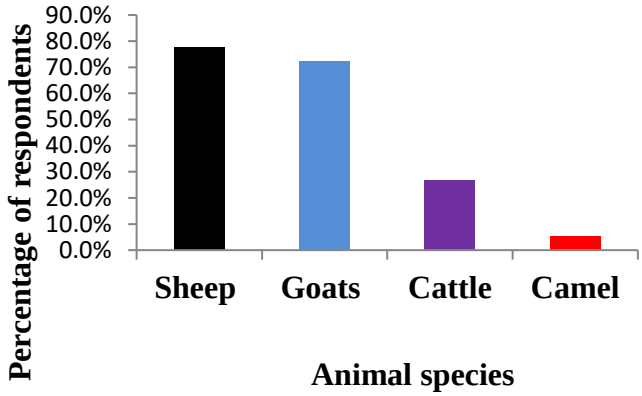
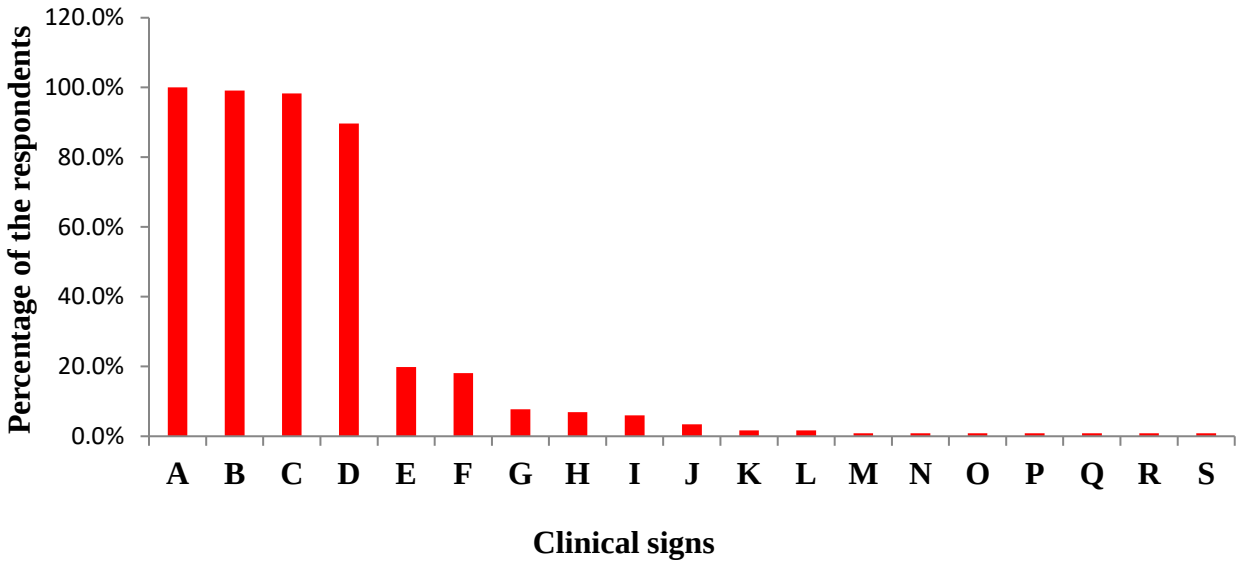


Figure 18: Animal species mostly affected or harmed by *Opuntia stricta*

Treated animals died irrespective of the treatment regimen given and period of time from treatment to death differed from one animal species to the other. Majority reported 1 – 5 months as the period of time in which animals died after treatment as follows: sheep, (87.5%), goats (77.4%) and cattle (72.9%) of the respondents. Camels died in 1 – 2 years' time (50%) of the respondents, 1 – 5 months (25%) and 3 – 5 years (25%).



A - Blindness **B** - Injuries in the mouth **C** - Loss of body condition **D** - Lack of appetite

E - Salivation **F** - Lameness **G** - Reddish diarrhea **H** - Decreased milk production

I - Skin injuries **J** - Red urine **K** - Foul smell from mouth **L** - Causes arthritis

M - Failure to close mouth **N** - Reddened mouth **O** - Spines on the skin

P - Swelling of the stomach **Q** – Infertility **R** - Causes teeth to come off

S - Causes teat injuries

Figure 19: Clinical signs associated with an animal that had eaten *Opuntia stricta*

3.8.5 Economic losses due to production

Livestock farmers incurred losses indirectly through reduced production and delayed reproduction period of their animals. Negative effects on lactation had severe consequences on growth rates and weight gains of the suckling animals and increased their mortalities. Consumption of *O. stricta* (98.3%) had effects on the lactating animals and caused decrease in milk production. The plant had effects on suckling young ones (96.6%) of the respondents and it

decreased growth rates and weight gains and increased death rates of both lambs and kids (95.7%). Consumption of the plant also decreased growth rate, decreased weight gain and increased death rate of cattle calves 83.6%. There were no effects on the growth rate, weight gain or death rate of the camel calves (66.4%) of the respondents and it decreased both growth rate and weight gain and increased death rates of the camel calves (33.6%).

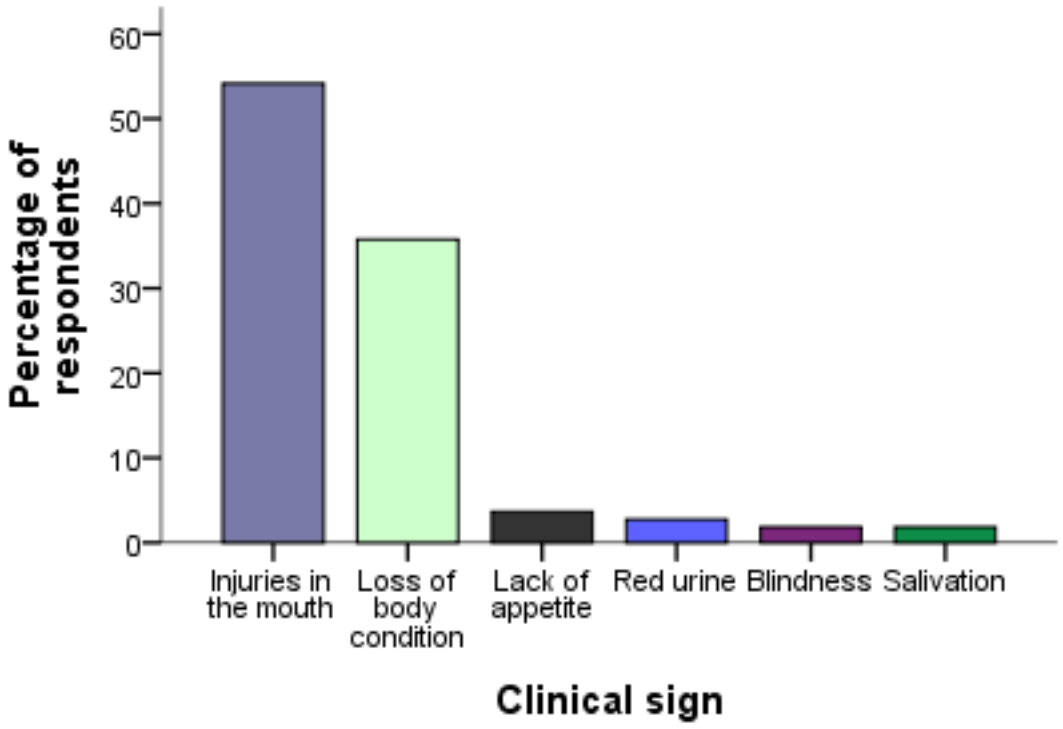


Figure 20: Respondent perspective of first clinical signs to appear after animals has eaten *Opuntia stricta*

Female animals affected by *O. stricta* took a long period of time to conceive again after calving, lambing or kidding due to poor body condition. Male animals affected by consumption of *O. stricta* expressed low libido. This situation resulted in low pregnancies in the herds and

subsequent reduction in herd sizes per households which impacted negatively on the pastoralists. Respondents (94.8%) stated that consumption of *O. stricta* increased the period of time taken by sheep and goats to conceive again after lambing and kidding respectively. For cattle (84.5%) of the respondents stated that the plant increased the period of time from calving to next mating. *O. stricta* had no effects on the reproductive cycle of camels (63.8%) of the respondents. Only 36.2% reported that the plant increased the period between calving to conception intervals in camels.

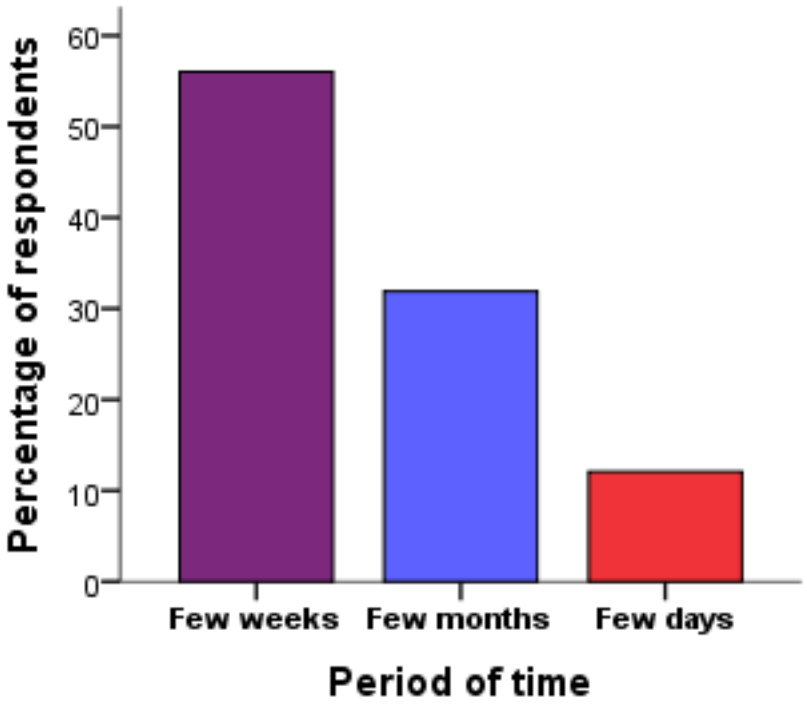


Figure 21: Period of time from the start of eating *Opuntia stricta* to appearance of clinical signs

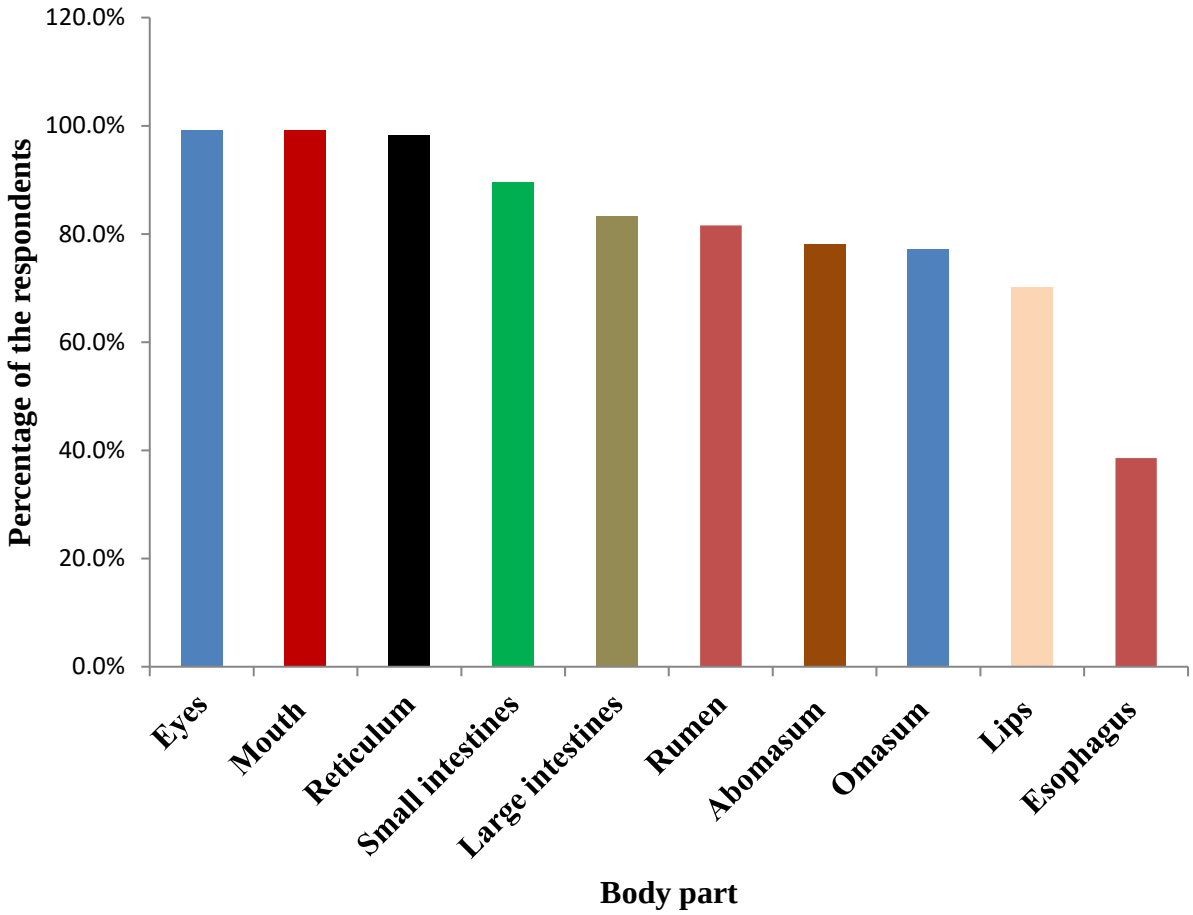


Figure 22: Parts of the body affected in an animal that has consumed *Opuntia stricta*

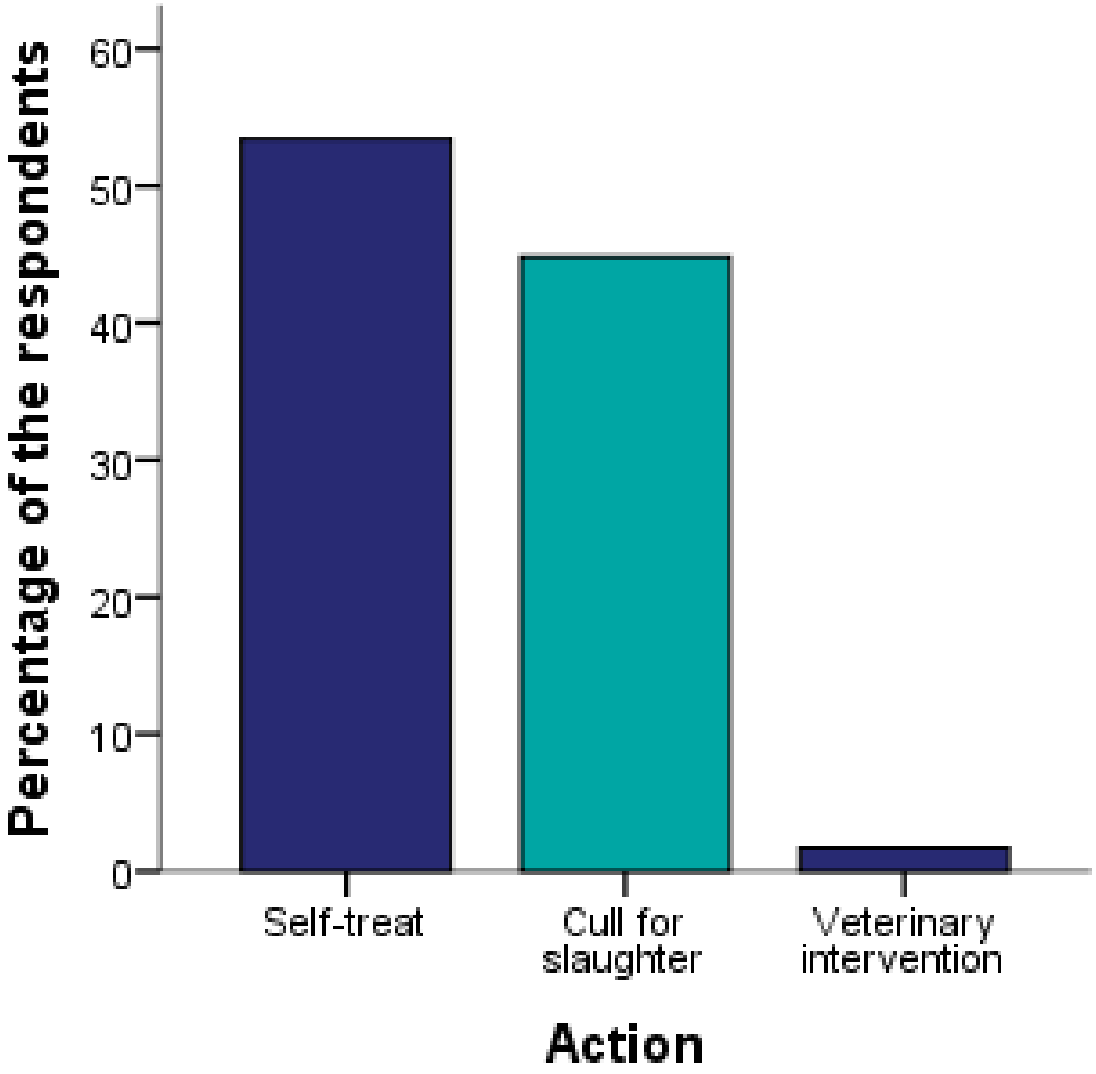


Figure 23: Action taken by respondents when their animals show symptoms arising from consumption of *Opuntia stricta*

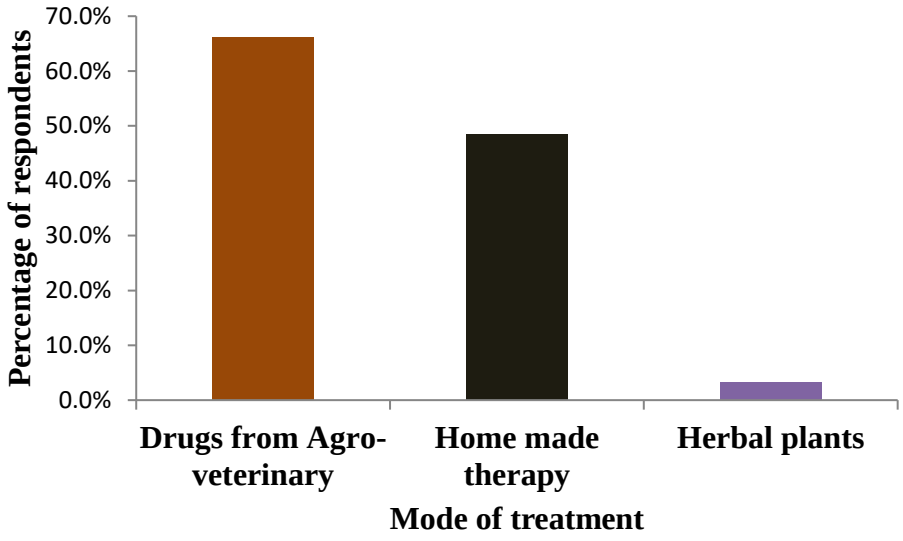


Figure 24: Methods used to treat *Opuntia stricta* related conditions by farmers

3.8.6 Additional Information on *Opuntia* Plant

The respondents shared their additional views on *O. stricta* which varied from one person to another. Majority (70.5%) appealed to the government to intervene and eradicate the plant in the area. Other views were that *O. stricta*: has displaced people from their areas of residence ("Manyattas") (25%), decreased the grazing land leaving them with nowhere to graze their livestock (21.4%), attracts elephants near Households "Manyattas" and has increased human wildlife conflicts (18.6%), is a disastrous plant and a big threat to people's livelihoods (17%), causes great loss to the "Maasai" community living in the area and has no benefits at all (17%), has limited the movement of people in the area (6.3%), has impoverished people due to death of their livestock (3.6%), has turned the area into a desert with no other plant surviving under it (2.7%) (Fig. 27).

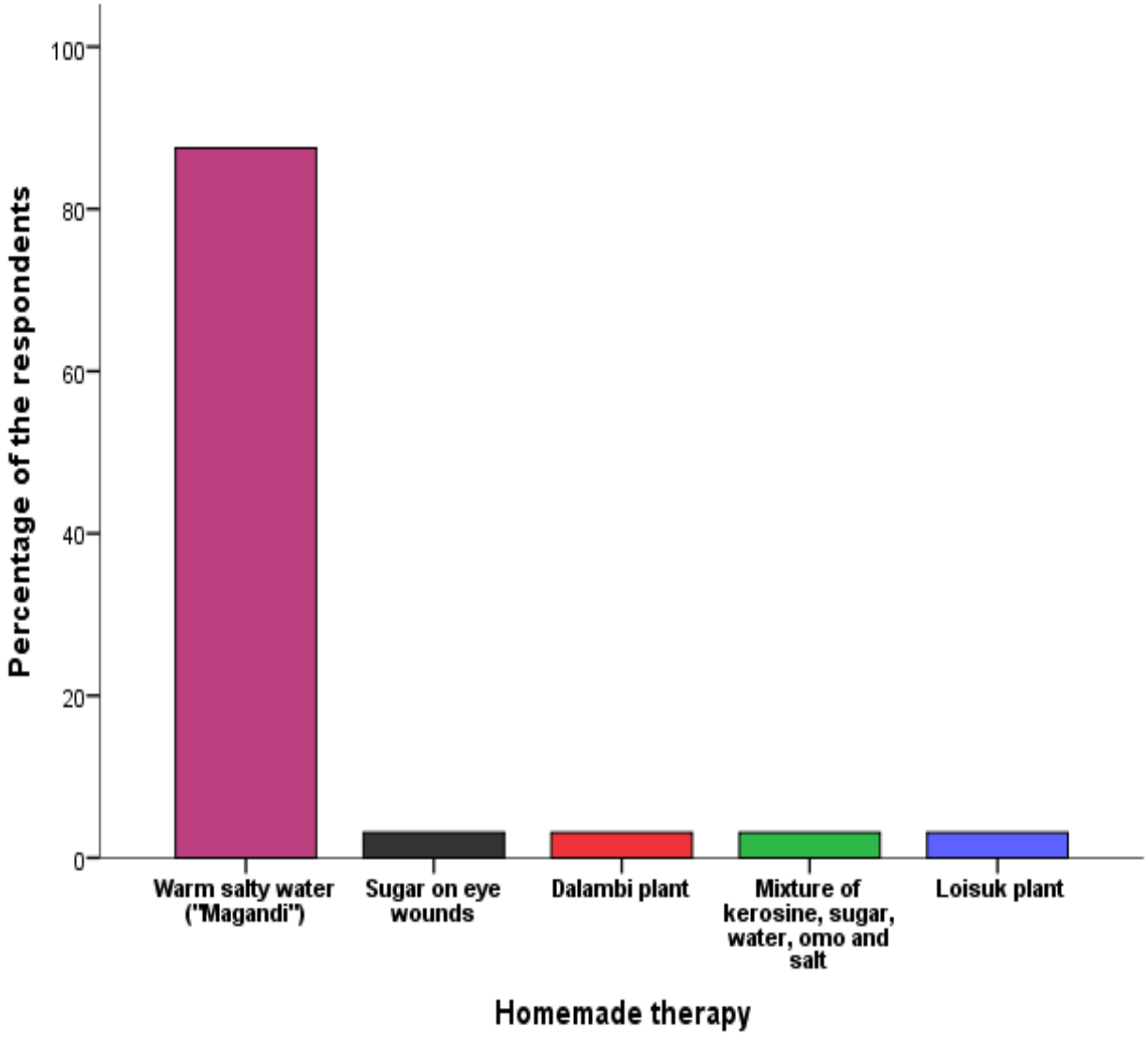
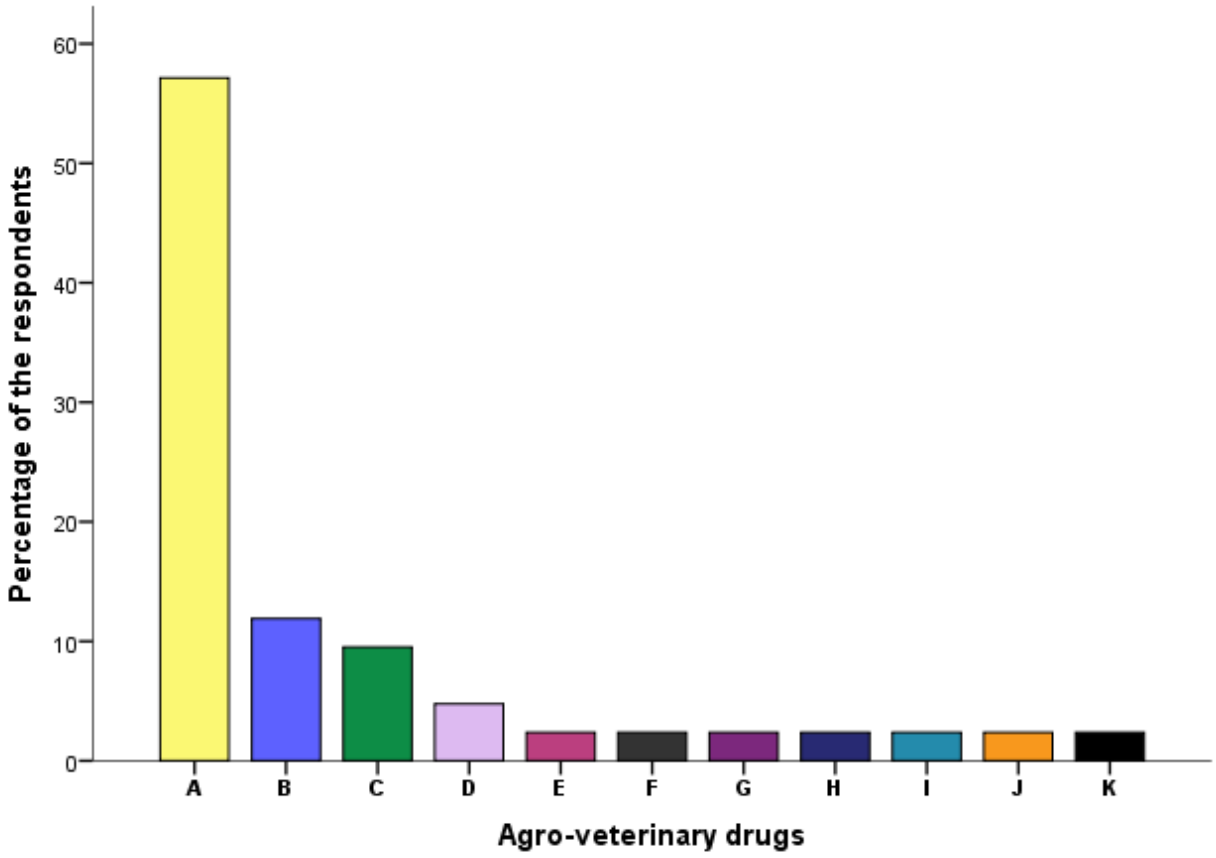


Figure 25: Homemade therapies used to treat animals affected by *Opuntia stricta*



A – Oxytetracycline injection **B** – Oxytetracycline eye powder

C – Adamycin injection **D** – Penstrep injection

E – Oxytetracycline and tylosin injections

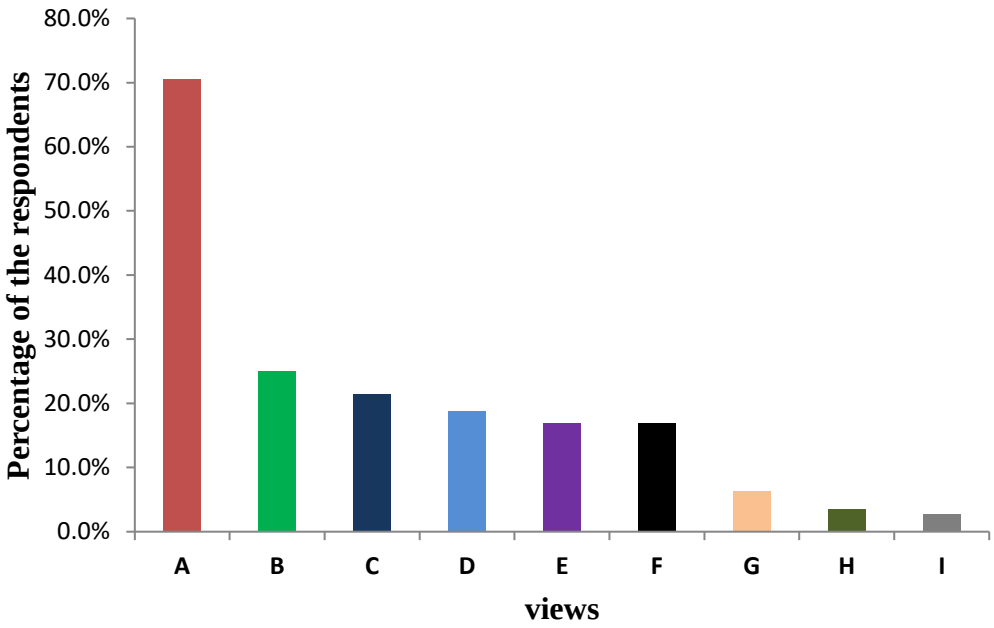
F – Oxytetracycline injection and eye powder

G – Oxytetracycline, Penstrep and tylosin injections

H – Noromectin injections **I** – Oxytetracycline injection and albendazole

J – Levafas **K** – Penstrep and levamisole

Figure 26: Conventional drugs used to treat *Opuntia stricta* related conditions



A - Appealing to government to intervene and eradicate *Opuntia stricta* in the area.
B - Displaced people from their area of residence ("Manyattas").
C - Decreased grazing land.
D - Attracts elephants near households ("Manyattas") increasing human wildlife conflict.
E - It is a loss to the community ("Maasai" people).
F – *Opuntia stricta* is a disastrous plant and a big threat to peoples's lives and livelihoods.
G – It has limited movement of people in the area.
H – It has impoverished people due to death of their livestock.
I - It has turned area into a desert with no other plants surviving under them.

Figure 27: Additional information given by respondents on *Opuntia stricta*

3.9 Discussions

Laikipia north Sub County is purely pastoral zone and communities' living here depends on livestock keeping as their sole source of income and livelihood. Invasion of their prime grazing land (Strum *et al.*, 2015; Shackleton *et al.*, 2017) by *O. stricta* has left them with nowhere to graze their animals. Consequently, livestock have turned to eating *O. stricta* as the only available

feed which they become accustomed to. In other countries of the world such as northern Mexico, spp. of spiny *Opuntia* are farmed as forage, fodder and animal nutrition and they do not cause problems to the animals. This is because before animals are allowed to feed on them, spiny *Opuntia* species are subjected to propane or paraffin flame in order to remove bristles of the entire plants (Mondragón-Jacobo and Pérez-González, 2001). This situation is different in Laikipia where livestock feed on *O. stricta in situ* together with thorns and spines. This results to injuries on the gastrointestinal system and development of septic ulcerative lesions on the lips and mouth. Thorns and spines get attached in the abomasum which results to development of abscesses and subsequent death of the animal (Nobel, 2002 and Shackleton *et al.,* 2017). Continued deaths of livestock especially sheep and goats in the study area has impacted negatively on the social economics, livelihoods and has increased vulnerability of the communities in Laikipia north. Goats were very important in the community as they were kept by majority of the households, followed by sheep and then cattle. Sheep and goats were considered as a bank Automated Teller Machine Card (ATM card) in the community because they could be exchanged easily at any time with money for subsistence use.

In the recent past the county has experienced conflicts related to competition for areas for grazing. As a way of saving their livestock pastoralist from *O. stricta* invaded area have been moving livestock towards Laikipia east and Laikipia west sub counties which are agro pastoral zones. In the process they invade and graze on the private farms and destroy crops. This has resulted to recurrent conflicts in the county. The situation may become worse because as the communities in Laikipia north lose their animals from the effects of *O. stricta*, they may turn to livestock rustling and other criminal acts in the region for their survival.

Even though the local name varied from one person to another majority of the respondents called it “Olmatundai”. Reporting by the respondents that this plant has been with them for the last 60 years, confirmed the earlier studies by Strum *et al*., (2015) and Shackleton *et al.,* (2017) that *O. stricta* was introduced in the study area over 50 years ago. Communities in the study area had a clear knowledge about *O. stricta* and they had developed many ways of surviving with this plant. Confidence in community knowledge and perspective is authenticated by long duration (60 years) that they had known this plant. Residents removed this cactus manually when it encroached into their households (“manyattas”). However due to aggressiveness of *O. stricta*, most of them were overwhelmed and they had to move to a new site. Pastoralists in the study area tried a number of ways to treat *O. stricta* related conditions in their animals. These included homemade therapies, herbal and conventional drugs even though they did not work.

The neighbouring conservancy called “Oljogi” has introduced a biological insect (aphid) called cochineal from South Africa which feeds and completely destroys *O. stricta*. Nevertheless, its rate of spread from one cactus stand to another is low and so far no change in reduction of *O. stricta* bushes has been experienced. Although about one percent of the respondents mentioned some benefits of *O. stricta* to both livestock and humans; all respondents reported that the plant was very harmful to both humans and livestock and damage so caused by far outweighed benefits. This scenario is different in other countries such as northern Mexico where both spiny and spineless spp. of *Opuntia* are considered as a resource with so many economic benefits. In these countries, the spiny *Opuntia* species are treated with propane or paraffin flame to remove thorns and spines before the animals are allowed to feed on them (Mondragón-Jacobo and Pérez-González, 2001). Both spiny and spineless *Opuntia* species are therefore highly valued as forage, fodder and animal nutrition. In addition, species of *Opuntia* plant has so many social economic

benefits in these countries. These include improving exposed rangelands used for grazing, reduction of soil erosion, used as living fence and plant barriers and natural carbon sequestering and gaseous fuel manufacturing (Barbera *et al*., 1995). Cactus in the genus *Opuntia* are also widely used for breeding cochineal which in turn produces dyes (Nobel, P.S., 2002; Barbera *et al*., 1995). In terms of human food, immature tender cladodes of *Opuntia* spp. known as nopalitos, are widely eaten as plant food in other countries of the world. They are utilized as a component in an extensive variety of foods, inclusive of sauces, salads, soups, snacks, pickles, drinks, confection and puddings and also as fruits (Barbera *et al*., 1995). *Opuntia* spp. is highly valued for numerous medicinal benefits in many countries among them being treatment of cardiovascular diseases, ulcers, and diabetes (Nobel, P.S., 2002). In Lebanon *Opuntia* spp. is used for making "arak" ('unsweetened anise'-flavoured distilled alcoholic drink) (Barbera *et al*., 1995). In Laikipia County, communities in the *O. stricta* invaded area have no technology to utilize this plant as it is used in other countries for their welfare and instead it is a disaster in their midst rather than a resource which requires urgent attention to save their livestock in order to improve their socioeconomics and livelihood.

3.10 Conclusions and recommendation

3.10.1 Conclusions

1. Community in Laikipia north had a clear knowledge on *Opuntia stricta* variety *stricta*.
2. The risk factors associated with the consumption of *Opuntia stricta* were environmental. These include reduction of rangeland grasses and other forage plants and trees which were livestock feeds as a result of invasion of the prime grazing land by *Opuntia stricta.*

Others were: land degradation, overstocking and poor rangeland management and recurrent and prolonged droughts in the study area.

3. *Opuntia stricta* is a disastrous plant posing great threat to the health of both livestock and humans and it affects livelihoods of people at a very high level.
4. Threat from this plant portends a looming conflict over lost resources in the county and in the region as a whole.
5. The communities affected by *O. stricta* in Laikipia north have devised many ways of surviving with this plant. These include manual removal of the plant from near their households and various ways of treating *O. stricta* related conditions in livestock. Nevertheless, invasiveness of this cactus has overwhelmed their efforts and it has displaced many from their areas of living. In addition, numerous methods employed to treat the affected animals does not work and *O. stricta* affected livestock dies irrespective of the kind of treatment given.

3.10.2 Recommendation

1. Government needs to take urgent measures to control the spread of *O. stricta* specifically in the prime grazing areas of Laikipia north Sub-county in order to save livestock from being wiped out by this plant.
2. Stakeholders should develop strategies to adopt technologies used in other countries to utilize *O. stricta* as animal feed and enterprise

CHAPTER FOUR

4.0 EFFECTS OF *OPUNTIA STRICTA* ON HAEMATOLOGICAL CHANGES OF GOATS

4.1 Introduction

Cacti in the genus *Opuntia* is farmed as forage worldwide (Mondragón-Jacobo and Pérez-González, 2001). Most species of *Opuntia* have thorns and spines which have to be treated with propane or paraffin flame to remove thorns and spines before the animals are allowed to feed on them. When animals forage on spiny *Opuntia* spp. naturally in the field without treating the plant to remove thorns and spines, animals gets injured by these spikes resulting to inflammatory and subsequently septic lesions (Mondragón-Jacobo and Pérez-González, 2001; Nobel, 2002). Forage with thorns and spines shelter a range of diseases causing microorganisms that are hazardous to herbivores feeding on them (Halpern *et al.*, 2007). These sharp organs of the plants introduce a number of pathogenic microorganisms into the body systems and cause infected lesions in animals, in a type of biological warfare (Halpern *et al.*, 2007; Lev-Yadun and Halpern, 2008). Halpern *et al.*, (2007) reported that both aerobic and anaerobic microorganisms introduced into the body of herbivores by thorns leads to disease conditions such as gas gangrene, anthrax and dermatitis. Earlier studies carried out by Shackleton *et al.*, (2017) in Laikipia north Sub-county showed that goats and other livestock species that were feeding on the ripened spiny fruits of *O.stricta* developed oral and GIT lesions; became blind, emaciated and dropped milk production and then died. The same scenario has been confirmed in this study (see chapter 3). Haematological changes of goats feeding on *O. stricta* in Kenya have not been reported before, yet such data are important in determining the impact caused by this plant on

health of animals feeding on it. The aim of this study therefore was to determine haematological changes of goats feeding on *O. stricta* variety *stricta* in Laikipia County as compared to the normal values reported by Jackson and Cockcroft, (2002)

4.2 Materials and methods

4.2.1 Selection of the study goats

Random purposive sampling for the study of haemato-biochemical changes and pathology in adult goats consuming *O. stricta* was carried out as documented in literature (Palinkas *et al*., 2015; Etikan *et al*., 2016). Twenty-four (24) small East African goats were purchased for the study. Eighteen (18) goats which had consumed *O. stricta* (referred to as sick goats – see figure 29 A) were purchased from three locations (Fig. 3) that were affected by *O. stricta* (Fig 28 A). The goats were bought as follows: 6 goats per location three of which were from two households ("manyattas") that were far apart in each location. At purchase, the sick animals were identified from the rests of animals in the herd as having been affected by *O. stricta* using unique clinical signs that were very familiar to the owners. These signs were: blindness, ulcerative wounds on the lips and mouth, inability to close mouth and chew cud, extreme emaciation, presence of *O. stricta* spines on the lips, mouth, eyes, face, ears, skin all over the body and red colouration of ripened *O. stricta* fruits on the lips (indicating that the animal had browsed on the plant some hours ago). The six (6) healthy goats which had not consumed *O. stricta* (referred to as controls see figure 29 B) were purchased from two *O. stricta* free ranches (Fig. 28 B) in the same Sub-county (3 goats per ranch). The criteria for their inclusion were that they had no signs of poor health and no trace of *O. stricta* linked effects. The origin, owner, age, breed, and sex of the goat were recorded. Each animal was identified with coded number starting from study goat 1 (SG1)

to study goat 24 (SG24). Blood samples for complete blood count and biochemistry were collected and processed as described below.

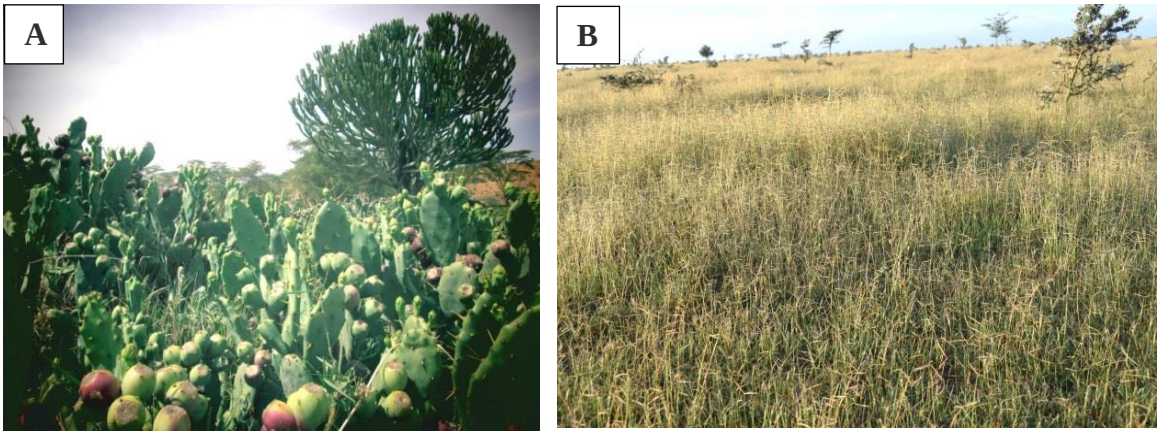


Figure 28: *Opuntia stricta* invaded area (A) and *Opuntia stricta* free ranch (B) in Laikipia north Sub-county.

Figure 29: Goats affected by consumption of *Opuntia stricta* (A) and ones not affected by *Opuntia stricta* (B) in the ranch

4.2.2 Ethical clearance

Animals' studies were approved by the Biosafety, Animal Use and Ethics Committee of the University of Nairobi (Appendix 2).

4.2.3 Blood samples for haematology

Lavender (purple capped) Becton Dickinson vacutainer tubes (BD Vacutainer® tubes) 4ml in volume with Dipotassium ethylene diamine tetra acetic acid (K_2EDTA) and Becton Dickinson vacutainer needles gauge 18 and 1 inch (BD Vacutainer® blood collection needle) were used to sample blood for haematology. Since the goats which had consumed *O. stricta* and the ones which had not consumed the plant were kept in two different locations far apart, blood samples for haematology of the two groups were taken in different days. Blood samples from goats consuming *O. stricta* were taken first. Before restraining each animal, BD Vacutainer® blood collection needle was fixed into the needle holder and two vacutainer tubes were labeled with goat's identification number. Ethylene diamine tetra acetic acid (EDTA) blood samples were collected in pairs. One of the EDTA blood was for hemogram (complete blood count) and the other one was for harvesting plasma for blood glucose and fibrinogen determination. Each goat was then restrained at a time in a standing position and once the animal was at rest, neck region around jugular area was swabbed with 70% alcohol to ensure that proper asepsis was maintained. Digital pressure was applied proximally just above the thoracic inlet to block blood movement through the jugular vein in order to raise its pressure. The vacutainer blood collection needle was then inserted through the skin into the jugular vein at approximately 30 degrees' angle (Appendix 3). The vacutainer tube was then inserted into the other end of the vacutainer blood collection needle through the needle holder. Adequate blood was collected into the vacutainer tube (leaving a space for mixing) to ensure proper blood-to-anticoagulant ratio. During blood collection, it was ensured that it did not come out of the vein in periodic variations but in a gentle continuous flow to avoid hemolysis of red blood cells. After adequate volume of blood was collected, vacutainer tube was detached from the blood collection needle. Thereafter vacutainer

needle was also removed from the jugular vein. Pressure was then applied on the puncture site for a minute to prevent extravascular leakage of blood and haematoma formation.

Immediately after blood collection, it was gently mixed by inverting vacutainer tubes 8-10 times. This ensured that blood was mixed promptly with EDTA to avoid sample clotting. Two smears were also made from each sample immediately after blood collection. The smears were fixed with absolute methanol immediately after drying. The samples were then properly packed in cool box with ice packs at 4 ^{0}C. Blood samples were kept out of direct contacts with ice packs by putting cotton wool between the blood tubes and ice packs in order to prevent freezing of red cell and subsequent hemolysis. The paired samples were then taken to Karatina regional veterinary investigation laboratory (RVIL) for analysis the same day. One sample was analysed for complete blood count (CBC) and the other was centrifuged, and supernatant transferred into Eppendorf tubes and was labelled plasma. The red blood cells were disposed in the laboratory's disposal system after analysis. The harvested plasma was transported under ice packs to Nanyuki veterinary office where they were stored in the deep freezer at -20 ^{0}C.

The same procedure was repeated for the goats which had not consumed *O. stricta* the following day. Three samples were collected per study goat and taken to Karatina RVIL same day for analysis. The samples were: Two EDTA samples (one for complete blood count and another for plasma harvesting) and the third one for serum harvesting. Two blood smears were also prepared from the blood sample meant for CBC and they were fixed with methanol. The serum was harvested as described for sick goats. The harvested serum and plasma for controls were also transported under ice packs to Nanyuki veterinary office where they were stored in the deep freezer at -20 ^{0}C.

4.2.4 Sample analysis for hemogram

At Karatina RVIL, EDTA samples for hemogram were well mixed on a roll mixer. The MS4se® automatic haematological machine was then calibrated with the appropriate controls for running Caprine haematology. All samples were then analysed one at a time and the results were printed (Appendix 4). The blood smears which were prepared and fixed immediately after sample collection in the field were stained with Giemsa stain at Karatina RVIL (Appendix 5).

4.3 Results

The haematological changes of each study goats are as presented in appendix 7.

4.3.1 Haematological changes of goats that had consumed *Opuntia stricta*

All the haematological values were lower than the control goats (Table 1). There was a marked increase in mean granulocyte counts and red cell distribution width. Mean lymphocyte counts, hematocrits (PCV), mean corpuscular hemoglobin (MCH) and hemoglobin (Hb) were lower than normal.

4.3.2 Haematological changes of goats that had not consumed *Opuntia stricta*

Total white blood cells, lymphocytes, monocytes and granulocytes were increased. Differential cell count showed slight decrease in lymphocyte counts while other cell types were in normal ranges. Platelet distribution width (PDW) was lower than normal while mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH) were slightly lower than normal ranges. Red cell distribution width (RDW) was markedly increased (Table 1)

Independent-Samples t-test was carried out for the haematological changes of the two groups of the study goats and p-values were determined. There was statistically significant difference between most haematological parameters of the two groups of the study goats (Table 2).

Table 1: Haematological changes of goats consuming and those not consuming *Opuntia stricta*

	Goats that consumed *Opuntia stricta* n =18	Goats that did not consume *Opuntia stricta* n = 6	Reference values for goats
	Mean ±SD	Mean ±SD	
White blood cells (WBC) $x10^9$/L	12.9506 ±5.93829	19.4817 ±10.92663	4.0 – 13.0
Lymphocytes %	35.7722 ±9.47193	49.067 ±14.9318	50.0 – 70.0
Monocytes %	3.9611 ±.98944	3.900 ±1.4199	1.0 – 4.0
Granulocytes %	60.2667 ±9.38936	47.033 ±14.5174	30.0 – 56.0
Total Lymphocytes $x10^9$/L	5.0011 ±3.95933	10.6183 ±9.55388	2.0 – 9.1
Total Monocytes $x10^9$/L	.4967 ±.24672	.6533 ±.21417	0.0 – 0.5

Total Granulocytes $x10^9/L$	7.4828 ±2.42162	8.2100 ±3.08484	1.2 – 7.2
Red Blood Cells (RBC) $x10^6/\mu l$	11.9922 ±3.18744	17.4283 ±1.59569	8.0 – 18.0
Mean Corpuscular Volume (MCV) fl	16.1722 ±1.91735	14.800 ±.6928	16.0 – 25.0
Haematocrit (PCV) (%)	19.0556 ±4.68756	25.750 ±2.7653	22.0 – 39.0
Mean Corpuscular Haemoglobin (MCH) pg	4.7333 ±.66155	4.733 ±.2658	5.2 – 8.0
Mean Corpuscular Haemoglobin Concentration (MCHC) g/dl	29.5722 ±1.76961	32.383 ±.9908	28.0 – 42.0
Red Cell Distribution Width (RDW) (%)	17.8667 ±1.42002	17.283 ±.6706	8.0 – 12.0
Haemoglobin (Hb) g/dl	5.6444 ±1.40471	8.367 ±1.1219	8.0 – 12.0
Thrombocytes (THR) $x10^3/\mu l$	285.5556 ±85.99263	324.000 ±94.1722	200 – 600

Mean Platelet Volume (MPV) fl	5.4167 ±.18231	5.583 ±.1169	4.0 – 9.0
Plateletcrit (Pct) %	.1522 ±.04223	.1800 ±.04858	
Platelet Distribution width (PDW) (%)	5.2111 ±1.12506	3.983 ±.3920	6.0 – 10.0
Key: % - percent; L – liter; µl – microliter; fl – femtoliter; pg – pictogram; g – gram; dl – deciliter			

Table 2: Independent-Samples t-test for haematological changes of the two groups of study goats

Haematological parameters which had statistically significant different means	**t-value**	**Degrees of freedom**	**p-value**
Differential lymphocyte counts %	-2.574	22	0.017
Differential granulocyte count %	2.606	22	0.016
Red Blood Cells (RBC) $x10^6/\mu/L$	-3.972	22	0.001
Haematocrit (packed cell volume) (%)	-3.282	22	0.003
Mean corpuscular haemoglobin concentration g/dL	-3.668	22	0.001
Haemoglobin g/dL	-4.291	22	0.000
Mean platelet volume (MPV) fl	-2.084	22	0.049
Platelet Distribution Width	3.964	21.804	0.001
Key: % - percent; L – liter; µl – microliter; fl – femtoliter; pg – pictogram; g – gram; dl – deciliter			

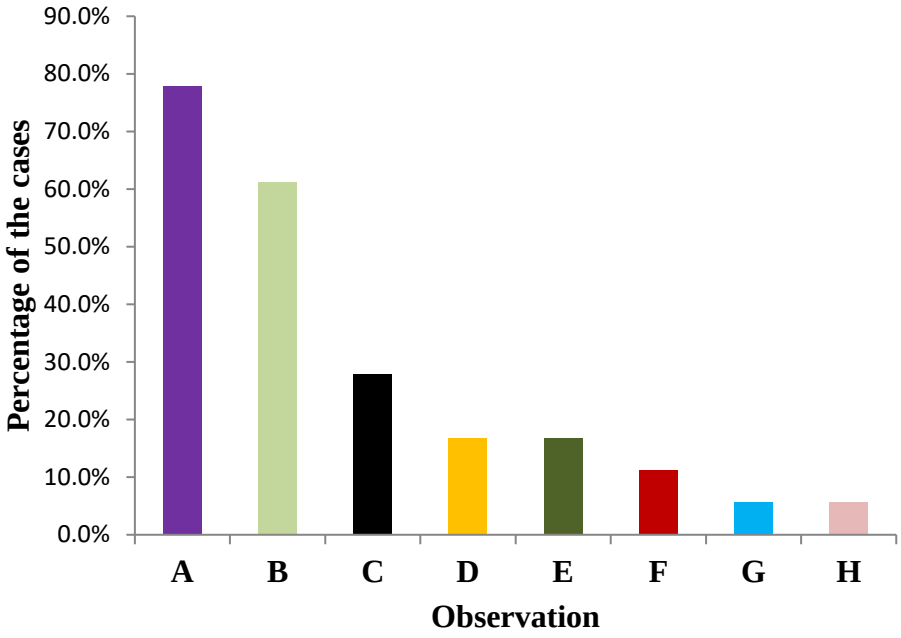
4.4 Blood smear

4.4.1 Blood smear results of goats that had consumed *Opuntia stricta*

Blood smear of goats consuming *O. stricta* showed that anisocytosis and poikilocytosis were 77.8% and 61.1% of the cases respectively. Other observations in this group were: *Anaplasma marginale* parasites (27.8%), hypochromasia (11.1%), normochromasia (5.6%), reduced RBC (16.7%), crenated RBC (16.7%) and keratocytes (Spindle shaped RBCs) 5.6% (Fig. 30).

4.4.2 Blood smear results of goats that had not consumed *Opuntia stricta*

Anisocytosis was seen in 50% of the goats that had not consumed *O. stricta* and poikilocytosis was in 33.3% of the cases. Blood smears which stained normochromatic were observed in 50% of the cases and *anaplasma marginale* parasites were observed in 16.7% of the cases (Fig. 31).



A – Anisocytosis

B – Poikilocytosis

C - *Anaplasma marginale*

D - Few RBC numbers

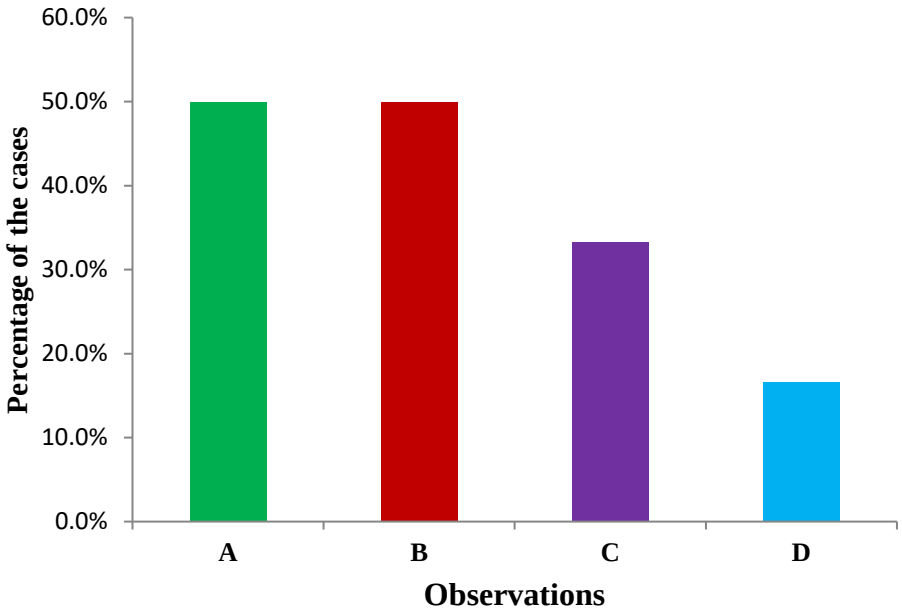
E - Crenated RBC

F - Hypochromic RBC

G - Keratocytes (Spindle shaped)

H - Normochromic RBC

Figure 30: Blood smear results of goats that had consumed *Opuntia stricta*



A – Anisocytosis **C** – Poikilocytosis

B – Normochromic **D** - *Anaplasma marginale*

Figure 31: Blood smear of goats that had not consumed *Opuntia stricta*

4.5 Discussions

The two groups of study goats showed anisocytosis and poikilocytosis but these two were more in the group of goats that had consumed *O. stricta* and less in the group that had not eaten *O. stricta*. Anisocytosis mostly occurs as a result of regenerative bone marrow reaction resulting in production of immature (larger than normal) polychromatophilic erythrocytes and Poikilocytosis is common feature in young goats (Jones, 2011). Observation of high level of anisocytosis in the goats that had consumed *O. stricta* indicates bone marrow reaction in response to loss of blood caused by injuries inflicted by *O. stricta* thorns and spines in various body parts. Goats that had consumed *O. stricta* had marked increase in granulocyte counts and low lymphocyte counts. Most of time increased WBC counts signify neutrophilia (Naeim *et al*., 2009) and neutrophilia

accompanied by lymphopenia is common in inflammatory and infectious conditions (Duncan and Prasse, 1987). Increased level of neutrophils (neutrophilia) is predicted if there is a considerable severe inflammation of the tissues underlying the skin. It occurs in inflammatory conditions of lungs and its associated structures; liver or gastrointestinal tract segments because mediators can simply get a way to the general blood circulation. Animals with severe inflammatory reaction have high levels of neutrophils and low levels of lymphocytes (neutrophilia accompanied by lymphopenia) (Stockham and Scott, 2013). A rise in neutrophils or neutrophilia might point out a stress or inflammatory reaction (Wilson, 2010). Respondents' reports of varied inflammatory injuries caused by *O. stricta* corroborate the leukocyte responses observed in this study.

Opuntia stricta consuming goats had low hematocrits (PCV), Mean corpuscular hemoglobin (MCH) and hemoglobin (Hb). Even though red blood cell counts of the goats that had consumed *O. stricta* were in the normal range, the levels were on the lower limit indicating depression of red blood cells production and anemia. This suggests that *O. stricta* variety *stricta* may be having phytochemicals which depress erythrocyte production or their release from the bone marrow. Reduced levels of haematocrits, haemoglobin and red blood cell counts are encountered in anemia and generally, reduction in RBC indices matches reduction in hemoglobin (Wilson, 2010; Duncan and Prasse, 1987). In iron deficiency anemia, the following RBC indices are lowered: mean corpuscular volume (MCV), Mean corpuscular hemoglobin (MCH) and Mean corpuscular hemoglobin concentration (MCHC). Lack of iron is therefore one of the reasons of presence of small red blood cells and low means corpuscular hemoglobin (microcytosis). The mean corpuscular haemoglobin (MCH) is subjective to mean corpuscular volume (MCV). This is because the reduced size of red blood cells holds a smaller amount of haemoglobin and therefore

they have reduced mean corpuscular haemoglobin (Duncan and Prasse, 1987). Observed injuries in the gastrointestinal tract in *O. stricta* affected animals could have a link with low red blood cell indices associated with interference in dietary intake of iron and other proerythrocytic nutrients.

4.6 Conclusions

1) Haematological changes in goats that had consumed *O. stricta* showed neutrophilia which was accompanied by lymphopenia indicating inflammatory and infectious conditions.
2) Mean corpuscular haemoglobin (MCH), hematocrit (PCV) and haemoglobin (Hb) levels in goats that had consumed *O. stricta* were far much below normal levels. Although red blood cells were within normal range, they were on the lower normal limit. This indicated anemia associated with iron deficiency and depression of erythrocytes production in this group of goats.
3) Marked anisocytosis characterized by large polychromaphilic erythrocytes, which were observed in blood of goats that had consumed *O. stricta* indicated concurrent regenerative bone marrow reaction

4.7 Recommendation

1) More research needs to be done on the haematology of goats consuming *Opuntia stricta*.

CHAPTER FIVE

5.0 BIOCHEMICAL CHANGES IN GOATS THAT HAD CONSUMED *OPUNTIA STRICTA*

5.1 Introduction

Clinical chemistry parameters such as alkaline phosphatase (ALP), proteins and creatine kinase (CK) among others are widely used as biological indicators in identification of the primary cause of an ailment or for following up the course of sickness, response to treatment or monitoring the health status of an animal (Duncan and Prasse, 1987; Putignano *et al.,* 2000). Some serum enzymes are specific for particular organ damage and are usually elevated whenever such an organ is injured. For example, an enzyme like CK that responds very fast to muscle injuries is used as a pointer to skeletal or cardiac muscle injury and elevated levels of this enzyme occurs when there is wasting or necrotizing muscle damage. Diseased organs and low metabolic status in an organ can lead to decreased production of the enzymes they synthesize. Diffuse, severe and chronic liver disease causes low albumin in the blood (Constable *et al.,* 2016, Huang *et al.,* 2012). An enzyme like CK can also be increased when there is inflammation of skeletal muscles by microorganisms such as *Neospora* sp, bacteria and *Toxoplasma* sp (Stockham and Scott, 2013; Neumann *et al*., 2005; Aktas *et al*., 1993).

Aspartate aminotransferase (AST), creatine kinase (CK) and lactic acid dehydrogenase (LDH) levels are elevated in acute diseases of muscles (Constable *et al*., 2016; Kim *et al.,* 2008). Diseases affecting biliary tract and conditions that obstructs flow of bile either from within or outside liver causes rise in alkaline phosphatase (ALP) (Petty *et al*., 2015; Kliegman *et al*., 2017). Insufficient nutritional intake, reduced uptake of food in the gastrointestinal tract and lack

of vitamin D also decreases alkaline phosphatase (ALP) (Thompson, 2013). Degenerative injuries to liver and muscle cells as well as necrosis or neoplasia causes increased levels of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) (Kaneko *et al*., 2008; Suckow *et al*., 2012; Zoppini *et al.*, 2016; Faqi, 2016).

Feeding of leafy part of *Opuntia* spp. to sheep and cattle is a problem at times because it leads to severe laxative activity. Even though this purgative activity is not an illness and has no harmful consequences on health of an animal Mondragón-Jacobo and Pérez-González, (2001), it causes persistent diarrhea which can have serious results in dry areas (Nobel, P.S., 2002). When animals feed on large amounts of leafy *Opuntia* spp. with little intake of roughage, the high quantities of calcium and phosphorus in this plant causes dietary imbalance and subsequent diarrhea (Mondragón-Jacobo and Pérez-González, 2001).

Opuntia spp. is also rich in nutritional oxalates which bind calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K) into insoluble compounds lowering their levels. Disease conditions associated with high oxalic acid consumption by animals includes inflammation of kidneys and inadequate gaseous exchange by the respiration system. calcium oxalate crystals can be a source of physical injury to the gastrointestinal tract, but those originating from leafy portions of *Opuntia* spp. are rather round, and might not cause problems. Herbivores have bacteria, microscopic algae and fungi in their GIT that break down and reduce calcium oxalate and take in the calcium, provided there is enough time for gastrointestinal microorganisms to acclimatize. In addition, abundant inorganic substances in leafy parts of *Opuntia* spp. may reduce bacterial growth in the rumen (Mondragón-Jacobo and Pérez-González, 2001; Nobel, 2002).

Consumption of spiny *Opuntia* spp. *in situ* in the field with intact thorns and spines results in septic inflammatory lesions (Mondragón-Jacobo and Pérez-González, 2001; Nobel, 2002).

Forage with thorns and spines such as *O. stricta* shelter a range of disease-causing microorganisms that are hazardous to herbivores feeding on them (Halpern *et al.,* 2007). These thorns and spines introduce a number of disease-causing microorganisms into the body systems of the animals resulting to infected lesions (Halpern *et al.*, 2007; Lev-Yadun and Halpern, 2008). When both aerobic and anaerobic microorganisms are introduced into the body of herbivores by thorns, they lead to disease conditions such as gas gangrene, anthrax and dermatitis (Halpern *et al.,* 2007). Studies done by Shackleton *et al.*, (2017) in Laikipia north Sub-county showed that goats and other livestock species feeding on the ripened spiny fruits of *O. stricta*, developed lesions in the oral cavity and along the GIT; became blind, emaciated and dropped milk yield and then died. Perspective of communities living in Laikipia north on *O. stricta* var. *stricta* which is reported in chapter three (3) showed that *O. stricta* causes harmful effects on the health of goats and other livestock species feeding on it. Biochemical changes of goats feeding on spiny *Opuntia* spp. *in situ* are not documented, yet they are important in health monitoring of animals consuming the plant. The aim of this study was to determine biochemical changes in goats that manifested clinical signs associated with consumption of *O. stricta* in Laikipia north Sub-county.

5.2 Materials and methods

The sampling procedure of the blood for serum was carried out as described in 4.2.3. Plain (red capped) 4ml Becton Dickinson vacutainer tubes (*BD Vacutainer*® tubes) were used. Prior to blood collection, the tubes were labeled as blood for serum. Blood samples were kept under room temperature for one hour for the clot to form. After one hour, clotted blood samples from the goats which had consumed *O. stricta* were centrifuged at Dol dol Sub-county hospital at a

revolution of 2000rpm for 10 minutes using laboratory centrifuge LMC – 3000 (Grant-bio)® (Appendix 6). The supernatant was transferred into Eppendorf tubes using sterile plastic Pasteur pipettes and red cells were disposed in the hospital's disposal system. Serum was then transferred to Nanyuki veterinary office and stored in deep freezer at -20 ^{0}C.

Blood samples for serum from the goats which had not consumed *O. stricta* were collected the same day with the hematology samples and later centrifuged at Karatina RVIL; serum was harvested and stored as described in section 4.2.3. Both plasma and serum samples were later transported to the College of Veterinary Sciences, department of Veterinary Pathology, Microbiology and Parasitology (VPMP) University of Nairobi and were stored in a deep freezer at -20 ^{0}C. Serum samples were analyzed in the biochemistry laboratory using visual semi-automated chemistry analyzer (Visual 60VB0357 No 958) in the department of clinical studies University of Nairobi.

The following parameters were analyzed: total protein (TP), albumin, alkaline phosphatase (ALP), alanine aminotransferase (ALT), aspartate aminotransferase (AST), creatine kinase (CK), creatinine, and blood urea nitrogen (BUN). Before each test was performed, the machine was first run with the blank to determine the influence of the instrument on the readings. This was followed by running of the controls to evaluate the reliability of the method to be used. The machine was then calibrated to convert the instrument readings to the units required. Calibration was done for tests that had not been run recently. Finally, each test was then carried out. Plasma samples were analyzed for fibrinogen using manual spectrometer and blood glucose using glucometer strips in the department of Veterinary Pathology, Microbiology and Parasitology University of Nairobi.

5.3 Results

The biochemical changes of each study goats are presented in appendix 8

5.3.1 Biochemical changes for goats that had consumed *Opuntia stricta*

The total protein and creatine kinase (CK) of goats that had consumed *O. stricta* were elevated while blood glucose was slightly higher than normal. Albumin levels, alkaline phosphatase (ALP), aspartate aminotransferase (AST), alanine aminotransferase (ALT), blood urea nitrogen (BUN) and creatinine were lower than normal ranges (Table 3).

5.3.2 Biochemical changes for goats that had not consumed *Opuntia stricta*

The total proteins and creatine kinase of goats that had not eaten *O. stricta* (controls) were elevated similar to those of the sick goats. Similarly, the levels of creatinine were lowered for the two groups of the study goats. However all other parameters: Alkaline phosphatase, aspartate aminotransferase, alanine aminotransferase, blood urea nitrogen and blood glucose were within the normal range for the goats which had not consumed *Opuntia stricta* (Table 3).

Table 3: Biochemical changes of goats consuming *Opuntia stricta* compared with naïve goats

	Goats that had consumed *Opuntia stricta* n=18	**Goats that had not consumed *Opuntia stricta* n=6**	**Normal range for goats**
Biochemical parameters of the study goats	Mean ±SD	Mean ±SD	Normal range

Total proteins (TP) g/dl	8.378 ±1.2670	8.467 ±1.3706	6.1 – 7.5
Albumin g/dl	2.2306 ±.26519	3.1433 ±.19273	2.3 – 3.6
Alkaline phosphatase units/L	46.189 ±64.0526	145.333 ±59.4982	61 – 283
Aspartate aminotransferase units/L	63.700 ±17.6876	68.867 ±14.1660	66 – 230
Alanine aminotransferase units/L	12.628 ±6.7612	25.283 ±5.7262	15 – 52
Creatine kinase units/L	51.994 ±26.0456	92.450 ±21.6538	16 – 48
Blood Urea Nitrogen mmol/L	4.2933 ±3.05159	6.2433 ±2.45835	4.5 – 9.2
Creatinine mg/dL	.544 ±.2307	.567 ±.0816	0.7 – 1.5
Blood glucose mmol/L	4.417 ±.7366	3.717 ±.3764	2.7 – 4.2
Key: mmol – millimole; L – liter; mg – milligram; g – gram; dL – deciliter			

Independent-Samples t-test was carried out for the analyzed biochemical parameters of the two groups of study goats and p-values were determined. There were significant statistical differences between the means of Albumin, Alkaline phosphatase, Alanine aminotransferase, Creatine kinase and Blood glucose (Table 4).

Table 4: Independent-Samples t-test for biochemical changes of the two groups of study goats

Biochemical parameters that had significant statistical different means	t-value	Degrees of freedom	p-value
Albumin g/dl	-7.728	22	0.000
Alkaline phosphatase units/L	-3.336	22	0.003
Alanine aminotransferase units/L	-4.105	22	0.000
Creatine kinase units/L	-3.417	22	0.002
Blood glucose mmol/L	2.210	22	0.038
Key: mmol – millimole; L – liter; g – gram; dL – deciliter			

5.4 Discussions

Analysis of total proteins and other biochemical parameters is important in identification of the main cause of an ailment or for following up the course of sickness. Changes in amounts of total proteins are of exploratory importance in patients with compound illnesses (Putignano *et al.*, 2000). Albumins are synthesized in the liver (Haschek *et al.,* 2013) and normally low albumin in the blood goes together with prolonged liver disorders (Huang *et al.,* 2012). Disorders of the liver that results to low albumins in the blood are commonly diffuse, severe and chronic (Constable *et al.,* 2016). The presence of low albumin in the blood without acute symptoms of kidney, liver or heart suggests protein losing enteropathy (Rich *et al*., 2012; Wallig *et al.,* 2017). *O. stricta* consuming goats had multiple abscesses in the abomasum and small and large intestines were empty full of pinkish red fluids. There was also a marked reduction in liver

weight compared to goats which had not consumed *O. stricta*. Lesions in the abomasum and lack of ingested feed in the small and large intestines may be the cause of low albumins in *O. stricta* consuming goats. Proteins were either not absorbed or they were lost due to diseased gastrointestinal tract as a result of injuries inflicted by *O. stricta* thorns and spines. Synthesis of albumin in the liver may have been interfered with by low metabolic status of the liver, in *O. stricta* consuming goats. This is consistent with the recorded lower weight of the liver in sick goats than in control goats.

Serum enzymes are usually increased in most disease conditions. Disorders of the muscles lead to elevation of blood creatine kinase (CK). Severe trauma or recumbency increases the levels of creatine kinase. Inflammation caused of muscles by microorganisms such as *Neospora,* bacterial, *Toxoplasma* may also increases CK in the serum. Nutritional deficiency in vitamin E and selenium and skeletal muscle degeneration caused by hypoxia and exertional rhabdomyolysis are other causes of increased levels of CK (Stockham and Scott, 2013; Neumann *et al,*. 2005; Aktas *et al*., 1993). The increased levels of creatine kinase in the *O. stricta* consuming goats may have been caused by traumatic injuries caused by *O. stricta* thorns and spines in various body parts of goats consuming this plant. Septic ulcerative lesions on the lips, mouth and tongue and multiple abscesses in the abomasum indicates inflammatory conditions by microorganisms introduced into the animal by thorns and spines of the *O. stricta* (Nobel, 2002; Shackleton *et al*., 2017) which could have caused increase in creatine kinase in the affected animals.

Acute diseases of muscles, especially those that affect muscle fibres elevate the levels of aspartate aminotransferase (AST), creatine kinase (CK) and lactic acid dehydrogenase (LDH) activities (Constable *et al.,* 2016; Kim *et al*., 2008). Alkaline phosphatase is produced in the liver, bone, intestines, kidneys and placentas and secreted into bile. Diseases affecting biliary

tract (liver, gall bladder and bile ducts) and conditions stopping the flow of bile either from within or outside liver causes rise in alkaline phosphatase (Petty *et al*., 2015; Kliegman *et al*., 2017). Decreased alkaline phosphatase (ALP) can be due to insufficient nutritional intake, reduced uptake of food in the gastrointestinal tract and lack of vitamin D (Thompson, 2013). Low ALP therefore shows malnutrition due to either poor diet or by any condition that interferes with absorption of food. AST is found in the cytoplasm of liver cells and mitochondria while ALT is widely found in the cytoplasm of the liver cells. Degenerative injuries to liver and muscle cells as well as necrosis or neoplasia therefore cause the two enzymes to leak into the extracellular fluid compartments and an increase of their level in blood (Kaneko *et al*., 2008; Suckow *et al*., 2012; Zoppini *et al*., 2016; Faqi, 2016).

In the *O. stricta* consuming goats, alkaline phosphatase (ALP), aspartate aminotransferase (AST), alanine aminotransferase (ALT) were all lowered. Although lowered alkaline phosphatase may have been due to malnutrition as a result of reduced uptake of food in the gastrointestinal tract of goats consuming *O. stricta* (Thompson, 2013), it is not clear why aspartate aminotransferase (AST), alanine aminotransferase (ALT) were all lowered. Goats that had consumed *O. stricta* had ulcerative wounds in the lips and mouth; abscesses in the abomasum and massive thorns and spines in the entire gastrointestinal tract. As a result, they were anorexic and this could have caused reduced metabolic activities in tissues of this group of study goats and subsequent lowering of aspartate aminotransferase (AST) and alanine aminotransferase (ALT). There is also a possibility that *O. stricta* has some biochemical components which depressed production or release of these enzymes from the organs where they are produced. It is notable that for all biochemical parameters other than CK, goats that had progressively consumed the plant had lower levels than controls.

BUN is the final product of the removal of ammonia from the body by the liver. Urea nitrogen concentration in blood may decrease with reduced transformation of ammonia to urea by the liver. Nevertheless, blood urea levels are not precise for hepatic disease. Low BUN levels are encountered in patients who have loss of appetite and are eating little amounts of protein. When ruminants lose appetite or when are fed on low protein diet, rumen microbes utilize BUN as a nitrogen supply for their own protein production. This causes reduction in serum BUN levels (Constable, 2016). *O. stricta* consuming goats were unable to feed due to ulcerative lesions on the lips, mouth and tongue and pain as a result of these lesions. Reduced feed intake may have caused low blood urea nitrogen in the affected goats.

5.5 Conclusion

1. Clinical chemistry parameters in goats that had consumed *Opuntia stricta* were lower than normal reference values. Many conditions which injure body organs such as liver results to increase in levels of serum enzymes. This indicates that consumption of *O. stricta* was depressing the release of serum enzymes from the organs of their origin or the plant may have antimetabolites that block enzymatic activities in the serum.

5.6 Recommendation

1. It is not clear why biochemical changes of goats that had consumed *Opuntia stricta* were all lowered than normal. Research on phytochemicals in both *O. stricta* fruits and cladodes need to be done to explain this.

CHAPTER SIX

6.0 PATHOLOGICAL LESIONS IN GOATS CONSUMING *OPUNTIA STRICTA*

6.1 Introduction

Cacti in the genus *Opuntia* are highly valued as a livestock feed and are farmed in many countries of the world as forage. There are many species of *Opuntia* used as goat feeds which includes: *Opuntia leucotricha, O.streptacantha, O.robusta, O.cantabrigiensis, O. rastrera, O.lindheimeri, O.imbricata, O.microdasys and O.leptocaulis.* All of these species have abundant, firm and prominent spikes. They also have abundant barbed bristle *(ahuates*), which can inflict severe harms to eyes and mouth of livestock that feed on them. Whereas, these *Opuntia* spp. can be subjected to propane or paraffin flame in order to remove bristles of the entire plants (Mondragón-Jacobo and Pérez-González, 2001), this is not a practical approach in purely pastoral livestock production system. In the wild, livestock feeds on thorny spp. of *Opuntia* together with its intact thorns and spines. When animals forage on spiny *Opuntia* spp. naturally in the field, the spines, spikes and barbed bristle becomes fixed on the fleshy parts of the upper and lower lips, tongues and buccal cavity and lower part of the GIT. Penetrating thorns initiate development of inflammatory lesions, swellings, sores and abscesses. Inflammatory lesions are frequently invaded by disease causing microorganisms, that turns out to be septic and subsequently cause death of the animal (Nobel, 2002; Shackleton *et al*., 2017).

Opuntia stricta var. *stricta* which is amongst 100 of the "World's Worst" invasive spp (BioNET-EAFRINET, 2011) has invaded northern part of Laikipia county and reduced prime grazing land (Strum *et al.,* 2015; Shackleton *et al*., 2017). Invasion of grazing fields by this cactus has resulted in depletion of grass and other range plants used as livestock feeds. Consequently, goats

and other livestock species in Laikipia north feed on ripened fruits of *O. stricta* as the only available feed. Consequently, they get accustomed to this plant and feed on it indiscriminately. Glochids on the fruits attach on the lips, buccal cavity, stomach, intestines, eyes and skin of the animals and initiate local injury at the site of attachment. Affected animals develop ulcerative oral lesions and abscesses along GIT, become blind, lame, emaciated and drop milk yield and finally die (Shackleton *et al*., 2017). A study about farmers' perception of *O. stricta* showed that livestock owners have been treating *O. stricta* related condition using conventional drugs, herbal and homemade therapies. No matter the mode of the intervention measure they instituted the *O. stricta* associated conditions do not respond to treatment (see chapter three). According to Shackleton *et al*., (2017), medical journals have documented that thorns and spines cause physical wounds in humans and may stimulates allergenic responses which leads to development of sarcomas, foreign-body granulomas and ulcerations. Pathological lesions caused by consumption of thorny and spiny *Opuntia* spp. have not been documented. An understanding of type and nature of lesions caused by this plant in animals is important in establishing the target organs and cause of death of animals consuming *O. stricta*. The aim of this study was to determine specific injuries caused by consumption of *O. stricta* var. *stricta* in goats and explains the actual causes of emaciation and subsequent deaths. Determination of the nature of pathological lesions, severity and their distribution wound assists in decision about the need or not to treat a sick animal, the suitable treatment to use and the response to treatment.

6.2 Materials and Methods

Experimental goats were obtained as described in 4.2.1. The purchased goats which had consumed *O. stricta* were kept in one of the households around Dol dol town which is in

Mukogodo location. Mukogodo location borders Mumonyont, Makurian and Ilpolei, the three locations invaded by *O. stricta*. Four (4) goats were slaughtered per day at Dol dol slaughterhouse to enable thorough examination of carcasses. Goats which had not consumed *O. stricta* were kept within the ranch where they were purchased and they were slaughtered at nearby Nanyuki slaughterhouse.

6.3 Examination of the study goats

Before slaughter, each goat was physically examined for external lesions caused by *O. stricta*. The lesions were categorized as mild, acute, subacute and chronic using criteria that are summarized in Table 5. Frequency of each category of lesion was then calculated as the percentage severity.

Table 5: Criteria used to score lesions caused by consumption of *Opuntia stricta*

Lesions	Classification
1) a) 1 – 100 O. *stricta* thorns and spines are attached on the skin, ears, eyes, lips/mouth, tongue and abomasum. b) There are no wounds on the skin, ears, eyes, lips, mouth, tongue but slight swellings occur at the sites of attachment by *O. stricta* thorns and spines c) Small swellings on the abomasum at the foci where *O. stricta* thorns and spines are attached.	Mild
2) a) 100 – 200 *O. stricta* thorns and spines are attached on the skin, ears, eyes, lips, mouth, tongue and abomasum. b) small reddened non-infected wounds measuring about 0.1 – 0.4 cm in diameter at the site of attachment by *O. stricta*	Moderate

c) Partially swollen glandular mucosa of the abomasum where thorns and spines attach to abomasal folds. In the areas where *O. stricta* thorn and spines are not attached, the abomasal folds are visible.	
3) a) Numerous (over 200) thorns and spines are attached on the skin, ears, eyes, lips/mouth, tongue and penetrating into the glandular mucosa of the abomasum. b) Isolated fresh wounds occur mostly on the lips and mouth measuring 0.5 cm and above in diameter. c) Glandular mucosa of the abomasum is inflamed and it has numerous swellings where *O. stricta* spikes are attached. Abomasal folds which are thick and conspicuous.	Severe acute
4) a) Numerous thorns and spines are attached on the skin, ears, eyes, lips and mouth, tongue and penetrate into the glandular mucosa of the abomasum. b) Septic ulcer measuring 0.5 cm and above in diameter is occurring on the lips and mouth. Some coalesce to form an extensive ulcer that covers almost half of the lips. c) Glandular mucosa of the abomasum is inflamed, swollen, hemorrhagic and abscessed with pus. Abomasa folds absent in the entire mucosa surface.	Severe chronic

6.4 Body condition score and weight measurement of the goats consuming *Opuntia stricta*

Body condition score of each goat was determined on a scale of 1 to 5, where 1 was very emaciated goat and 5 - fat goats (Table. 6). Body condition score was determined by touching and feeling the amount of muscle and fat cover at lumbar area, sternum (breastbone) and rib cages as described by Villaquiran *et al*., (2004). Live body weight of each goat was taken using "Original" Hanson® model 21 Trade mark No 595766 spring balance (India). Each goat was

placed in an improvised pouch made of sack and then lifted on to the hanging spring balance (Fig. 32A). All measurements were recorded.

Figure 32: Taking live body weight of *Opuntia stricta* affected goat (A) and Organ weights (B) at Dol dol slaughterhouse

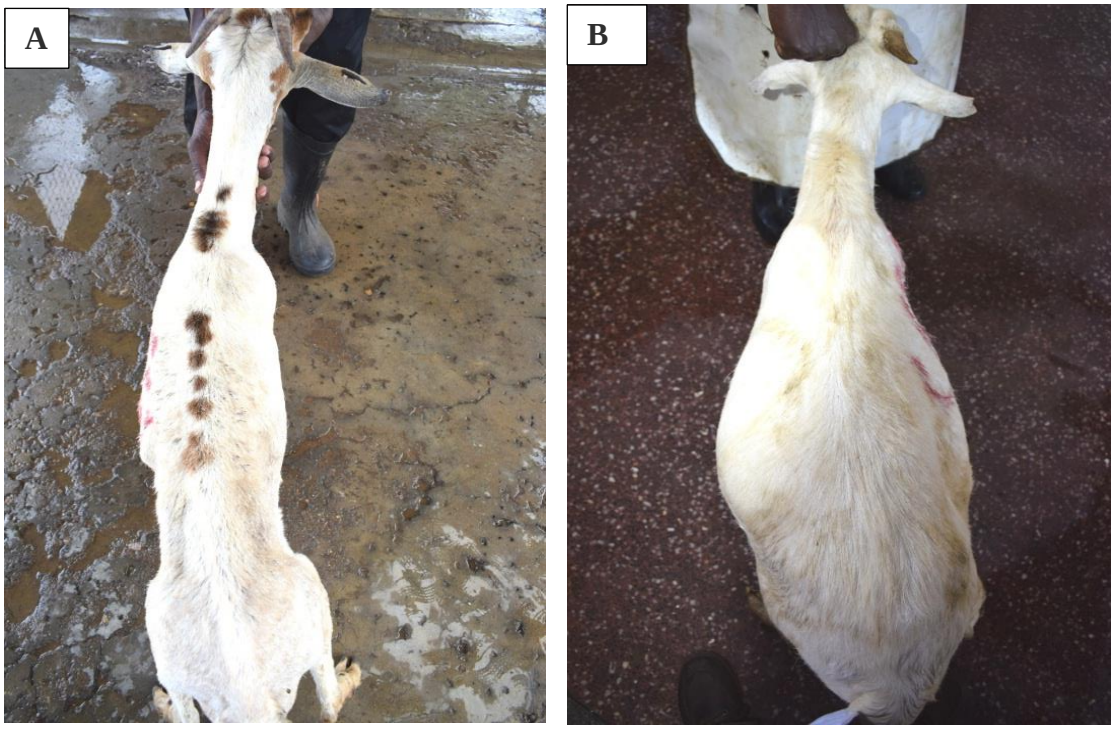


Figure 33: Dorsal view of a goat that has consumed *Opuntia stricta* (A) and the one which has not consumed *Opuntia stricta* (B)

Table 6: Body condition score of the two groups of the study goats.

Study goat (SG) identification	Body condition score
SG – 1	1
SG – 2	1
SG – 3	1
SG – 4	1
SG – 5	1
SG – 6	1
SG – 7	1
SG – 8	1
SG – 9	1
SG – 10	1
SG – 11	1
SG – 12	1
SG – 13	1

SG – 14	1
SG – 15	1.5
SG – 16	1
SG – 17	1
SG – 18	1
SG – 19	4.5
SG – 20	4.5
SG – 21	4.5
SG – 22	4.5
SG – 23	4
SG – 24	4.5
Study goat 1(SG 1) to study goat 18(SG 18) had consumed *Opuntia stricta* (sick goats) Study goat 19 (SG 19) to study goat 24 (SG 24) had not consumed *Opuntia stricta* (controls)	

6.5 Necropsy examination, carcass and organ weights

Goats were stunned and slaughtered one at a time and a detailed postmortem examination conducted as described by Brown *et al*., (2012) and King *et al.,* (2014). Carcasses were carefully skinned observing all lesions on the skin and subcutaneous tissue. Weight of carcasses and organs (Fig. 32B) at slaughter were recorded. Carcass weight was taken using Hanson® model 21spring balance while organs were weighed using electrical weighing balance (make ACS – 30®). Gross lesions and their distribution were described for each organ and body system. Severity of tissue damage (lesions) was scored in accordance with the criteria described in table 5. The distributions of internal lesions of the *O. stricta* affected goats were recorded and their percentages calculated.

6.6 Histopathology

Tissues (0.5 - 1cm thick) were collected for histopathology from organs with or without gross lesions and immersed into 10% neutral buffered formalin. Samples were taken from the skin, liver, kidneys, lungs, heart, spleen, pancreas, lymph nodes and all segments of GIT system, with or without lesions. Intestinal contents from abomasum, small and large intestines were collected and preserved in 70% ethanol for total worm count. All samples for histopathology and intestinal contents for parasitology (worm count) were transported to the department of Veterinary Pathology, Microbiology and Parasitology University of Nairobi for processing, examination and analysis.

6.7 Results

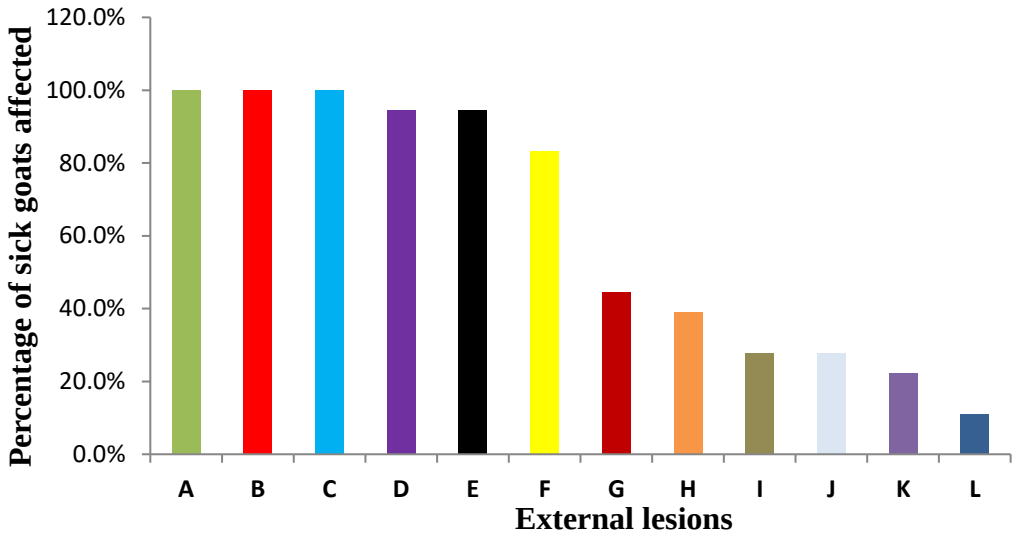
6.7.1 Body condition score

Goats that had consumed *O. stricta* were emaciated and had low body weight (Fig. 33A). They had a mean body condition score of 1.028 ±0.1179. Goats that had not consumed the plant (controls) were fat and had a mean body condition score of 4.417 ±0.2041. Independent samples t-test showed that there was a significant difference between the body condition scores of the two groups of the study goats (t = -50.579, df = 22 and p=0.000).

6.7.2 External gross lesions

The distribution of external gross lesions and their frequency in goats that had consumed *O. stricta* is summarized in figure 34. All affected goats (100%) had thorns on the head (ears, face, eyes, lips and mouth) (Fig. 35A); on the tongue, and on the body and legs. Ulcerative wounds on the lips and mouth occurred in 94.4% of the sick goats (Fig. 36 A and 37A) and 83.3% had

wounds o on the tongue (Fig. 38A). There was salivation, purulent or mucopurulent oral and nasal discharges in some goats (Fig. 36A).



A - Spines on the head (ears, face,eyes and lips)
B - Spines on the body and legs
C - Thorns on the tongue
D - Ulcerative wounds on the lips
E - Ulcerative wounds on the mouth
F - Wounds on the tongue
G - Missing/worn out teeth
H - Cateracts on one or both eyes and blind
I - Enlarged prescapular lymphnodes
J - Enlarged parotid lymphnodes
K - Abscesses
L - Enlarged precrural lymphnodes

Figure 34: External gross lesions in goats that had consumed *O.stricta*

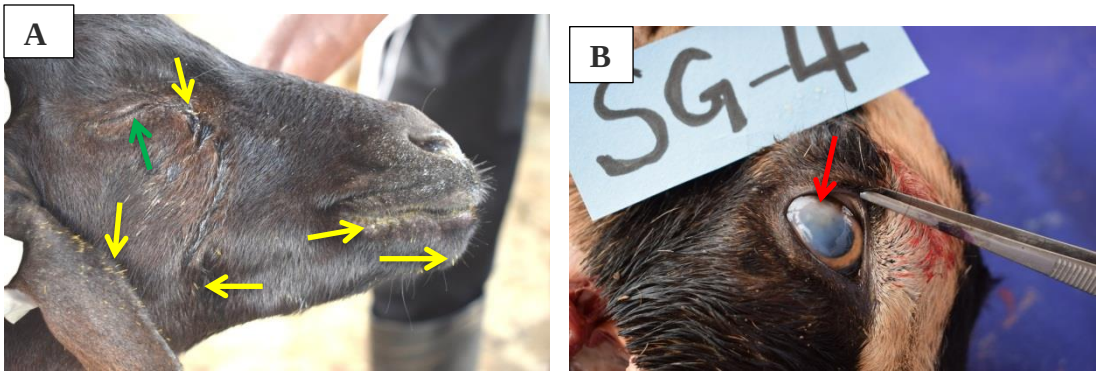


Figure 35: Spines on the ears, face, lips and mouth (yellow arrows) and closed blind eye with ocular discharge (green arrow) (A) of a goat that had consumed *Opuntia stricta*. Eye cataract (red arrow) (B)

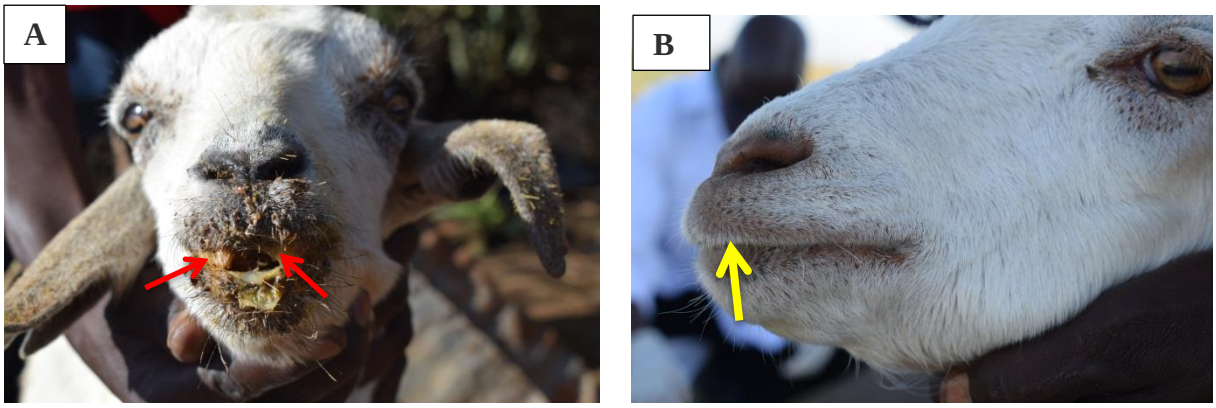


Figure 36: Septic ulcerative wounds on the lips and mouth of goat that had consumed *Opuntia stricta* (red arrows A) and clean lips and mouth of a goat that had not consumed *Opuntia stricta* (yellow arrow B)

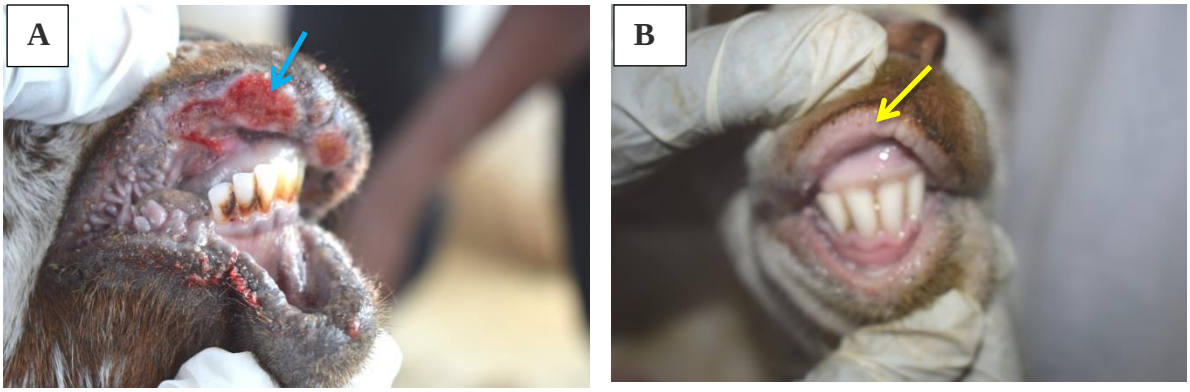


Figure 37: Ulcers on the lips of a goat that had consumed *Opuntia stricta* (blue arrow A) and clean lips of a goat that had not consumed *Opuntia stricta* (yellow arrow B)

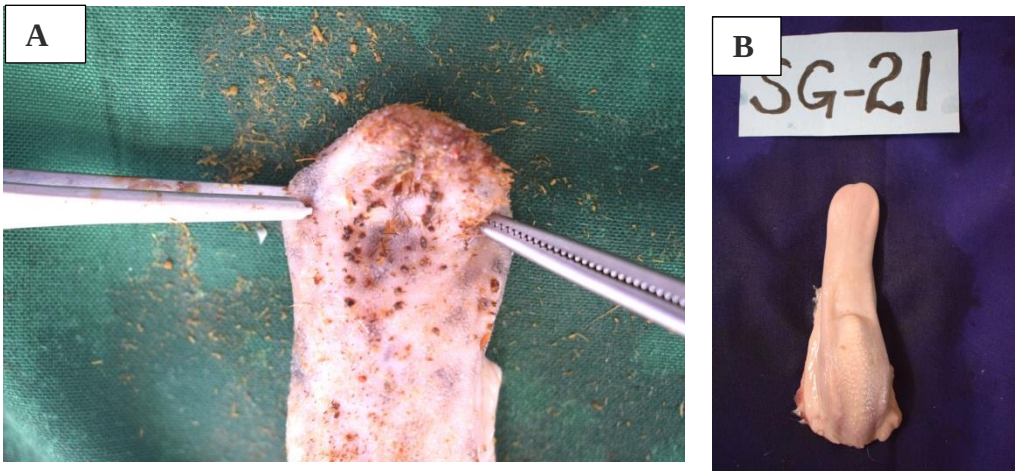


Figure 38: Ulcerated tongue of a goat that had consumed *Opuntia stricta* (A) and clean tongue of a goat that had not consumed *Opuntia stricta* (B)

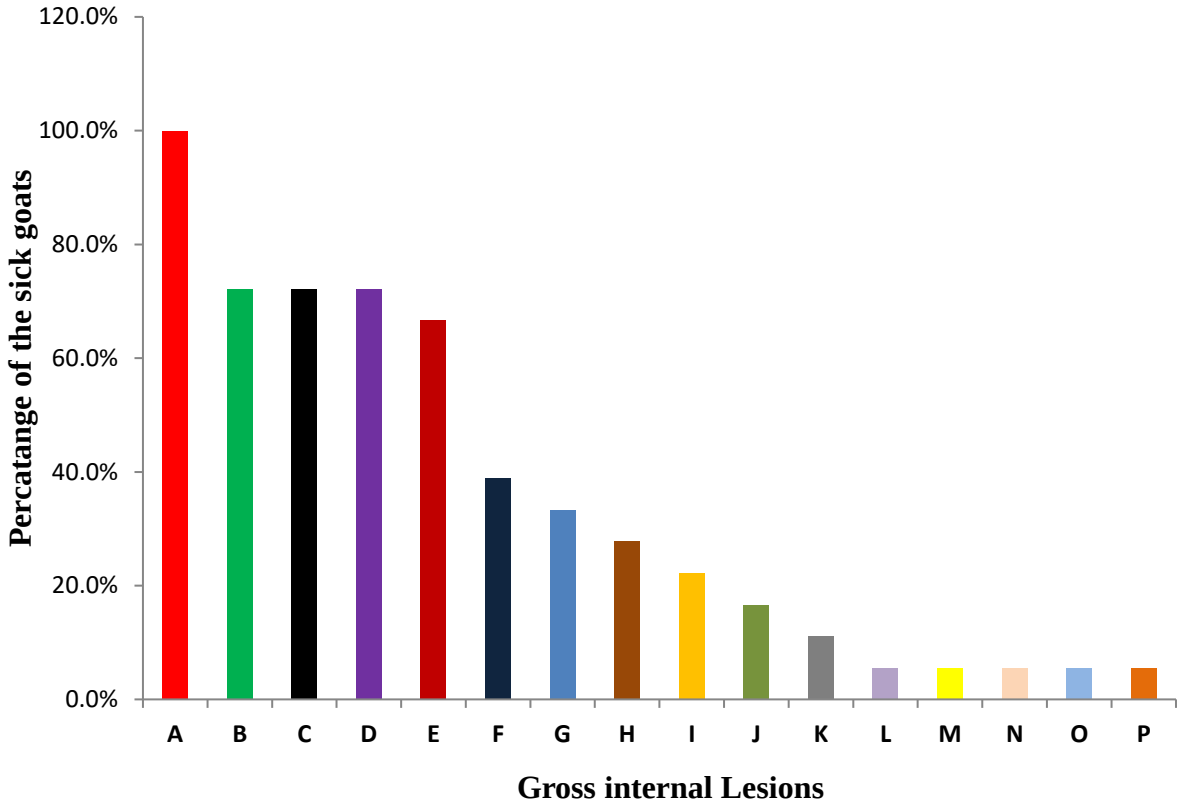
Affected goats with missing or worn out teeth were 44.4%. Cataracts on one or both eyes with blindness (Fig. 35B) occurred in 38.9% of the animals. Some goats had eyes lesions concurrently with serous or mucopurulent ocular discharges that matted the hair on the face. Other external lesions were enlarged prescapular lymph nodes (27.8%), enlarged parotid lymph nodes (27.8%), abscesses (22.2%) and enlarged precrural lymph nodes (11.1%). External abscesses were

encountered on the legs, abdomen and lateral sides of the face. Some parts of the skin especially on legs and abdomen were rough and nodular.

6.7.3 Distribution and frequency of gross lesions in internal organs and body systems of goats consuming *Opuntia stricta*

The distribution of internal gross lesions in internal organs and body systems of goats that had consumed *O. stricta* is summarized in figure 39. All affected goat*s* had poor muscular cover, atrophy of body fat manifesting as gelatinous edematous tissues on the subcutaneous and other fat reserves tissues that are consistent with emaciation (Fig. 40A). *O. stricta* thorns and spines were embedded in the muscles and subcutaneous tissues of the affected goats (5.6%) (Fig. 41). Some goats had mild ascites, hydrothorax and increased pericardial fluid. There were spines in the rumen, reticulum and omasum (fore stomachs) in 72.2% of the cases. Thorns were embedded but did not cause injuries on the surfaces of the ruminal papillae, mucosa of the reticulum (honeycomb) and omasal folds. All goats that had consumed *O. stricta* (100%) had thorns and hairy spines in the abomasum. Abomasal folds were thick as a result of oedema and glandular swellings caused by inflammation (Fig. 42). Thorns and spines had penetrated into the abomasal mucosal (100%) causing severe inflammatory reactions and some had septic abscesses (Fig. 43A). A few goats had spines in the duodenum (5.6%). Large and small intestines of affected

goats (sick goats) contained pinkish-red fluid (33.3%) but had no solid contents.



A - Spines in the Abomasum and reactive
B - Spines in the rumen
C - Spines in the reticulum
D - Spines in the Omasum
E - Lungs pneumonic (interstitial/bronchial)
F - Capsule adhesed to the kidneys
G - Reddish fluid in the small or large intestines
H - Liver Abscesses
I - Hydatid cysts in the lung, liver or body cavity
J - Rumen papillae reduced
K - Kidneys abscesses
L - Spines in the duodenum
M - Lung absesses
N - Abscess on the thoracic area ventral to spinal cord
O - Abscess on the abdominal area
P - Thorns and spines in the subcutaneous tissues and muscles

Figure 39: Gross internal lesions in organs and body systems of goats that had consumed *Opuntia stricta*

Figure 40: Dressed carcass of a goat that had consumed *Opuntia stricta* (A) and the one which had not consumed *Opuntia stricta* (B)

Lesions outside the GIT were: pneumonia (interstitial/bronchopneumonia) in one or both lobes of lungs (66.7%), capsules adhered to the kidneys (38.9%), reduced rumen papillae (16.7%); and abscess in: liver (27.8%), kidneys (11.1%) and lung (5.6%); on the thoracic area ventral to spinal cord (5.6%), and on the abdominal area (5.6%).

Figure 41: *Opuntia stricta* thorns and spines (Red arrows) in the muscles and subcutaneous tissues of goat affected by the plant

Figure 42: Abomasum of goats that had consumed *Opuntia stricta* showing thorns and spines penetrating into the mucosa and thickened abomasal folds

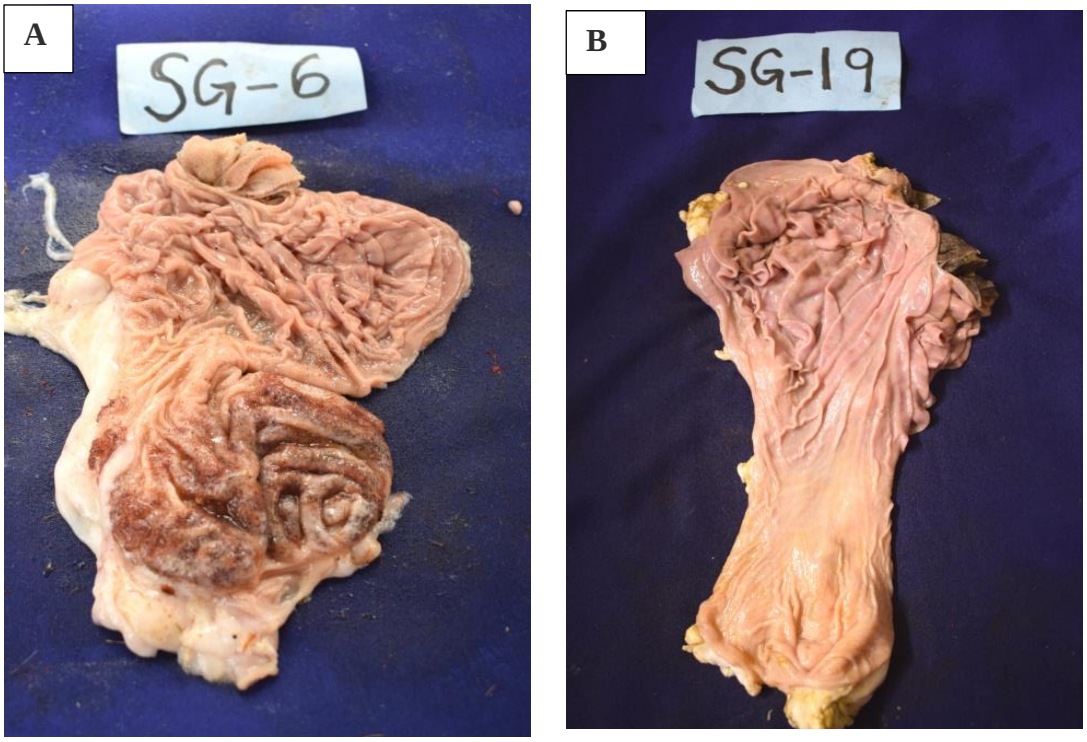


Figure 43: Abomasum (A) of goat that had consumed *Opuntia stricta* full of spines and with diffuse abscesses and exaggerated mucosal folds; (B) abomasum of a goat which had not consumed *Opuntia stricta*

6.7.4 Classification of the lesions on the lips, mouth and abomasum

Lesions inflicted by *O. stricta* were observed on the lips, mouth and abomasum. These lesions were classified as mild, moderate or severe (Table 7). Classification of the lesions was based on the burden of thorns and spines of *O. stricta* to lips / mouth and abomasum; type, number and extent of the lesions in the same body parts and the nature of the reaction elicited by the thorns and spines on the affected organ or body part.

Table 7: Classification of lesions on the lips, mouth and abomasum of goats consuming *Opuntia stricta*

Effects on the lips and mouth		
Classification of the lesion	**Frequency**	**Percent**
Mild	5	27.8
Severe	13	72.2
Total	18	100
Effects on the Abomasum		
Mild	5	27.8
Severe	13	72.2
Total	18	100

Severe lesions on lips, mouth and abomasum occurred in 72.2% of the sick goats. It was observed that goats that had severe lesion on lips/mouth also had severe lesions on abomasa. Mild lesions on the lips and mouth were seen in 27.8% of the *O. stricta* affected goats which also corresponded with mild lesions on the abomasum. There were no moderate lesions; all cases were either mild (beginners who ate *O. stricta* fruits) or severe ones which were either acute or chronic. Severe acute cases were characterized by massive spines penetrating abomasal mucosa resulting in and marked inflammatory reaction with swelling and exaggerated thickening of the abomasal folds. Severe chronic cases had massive spines embedded (penetrating) into the abomasal mucosa and concurrent abscesses with pus (Fig. 43A)

6.7.5 Live, carcass and organ weights; and body condition score of the study goats

Mean live, carcass, and organ weights; and body condition scores of the two groups of goats are summarized in the table 8. Independent-Samples t-test to determine differences in the means weights and body condition scores of goats was carried out and p-values determined. There were significant statistical differences in the means of live, carcass, liver, spleen weights and body condition scores (Table 9). Calculated mean organ weight-to body weight ratios of the two groups of animals (Table 10) were higher in goats that consumed *O. stricta* than in those that did not consumed the plant (Fig. 44).

Table 8: Mean live, carcass and organ weights and body condition scores of goats consuming and those not consuming *O. stricta*

Item (units)	Mean weight± SD in goats that had consumed *O. stricta* n= 18	Mean weight ±SD in goats that had not consumed *O. stricta* n = 6
Heart (g)	120.59 ±21.929	135.00 ±20.736
Lungs (g)	278.24 ±56.151	298.33 ±36.009
Kidneys (g)	89.17 ±15.648	93.33 ±15.055
Liver (g)	424.71	595.83

	±89.416	±100.370
Spleen (g)	44.444 ±13.6003	60.00 ±19.494
Live goat (kg)	20.389 ±2.8313	33.250 ±5.8459
Carcass with intestinal contents (kg)	15.417 ±2.4025	25.667 ±5.0166
Dressed weight of the carcass (kg)	9.594 ±1.0835	15.1250 ±2.62560
Body condition score	1.028 ±.1179	4.417 ±.2041

Table 9: Independent-Samples t-test: carcass, organ weights and body condition scores in goats that consumed and those which did not consume *O. stricta*

Item	**t-value**	**Degrees of freedom**	**p-value**
Weight of the liver in grams	-3.911	21	0.001
Weight of the spleen in grams	-2.179	22	0.040
Live weight of the goat in kg	-7.302	22	0.000
Weight of the carcass with intestinal contents	-4.824	5.784	0.003
Dressed weight of the carcass	-5.003	5.651	0.003
Body condition score	-50.579	22	0.000

Table 10: Organ weight and organ to body weight ratio of goats consuming and those not consuming *O. stricta*

Organ	Mean Organ weight (kg) of *O. stricta* consuming goats n = 18	Mean live weight (kg) of *O. stricta* consuming goats n = 18	Mean organ weight (kg): body weight (kg) ratio of *O. stricta* consuming goats n = 18	Mean Organ weight (kg) of the controls n = 6	Mean live weight (kg) of controls n = 6	Mean organ weight (kg): body weight (kg) ratio of controls n = 6
Heart	0.12059	20.389	0.0059144	0.135	33.250	0.0040601
Lungs	0.27824	20.389	0.0136465	0.29833	33.250	0.0089723
Kidneys	0.08917	20.389	0.0043734	0.09333	33.250	0.0028069
Liver	0.42471	20.389	0.0208303	0.59583	33.250	0.0179196
Spleen	0.044444	20.389	0.0021798	0.06000	33.250	0.0018045

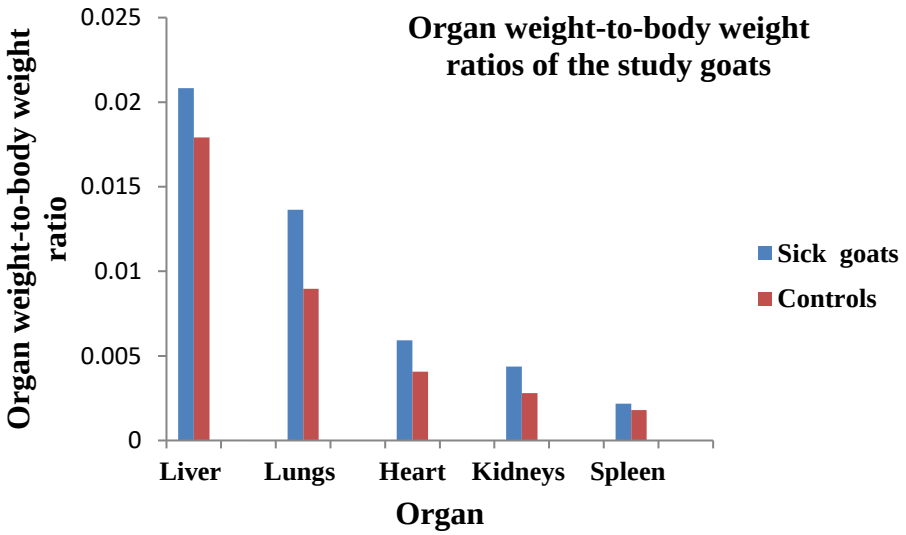


Figure 44: Organ-to-body weight ratios of goats consuming (sick goats) and those not consuming (control) *Opuntia stricta*

6.8 Gastrointestinal worm counts in the study goats

Hydatid cysts were observed in the lungs, liver or body cavities (22.2%) of affected goats. Worm count for each study goat is described in appendix 9

6.8.1 Worm count in the abomasum, small and large intestines of goats that had consumed *Opuntia stricta*

Goats that had consumed *Opuntia stricta* had gastrointestinal worms in the abomasum (86.7%) and in the large intestines (53.3%); but had no worms in the small intestines (Table 11). Specifically, *Haemonchus contortus* occurred in 72.2% of abomasal contents, while 27.8% had no worms in abomasum. The following worms were isolated in the large intestines: *Oesophagostomum columbianum* (16.7%) and *Trichuris spp* (27.8%) but, 55.6% of goats had no worms in the large intestines (Table 12).

Table 11: Presence of gastrointestinal worms in the two groups of study goats

Presence of gastrointestinal worms in goats that had consumed *Opuntia stricta*. n = 18	
Section of the GIT	Percent
Large intestines	53.3%
Abomasum	86.7%
Presence of gastrointestinal worms in goats that had not consumed *Opuntia stricta* n = 6	
Large intestines	40.0%
Abomasum	100.0%

6.8.2 Worm count in the abomasum, small and large intestines of goats that had not eaten *Opuntia stricta*

Worms were present in the abomasum of goats that had not eaten *O. stricta* (100%). Only 40% of the goats that had not consumed *O. stricta* had worms in the large intestines (Table 11). There were no worms in the small intestines of the goats that had not consumed *O. stricta*. Eighty three percent (83.3%) of goats that had not consumed *O. stricta* had Haemonchus *cotortus* in the abomasal content and thirty three (33.3%) of same group had *Oesophagostomum columbianum* in large intestines (Table 12).

Table 12: Gastrointestinal worms in abomasum and large intestines of study goats

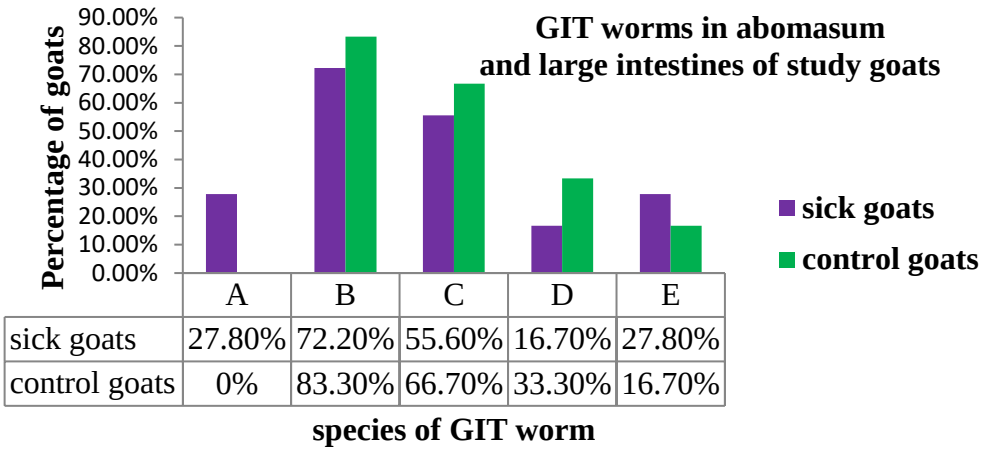
Species of worms in the abomasum and large intestines of goats consuming *Opuntia stricta*. n = 18	
Large intestines	Percent

Trichiuris spp.	27.8%
Oesophagostomum columbianum	16.7%
Worms absent in large intestines	55.6%
Abomasum	
Haemonchus contortus	72.2%
Worms absent in abomasum	27.8%
Species of worms in the abomasum and large intestines of controls. n = 6	
Large intestines	
Trichiuris spp.	0%
Oesophagostomum columbianum	33.3%
Worms absent in large intestines	66.7%
Abomasum	
Haemonchus contortus	83.3%
Worms absent in abomasum	16.7%

Mean and standard deviation of GIT worms in both groups of animals were analyzed. *O. stricta* consuming goats had low mean *Haemonchus contortus* of 58.94 compared to those which had not consumed the plant with a mean of 111 (Table 13). The numbers of worm counts in controls were more than those of the *O. stricta* consuming goats. However this was not statistically significant (Fig. 45).

Table 13: Mean ±SD of gastrointestinal worms in *Opuntia stricta* consuming goats and those not consuming *Opuntia stricta*

	Mean ±SD of GIT worms in sick goats n = 18	Mean ±SD of GIT worms in controls n = 6
Haemonchus contortus in the abomasum	58.94 ± 65.315	111.00 ±80.032
Trichiuris in the large intestines	5.00 ±12.866	.00
Oesophagostomum in the large intestines	1.50 ±5.009	.83 ±1.329



	A	B	C	D	E
sick goats	27.80%	72.20%	55.60%	16.70%	27.80%
control goats	0%	83.30%	66.70%	33.30%	16.70%

A – *Trichiuris* spp. B - *Haemonchus contortus*
C - Worms absent in large intestines
D – *Oesophagostomum* spp. E - Worms absent in abomasum

Figure 45: Gastrointestinal worms in abomasum and large intestines of goats consuming *Opuntia stricta* and goats' not consuming *Opuntia stricta*

6.9 Histopathology

Formalin-fixed tissues from twelve (12) out of twenty-four (24) study goats were processed for histopathology using standard procedures and then stained with haematoxylin and eosin (H&E) as described by Slaoui and Fiette, (2011). Among the twelve goats, nine were consuming *O. stricta* and were selected on the basis of severity of gross pathology lesions on the lips, mouth and abomasum. The nine sick goats were equally distributed in three categories namely: severe, moderate or mild (Table 7). Three of the twelve goats were selected from the control group. The following tissues were processed for histopathology: ears, lips, tongue, esophagus, rumen, reticulum, abomasum, duodenum, small and large intestines and lymph nodes. Histopathology slides were examined under light microscope using x4, x10, x40 and x100 objective lenses and

photomicrographs taken using Olympus microscope mounted with live view digital SLR Olympus camera (E-330).

6.9.1 Histopathology results

Foreign body granulomas in the ears, lips, tongue and abomasum were the characteristic histopathological lesions in all the affected goats. One goat had a few granulomas in the esophagus and duodenum. Each granuloma consisted of a foreign body (thorn/spine that were orientated in longitudinally and/or transversely in the tissue), macrophages, lymphocytes and plasma cells and was walled off by mature granulation tissue. Few neutrophils were seen in areas with fresh lesions. The detailed histopathological lesions in the affected body parts/GIT sections are described below.

6.9.2 Abomasum

Thorns were located mainly in tunica mucosa penetrating all layers namely: lamina epithelialis, lamina propria, stratum compactum and lamina muscularis mucosae (Fig. 47B). There was shredding of the mucosal epithelium into lumen of abomasum. Some thorns and spines extended to tunica submucosa and tunica muscularis. Longitudinally orientated thorns and spines appeared as single, cylindrical, elongated, brownish-yellow, penetrating objects with a tapering end. Transversely orientated thorns appeared as cross sections of multifocal yellow-brown objects that were surrounded by mononuclear cells. Mononuclear cells together with each thorn were walled by a heavy connective tissue reaction constituting a typical foreign body granuloma (Fig. 49B). In the pylorus, adjacent granulomas coalesced to form multiple focal centers of thorns surrounded by mononuclear cells and granulation tissue. Granulomas in the glandular mucosa caused pressure atrophy of the gastric glands (Fig. 48A). Spines and thorns had disrupted and

mechanically destroyed the affected tissues. Large, recently attached thorns were surrounded by heavy population of mononuclear cells but had no granulation tissue (Fig. 50 B). Deep in the mucosa, the older penetrating thorns were smaller in size and were deeply buried in the granulomatous tissue. The highest load of thorns was located on the glandular mucosa mostly near the lumen (recently attached) and deep in the mucosa affecting lamina propria and gastric glands. Few thorns and spines penetrated stratum compactum and lamina muscularis mucosae and others extended to tunica submucosa and tunica muscularis where they caused the same reaction as in tunica mucosa and subsequent foreign body granulomas.

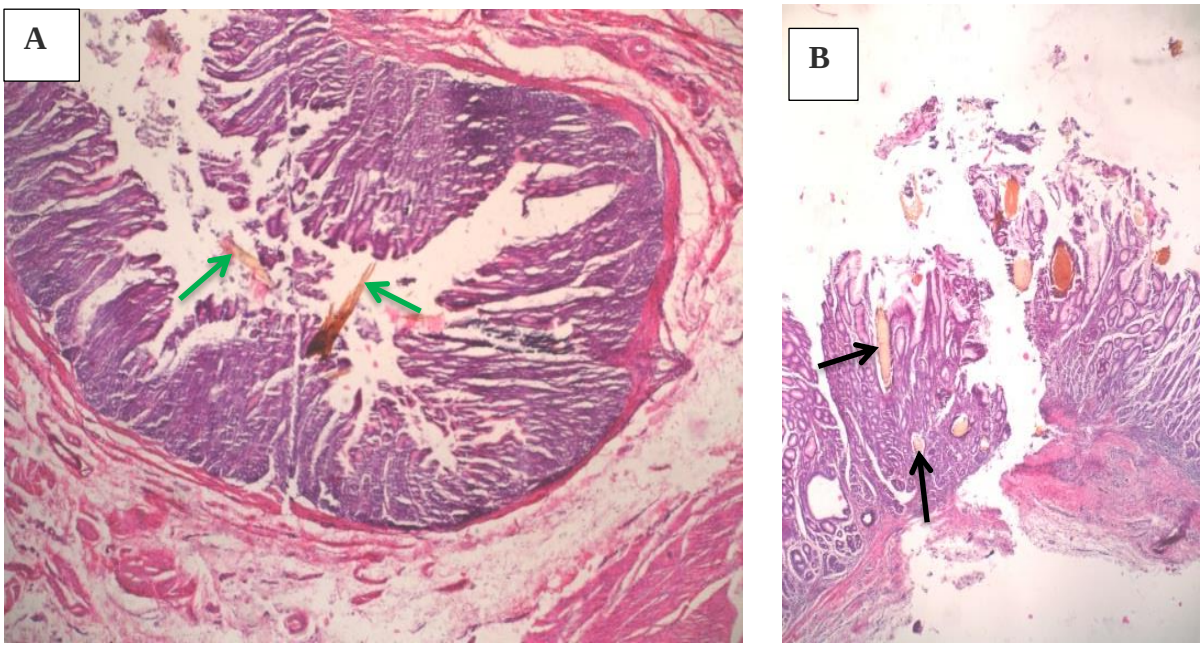


Figure 46: Thorns of *Opuntia stricta* (A) (green arrows) in the lumen of abomasum and ones penetrating different parts of the mucosa (B) (black arrows) x10

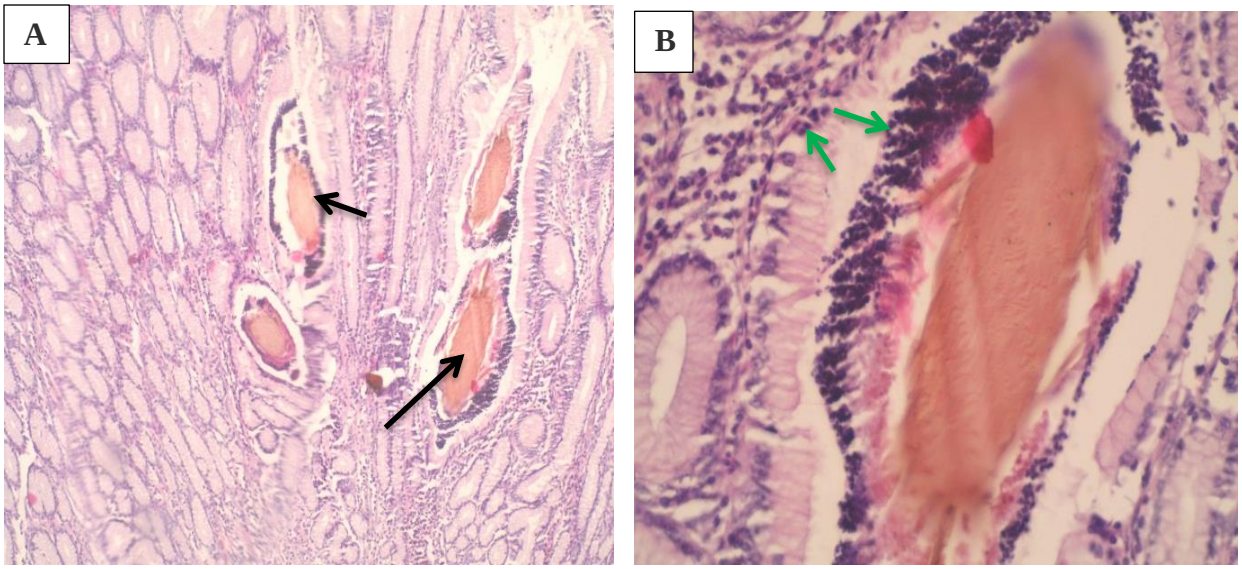


Figure 47: *Opuntia stricta* thorns in the glandular mucosa of abomasum (A) (black arrows) causing pressure atrophy of glands. Mononuclear infiltration around *O. stricta* thorn (B) (green arrows) x100

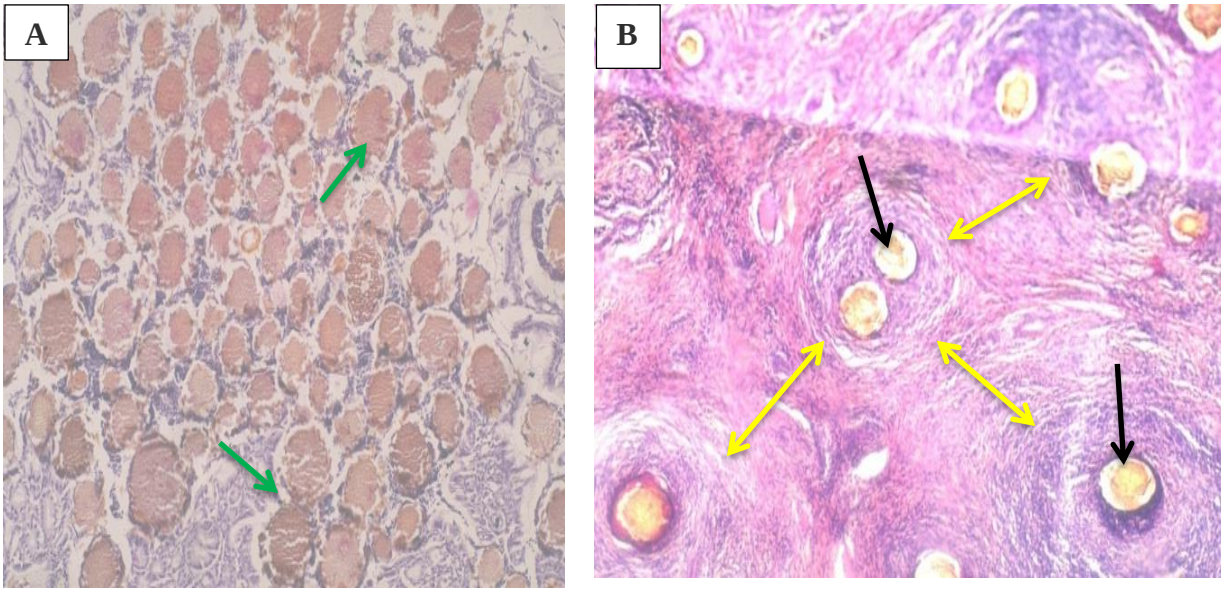


Figure 48: Numerous *Opuntia stricta* thorns (A) (green arrows) in the glandular mucosa of abomasum (x10). Multifocal *O. stricta* thorns (B) (Black arrows) and associated coalescing granulomatous lesions (yellow arrows) (x40)

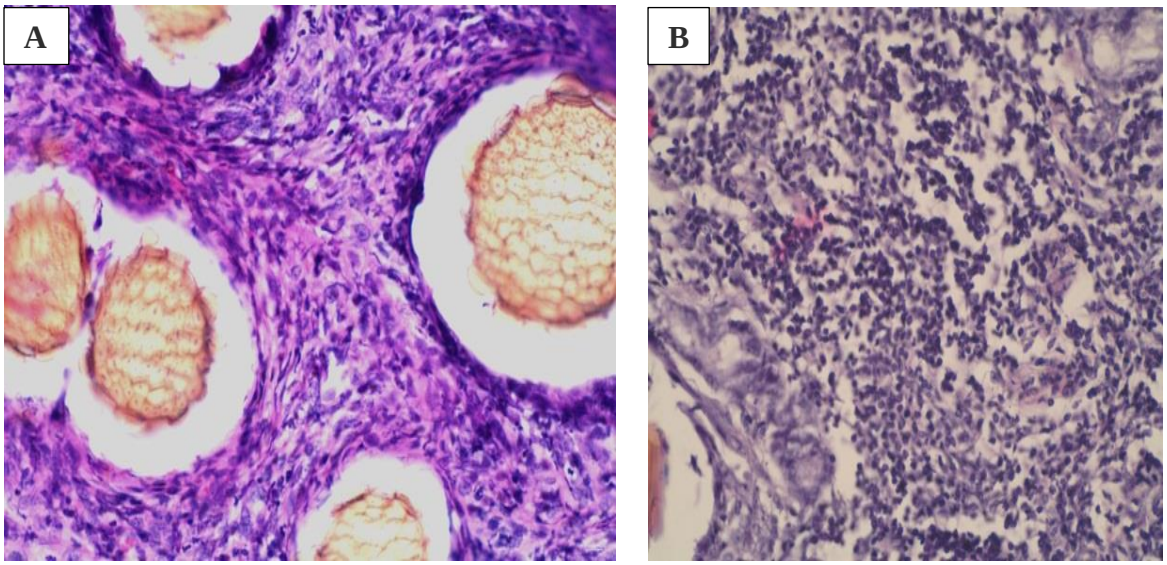


Figure 49: Mononuclear cells (A and B) infiltrating areas where *Opuntia stricta* are attached in the abomasum (x100)

6.9.3 Ears and lips

The affected areas of ears and lips were characterized by loss of epidermis caused by complete destruction of all layers of the epidermis (stratum corneum, stratum granulosum, stratum spinosum and stratum basale) (Fig 51). Areas of the skin adjacent to the damage had marked thickening of all layers of the epidermis with elongated and expanded rete ridges (acanthosis) (Fig 51 B). There was hyperkeratosis and parakeratosis involving the stratum corneum at multiple centres of granulomas caused by numerous thorns penetrating ears and lips. Some *O. stricta* thorns penetrated the ear to the level of cartilage. In areas where multiple thorns lodged deep in the lips, skeletal muscles adjacent to skin lesions were destroyed and completely covered and replaced by multiple granulomatous lesions (Fig 52 B). Affected areas were infiltrated by increased mononuclear cells in the dermis in both ears and lips.

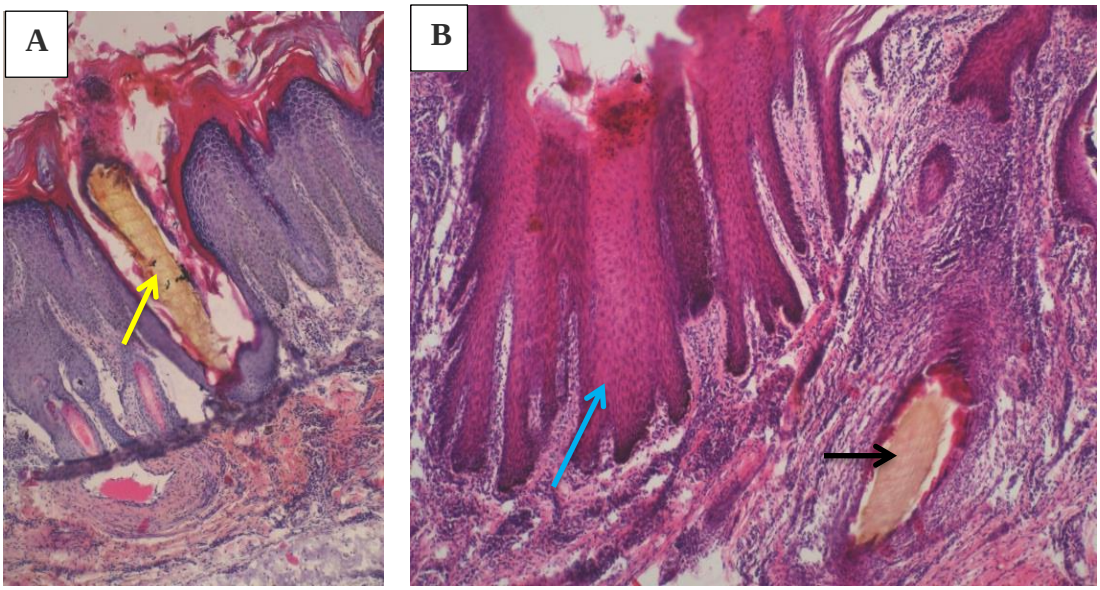


Figure 50: A) Skin of the ear ruptured by *Opuntia stricta* thorns (yellow arrow) (x4). B) *O. stricta* thorn deep in the ear muscles infiltrated by mononuclear cells and granulation tissue (black arrow). Elongated and expanded rete ridges (B) (blue arrow) (x10)

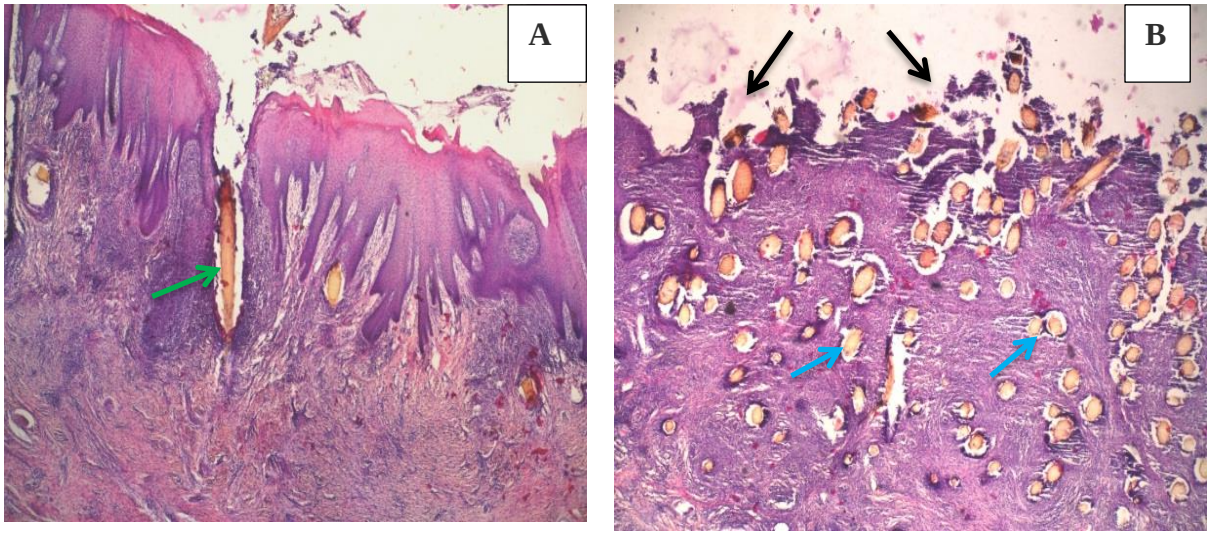


Figure 51: *Opuntia stricta* thorns penetrating epidermis layer of lips (green arrow A) (x4). B) Epidermis layer of lips completely eroded (black arrows) and numerous thorns deeper in the muscles of lips and the associated multifocal granulomas (blue arrows) (x40)

6.9.4 The tongue

O. stricta thorns penetrated into the tongue making several rupture wounds in the mucosa and deeper injuries in the skeletal muscles (Fig. 53 A). In some areas, there were erosions and pressure atrophy of the mucosa adjacent to the granuloma. The papillae were completely eroded and some thorns were attached to the surface. Some thorn penetrated deeper and affected the sublingual glands of the tongue forming granulomatous lesions and increased mononuclear cell infiltrations in the affected sites (Fig 53 B).

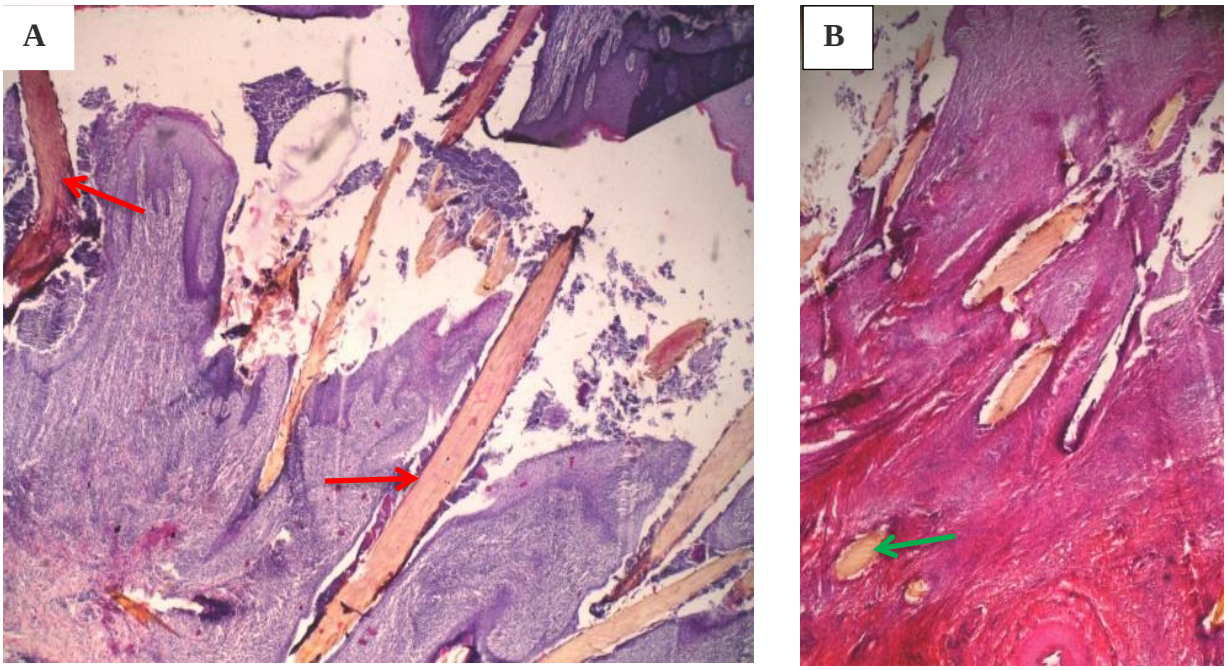


Figure 52: A) *Opuntia stricta* thorns (red arrows) penetrating the tongue (x10). B) Thorns deep in the muscles forming granulomas (green arrows) (40)

6.10 Discussion

Animals feed on undesirable plants due to improper management, shortage of forage resulting from range environment and drought (James *et al*., 1992). The wide spread invasion of *O. stricta* in the study area diminished grass and other forage which were livestock feeds (Strum *et al*., 2015; Shackleton *et al*., 2017). This predisposed animals to consume *O. stricta* as the only available feed. According to goat keepers in the area, the taste of its ripened fruits charm the animals to continuously feed on it, despite the injuries that the spikes and thorns inflict on the animal. The main (classical) external clinical signs in an animal that is afflicted by eating *O. stricta* are: presence of spines and thorns on various body parts. The location of lesions corroborated the observations by respondents and validated the capability of goat keeper to correctly identify *O. stricta* associated clinical signs. Injuries by thorns produced ulcerative wounds on the lips and mouth, tongue - especially on the median sulcus. Presence of numerous thorns and spines on injured parts contributed to development of salivation, mucopurulent discharges and ocular lesions (some progressing to cataract) in one or both eyes. Abscesses and enlargement of superficial lymph nodes were also caused by spines.

Abomasum was the most affected part of gastrointestinal tract. Although spines were located on the surfaces of esophagus, rumen, reticulum and omasum, the only pathology observed at these sites was occurrence of reduced size of rumen papillae. Large areas of abomasum had widely distributed spines that were embedded in the mucosa, most prominently at the pyloric region. Spines elicited severe sub-acute to chronic inflammatory reaction and thickening of the abomasa mucosa (glandular swelling). Chronic cases showed septic abscesses with pus. There was a

correlation between severity of lesions in the lips and mouth and the extent and severity of the lesions in the abomasum.

Histopathology showed that mechanical tissue destruction and inflammation characterized by foreign body granulomas were the characteristic lesions in goats that had consumed the plant. Presence of granulomas in the ears, lips, tongue and abomasum caused stress to the animal as a result of extensive tissue damage. This may explain the marked loss of body condition that was recorded in affected animals.

Marked loss of body condition was characterized by reduction in live weight, carcass and organ weights of the sick goats as compared to healthy ones. There were statistically significant differences in mean weight of liver and spleen, live weight, carcass weight and body condition scores. *O. stricta* consuming goats had higher mean organ weight to body weight ratio than controls, which is consistent with occurrence of prominent sub-acute to chronic granulomatous, occasionally abscess forming, inflammation observed at the location of spines and thorns.

Generally, worm burden in abomasa and large intestines of the two groups of the study goats was more in goats that had consumed *O. stricta* than controls. The GIT worm count showed that the mean number of *H. contortus* in the abomasum of the sick goats was far much lower than in the healthy goats. The mechanism of reduction in abomasum worm burden in goats feeding on *O. stricta* is not known. The presence of numerous thorns and spines in the abomasa of sick goats may have created unfavorable environment for the survival of *H. contortus* as compared to the controls. However this should be investigated further. It is notable that mean numbers of *Trichuris* spp. and *O. columbianum* in the large intestines of goats which had not consumed *O.*

stricta was almost negligible compared to *O. stricta* consuming goats. However there was no significant difference in the presence of GIT worms in the two groups of the study goats.

6.11 Conclusions

1. *Opuntia stricta* thorns and spines caused widespread multiple abscesses on the skin of goats and occasionally in internal organs. Its spikes also inflicted severe septic ulcerative lesions, on the lips and mouth. In the abomasum, thorn and spines were embedded mostly in all layers of the sub mucosa resulting in abscesses. This may have compromised food absorption.
2. Foreign body granulomas are the characteristic microscopic lesions caused by *O. stricta* thorns and spines in the ears, lips, tongue and abomasum.
3. The extensive damage caused by *O. stricta* thorns and spines on the lips, mouth, tongue and abomasum were associated with the loss in anatomical and physiological functions of affected organs. The affected animals therefore could not eat or digest food properly hence loss of body condition.
4. Pain associated with lesions in various body parts was so severe and stressful to animals that it affected their ability to feed.
5. *O. stricta* inflicted eye lesions and blindness and the affected goats could not easily access forage, contributing to inability of the animal to feed and loss of body condition.
6. Loss of body condition as a result of inability to feed and absorb nutrients negatively affected organ weights; carcass quality and weights at slaughter.

7. The many thorns and spines penetrating deeper layers of lips, mouth, tongue and abomasum cannot be removed by any means and the damages so caused in these organs cannot be reversed by any means of treatment.

6.12 Recommendation

1. The only viable intervention measure is to keep goats and other livestock away from accessing *O. stricta*. This can only be done by controlling the spread of *O. stricta* in the grazing area.

CHAPTER SEVEN

7.0 LIVESTOCK ECONOMIC LOSSES CAUSED BY CONSUPTION OF *OPUNTIA STRICTA*

7.1 Introduction

Livestock industry suffers great economic losses due to animals consuming toxic foliage. However there is no methodical way of accounting for the magnitude of these losses. Losses in livestock business can be direct or indirect. Direct losses come through livestock deaths, weight loss (emaciation) and decreased efficiency. Reduced performance accounts for greater losses than deaths. In western countries, livestock deaths and some reproductive losses results to about $ 340,000,000 annually (Nielsen, 1978; James *et al*., 1992).

The economic losses which resulted from consumption of *O. stricta* by livestock were either direct or indirect. Direct losses caused by deaths of livestock and extreme emaciation reduce the number of live animals in the market and the carcass weight at slaughter. Indirect losses occur through: increased culling of the breeding stock; increased period of lambing/kidding/calving to mating intervals; reduced growth and weight gains and high death rates of the young ones. All these affect herd size negatively per household.

7.2 Materials and methods

A semi-structured questionnaire (appendix 1) which was used to determine knowledge, attitude and practices in chapter 3 also captured the death of animals in the past 1 year. Cost of each livestock species in the livestock markets found in the study areas was also determined in the questionnaire data. Loss of live goats, carcass and organ weights that had consumed *O. stricta*

were determined in chapter 6 (Fig. 32). Both questionnaire data on livestock deaths in the past one year and loss of both live and carcass weights were used to calculate the economic losses occasioned by consumption of *O. stricta.*

7.3 Results

Mean live, carcass and organ weight losses of goats that had consumed *O. stricta* compared to the ones which had not eaten the plant are summarized in table 8. Mean and standard deviation of each livestock species lost as a result of feeding on *O. stricta* per household in one year is described in table 14. The mean and standard deviation of cost per animal species in Laikipia north livestock markets is described in table 15.

Table 14: Number of livestock which died in one year due to the effects of *Opuntia stricta* in Laikipia north

	cattle	sheep	goats	camels
N	116	116	116	116
Mean ±SD of livestock species lost in 1 year due to consumption of *Opuntia stricta*	7.04 ±12.923	35.58 ±41.018	35.84 ±44.830	.06 ±.356
Total number of animals lost in one (1) year due to consumption of *Opuntia stricta*	817	4127	4157	7

Table 15: Mean cost per livestock species at livestock markets in Laikipia north

	cattle	sheep	goats	camels
N	71	110	108	4
Mean ±SD of cost of one animal in Laikipia north livestock market	36154.93 ±14638.157	5250.00 ±1924.909	5402.78 ±2026.067	90000.00 ±11547.005
Total	2567000	577500	583500	360000

7.4 Calculated economic losses due to deaths of livestock consuming *Opuntia stricta* in Laikipia County

In one year 817 cattle, 4127 sheep, 4157 goats and 7 camels died in the study area because of effects of *O. stricta*, (Table 14). These translate to each household losing at least 1 cow, 3 goats and 3 sheep per month. The mean market price of one cow, one sheep, one goat and one camel in the study area was Ksh 36,154.93; 5,250.00; 5,402.78 and 90,000 respectively. Thus within one year the interviewed respondents from 116 households lost an average of Kes 74,294,684.27 from the deaths of 817 cattle, 4127 sheep, 4157 goats and 7 camels. Excluding camels (since very few households had camels), each household lost an average of between Kes 193,635.60 – 634,961.30 per year or between 16,208.30 – 68,113.30 per month depending on whether that household had cattle, sheep or goats.

7.5 Economic losses due to emaciation and condemnations of goats consuming *Opuntia stricta* in Laikipia County

Emaciation was characterized by loss of adipose tissue and muscles in the whole body and hence loss of body weight. This had direct effect on value of animals at both market price and at slaughter. Consumption of *O. stricta* resulted in reduced live and dressed carcass weights of goats and subsequent low prices of live goats at the markets and dressed carcasses at the slaughter. The mean live weight of goats that had consumed *O. stricta* was 20.39kg and the mean live weight of those which had not consumed *O. stricta* was 33.25 kg (Table 8). This gave a mean weight difference (loss) of 12.86kg. The mean cost of one healthy goat at the study area was Ksh 5,402 (Table 15). By losing 12.86 kg, the price of one live goat at the livestock market reduced from Ksh 5402 to about Ksh 3,313, losing approximately Ksh 2,089 which was 38.67%. The mean dressed carcass weight of *O. stricta* consuming goats was 9.6 kg while that of those which did not consume the plant was 15.13 kg (Table 8) indicating a difference (loss) of 5.53 kg. Butcheries in the study area and its environs sold one kg of goat meat between Ksh 450 to Ksh 500. This translated to a direct loss of 2,488.50 per carcass of *O. stricta* affected goat. The poor carcass quality also affected the sale of meat from *O. stricta* consuming goats compared to the ones which had not consumed *O. stricta*. More losses were incurred by frequent condemnation of organs and whole carcasses due to multiple abscesses, hemorrhages and other effects such as presence of *O. stricta* thorns and spines in the muscles (Fig 41) making meat unfit for human consumption.

7.6 Goat production: Economic losses

Livestock farmers incurred losses indirectly through reduced production and delayed reproduction period of their animals. Negative effects on lactation had severe consequences on growth rates and weight gains of the suckling animals and increased their mortalities. Indirect losses caused by consumption of *O. stricta* are well described in section 3.8.5. Other losses such as aesthetic value of the animal to the owner and treatment costs are difficult to quantify.

7.7 Discussion

In Chapter three of this study, respondents to a KAP study indicate that all animals that develop clinical signs after consuming *O. stricta* die irrespective of intervention measures of treatment undertaken. Farmers treat affected animals with conventional drug purchased from agro-veterinary shops and homemade therapies but all these do not work and eventually affected animals die. From this study, economic losses from livestock death, reduced number of live goats at markets and dressed carcass weights at slaughter were enormous.

The average economic loss per household per year due to livestock deaths in this study was between Kenya shillings 193,635.60 – 634,961.30 (US$ 1936 – 6350) per year or between 16,208.30 – 68,113.30 (US$ 162 – US$ 681) per month. This is much higher than what Shackleton *et al*., *(2017)* had reported earlier in the same study area that the annual economic losses due to death of livestock from the effects of *O. stricta* ranged between US$ 500–1000 and US$100–500 per home. This author had evaluated and derived his figures from clinical observation.

Economic losses impacted by loss of body condition (emaciation) of goats at livestock market were about Ksh 2,089 (US$ 20.89) per goat. At slaughter losses were between Ksh 2,488.50 – Ksh 2,765 (US$ 24.885 – US$ 27.65) per dressed carcass. Economic losses at slaughter could be even higher if frequent condemnation of whole goat carcasses and body organs due to multiple abscesses, hemorrhages, gelatinous carcass and other effects such as presence of *O. stricta* thorns and spines in the muscles were accounted for. Similarly, Shackleton *et al.,* (2017) reported that in US, national beef quality audit indicated that 22.5% of cattle had inflammation, protuberances and sores of lips, tongues and buccal cavities caused by the spikes and barbed bristle of the cactus. This condition specifically called pear mouth and cactus tongue made cattle not suitable for sale and for people to eat. In this case, the whole head could also be condemned besides other internal organs of the goat.

Costs of purchasing drugs from agro-veterinary outlets were enormous. The range of veterinary drug used was wide, indicating misuse of antibiotics in the market and risks of possible exposure to humans and hence antimicrobial resistance. In addition, the effect of ethno-veterinary products used on the microbes may contribute to antimicrobial resistance as well. This need to be evaluated in future studies.

Reduced milk production resulted in decreased growth rate and weight gain of young ones and increased mortalities. This together with increased calving/lambing/kidding to mating interval, high culling rates of the affected breeding stock and reduced herd sizes for every household, contribute to great loss by the farmers.

7.8 Conclusions and Recommendations

7.8.1 Conclusions

1. Direct economic losses incurred by farmers due to goats consuming *O. stricta* was as a result of deaths, emaciation (which reduced the value of animals at livestock market and at slaughter) and condemnation of organs and whole carcasses in the slaughterhouses.
2. Indirect economic losses were due to delayed heat cycles, high rate of culling of the breeding stock and high mortalities of young ones and poor weight gains due to lack of milk. All these reduced hard sizes per household.
3. Economic losses in goat production impact negatively on the livelihood of communities in Laikipia north and increase their vulnerability.

7.8.2 Recommendation

1. There is an urgent need to control the spread *O. stricta* in the prime grazing areas of Laikipia north Sub-county. This will prevent livestock deaths and improve social economics of the pastoral communities living in the area.

CHAPTER EIGHT

8.0 GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

8.1 General discussion

Opuntia stricta variety *stricta* was introduced in Laikipia north Sub County over fifty years ago as a living fence (Strum *et al*., (2015); Shackleton *et al.,* (2017), but it turned out to be an invasive plant species later on as a result of land degradation. In this study, residents agreed that they have known and lived with *O. stricta* for the last sixty years. In this period of time, communities have developed different strategies to survive with this plant. Though *O. stricta* is very aggressive in terms of invasion, residents intervene by removing it manually from their households and try to treat animals that are affected by consumption of this plant. Nevertheless, they do not succeed and the cactus ends up displacing them from their residents. All intervention measures they use to treat *O. stricta* related conditions in their livestock do not work and finally animals affected by consumption of this plant die.

The alterations in land use especially from pastoralism to settlements (Strum *et al.,* 2015) by the communities living in Laikipia north is the contributing factor for *O. stricta* to invade Mumonyont, Makurian and Ilpolei locations. Unlike the past when Mukogodo "Maasai" occupying Laikipia north used to move from place to place with their animals, they have permanently settled in the communal ranches and some of them have put up permanent homesteads. Animal manure around households ("Manyatas") and concentration of *O. stricta* seeds in livestock faeces around homesteads encourages fast growth and spread of this cactus (Shackleton *et al.,* 2017). Besides livestock and human, activities such as using *O. stricta* as live fence around homesteads, elephants and Baboons (Velvet monkeys) are key dispersal agents of this plant. Coverage of the grazing areas by the *O. stricta* and extinction of rangeland grasses and

other range plants and tree species which were livestock feeds; recurrent and prolonged droughts in the area due to climatic change cause goats and other livestock species to feed on the *O. stricta* as an alternative and the only feed available.

The cladodes and fruits of *O. stricta* (Haw.) are the two parts of this cactus that are eaten by the livestock. Cladodes are protected by thorns and spines; while the fruits have small spines called glochids. According to residents, ripened *O. stricta* fruit is preferred by goats because its reddish colour charms the animals and its taste is appealing to goats. Therefore, animals feed on fruits in all seasons whether there are other feeds or not. This study agrees with previous ones that, the spines and thorns of *O stricta* inflict marked damage to the digestive system and other parts of the body; some animals become blind; others develop septic abscesses (Nobel, (2002).

Affected animals develop clinical signs within a few weeks in goats browsing *O. stricta.* The study further confirms that clinical signs are directly associated with presence of spines on the entire body including ears, face, eyes, lips, mouth and the entire skin. Further, presence of thorns and spines inflicts ulcerative wounds on the lips, mouth and tongue. Thorns are present at the wound especially on the body of the tongue (prominently on the median sulcus). They cause trauma induced cataracts in one or both eyes; abscesses on various parts of the body and enlargement of superficial lymph nodes. The study confirms that goats' lose up to a mean live weight of 12.86 kg and mean dressed weight of 5.53 kg and become emaciated and die within 1 – 5 months. Postmortem findings in this study reveals that, the main parts of gastrointestinal tract affected by *O. stricta* spines are lips, mouth, tongue and the abomasum. Rumen, reticulum and omasum bear the spines on their mucosal surfaces but do not show much pathological changes (some rumens develop reduced papillae). In the lips and tongue, *O. stricta* thorns penetrate and cause ulcerative septic lesions. Spines embed the abomasal mucosa at the pyloric region eliciting

severe inflammatory reaction and thickening of the abomasal mucosa (glandular swelling). Chronic lesions observed in this study are septic abscesses that are most likely caused by microorganisms carried on the thorn (Nobel, 2002; Halpern *et al.,* 2007; and Shackleton *et al.,* 2017). This study showed a correlation between the severities of lesions at the lips, mouths and abomasum. Lesions were either mild, severe sub-acute or severe chronic. Histopathology showed that the lesions are foreign body granuloma.

Goats consuming *O. stricta* (sick goats) developed marked increase in differential granulocyte counts and low lymphocyte counts. Goats' not consuming *O. stricta* (controls) had a very slight decrease in lymphocyte counts but their other WBC parameters were within normal range. Sick goats had low Haematocrits (Hct), haemoglobin (Hb) and Mean corpuscular haemoglobin (MCH). Control goats had lower mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH) than normal range. Control showed lower Platelet Distribution Width (PDW) than normal. Although anisocytosis is a common finding in caprine species and it was present in the two groups of the study goats; it was markedly high in goats that had consumed *O. stricta* than the ones which had not consumed the plant. Slight anisocytosis is common in ruminants (Jones, 2011). Remarkable anisocytosis is characterized by presence of large polychromatophilic erythrocytes among varied sized ones; a typical feature of a regenerative bone marrow reaction (Jones, 2011). Poikilocytosis is common in young goats Jones, (2011) and in this study; it was moderate in goats that had consumed *O. stricta* and mild in goats which had not consumed it. Hypochromasia, reduction in RBC and keratocytes (spindle shaped RBC) were observed in *O. stricta* consuming goats only. Hypochromic red blood cells are an outcome of diminished intracellular haemoglobin concentration resulting from insufficient iron. Proper iron insufficiency (also known as complete lack of iron) causes anemia. Iron insufficiency in

livestock occurs in prolonged loss of blood and in low dietary intake of iron. Iron insufficiency anemia is classified as recovering or not regenerative. Typically blood with iron insufficiency is seen as microcytic (low MCV), hypochromic (low MCHC) anemia. Microcytosis classically progresses before hypochromasia (Michael, 2013). *O. stricta* consuming goats were progressively losing blood through wounds inflicted by thorns and spines. This might have contributed to the observed low hematocrits (PCV), mean corpuscular hemoglobin (MCH), hemoglobin (Hb) and high level of anisocytosis that are associated with iron deficiency which occurs in chronic iron deficiency (Wilson, 2010).

Neutrophilia accompanied by lymphopenia is common in inflammatory and infectious conditions (Duncan and Prasse, 1987). Response to ongoing activities in the body (infection, irritation, trauma, treatment or tumors) and key anomalies in the control of bone marrow neutrophil production are the main reasons for increased neutrophils in circulation (Naeim *et al*., 2009). An increased level of neutrophils (neutrophilia) is anticipated as in this study, if there is a considerable severe inflammation of the tissues underlying the skin or inner tissues such as lungs and its associated structures, liver or gastrointestinal tract segments for the reason that mediators can simply get a way to the general blood circulation. Animals with severe inflammatory reaction have high levels of neutrophils (neutrophilia) and low levels of lymphocytes (lymphopenia) (Stockham and Scott, 2013). A rise in neutrophils might point out a strain or inflammatory reaction (Wilson, 2010).

Increased circulating neutrophils (except the one related to stress) are virtually at all times as a result of reaction to some inflammatory causes. Established and prolonged irritation leads to prolonged increased neutrophils (Constable *et al.,* 2016; Muslin and Greene, 2010). An increase in circulating neutrophils is perceived in noninfectious conditions such as traumatic injuries,

necrosis, infarction, burns and thrombosis. Inflammation may also cause low lymphocytes in circulation besides infections resulting from viruses and bacteria (Roland *et al*., 2014). Diseases that cause inflammation of small and large intestine are frequently linked to an increase in circulating neutrophils due to discharge of cytokines such as: Tumour Necrotic Factor α (TNF-α), Granulocyte Colony Stimulating Factor (G-CSF), Granulocyte Monocytes Colony Stimulating Factor (GM-CSF), Interleukin – 6 (IL - 6) and Interleukin – 8 (IL - 8) (Naeim, 2012). Goats which had consumed *O. stricta* had inflammatory lesions on the lips, mouth, gum, tongue and abomasum. These inflammatory lesions are consistent with marked elevation of neutrophils in *O. stricta* consuming goats.

Reduced levels of haematocrits, haemoglobin and red blood cell counts are encountered in anemia and generally, reduction in RBC indices matches reduction in hemoglobin (Wilson, 2010; Duncan and Prasse, 1987). In iron deficiency anemia, the following RBC indices are lowered: mean corpuscular volume (MCV), Mean corpuscular hemoglobin (MCH) and Mean corpuscular hemoglobin concentration (MCHC). Lack of iron is the cause of small red blood cells (microcytosis) and low means corpuscular hemoglobin (MCH). The size of red blood cells determines the amount of hemoglobin it carries. A small sized red blood cell carries little amount of hemoglobin and therefore mean corpuscular hemoglobin concentration (MCHC) varies with mean corpuscular volume (MCV) (Duncan and Prasse, 1987). *O. stricta* consuming goats had low hematocrits (PCV), mean corpuscular hemoglobin (MCH) and hemoglobin (Hb). Although their red blood cell counts were within normal range, they were in the lower normal indicating reduction in red blood cells. These parameters support the presence of anemia in *O. stricta* consuming goats.

Red cell distribution width (RWD) is the measurement of extent of anisocytosis or dissimilarities in dimensions of the red blood cells (Duncan and Prasse, 1987; Stockham and Scott, 2013). RDW therefore, being a guide to the extent of anisocytosis of red blood cells is normally increased when there is presence of immature RBC (reticulocytes) and anemias with microcytes or macrocytes. RDW that occurs concurrently with low mean corpuscular volume is consistent with iron deficiency (Lanzkowsky *et al*., 2016; Wallig *et al*., 2017). Failure of erythrocytes to take up as much haemoglobin as they should due to their smallness in size results to microcytic anemia. Lack of iron and subsequent small sized red blood cells and less haemoglobin contents (low MCV and low MCH) can be caused by malnutrition or nutrition deficiencies. In some cases of iron deficiency anemia, mean corpuscular hemoglobin (MCH) may decrease before mean corpuscular hemoglobin concentration (MCHC) decrease (Duncan and Prasse, 1987). Anemia with substantially small red blood cells (microcytosis) or large blood cells (macrocytosis) is characterized by high red cell distribution width (Duncan and Prasse, 1987). In the present study, the two groups of animals had a marked Red Cell Distribution Width (RDW) indicating hematological disease or anemia (Feng *et al*., 2017). The presence of *Anaplasma marginale* in the two groups of study goats may have contributed to their increased RDW. Even though the two groups of animals were infected by *Anaplasma marginale* parasites, more sick goats were infected than controls.

Amplified variations in size of red blood cells (anisocytosis) are normally found in regenerative anemia. It can happen when there is increased production of small sized RBC (microcytes) than normal cells that is consistent with iron deficiency; or when there is production of many large sized RBC (macrocytes) than normal consistent with increased production of reticulocytes (Harvey, 2012). Microcytes also occur in pyridoxine deficiency anemia. Small sized red blood

cells also occur in portosystemic shunts (PSS) and low sodium levels (Duncan and Prasse, 1987; Stockham and Scott, 2013).

Total proteins of the sick and control goats were elevated. Creatine kinase of goats that had consumed *O. stricta* was slightly increased while for the controls were markedly elevated. Albumin, Alkaline phosphatase (ALP), Aspartate aminotransferase (AST), Alanine aminotransferase (ALT), Blood urea nitrogen (BUN) and Creatinine levels of the *O. stricta* consuming goats were all lower than normal ranges but blood glucose was slightly higher than normal. Except for creatinine levels which were lower than normal for the goats which had not consumed *O. stricta*, all other parameters were in the normal range.

Levels of protein in the blood are routinely used in diagnosis and monitoring the course of disease (Putignano *et al.,* 2000). Initially when there is an infection, trauma or other tissue damage in animals, acute phase response results in an increase of acute phase proteins (these occur at insignificant level in healthy animals) (Coskun *et al.,* 2012). Changes in amounts of total proteins, even though not precise, might be of investigative importance in patients with compound illnesses (Putignano *et al.,* 2000). In situations of moderate lack of fluids (and other forms of dehydration), albumin and globulins are increased proportionally (Wallig *et al.,* 2017). Albumin is synthesized in the liver and constitutes approximately 50% of the total plasma proteins. It contributes about 75% of the colloidal functions in plasma (Haschek *et al.,* 2013). Commonly low albumin in the blood occurs in prolonged liver injury (Huang *et al.,* 2012). The presence of low albumin in the blood without acute symptoms of kidney, liver or heart diseases suggests protein losing enteropathy. In canine species with protein loss enteropathy, the principal reasons for low albumin levels are losses via digestive, urinary, or vascular systems (Rich *et al*., 2012; Wallig *et al.,* 2017). Low albumin levels accompanied by normal or increased blood

globulin levels occur in diseases in which there is inadequate production of albumin by the liver or too much or discriminate loss of albumin compared with loss of globulin. Diseases of the liver that cause low albumin in the blood are diffuse, severe and chronic (Constable *et al.,* 2016). In ruminants circulating haptoglobin (Hp) and serum amyloid A (SAA) are increased up to 100-fold in inflammatory, traumatic or chronic pathological conditions (Coskun *et al*., 2012). Generally, in reaction to inflammation, acute phase proteins like alpha$_2$-macroglobulin, haptoglobulin and ceruloplasmin are produced among other globulins (Wallig *et al.,* 2017). Earlier studies done by Coskun *et al*., (2012) showed that cattle naturally infected with *Anaplasma marginale* had increased levels of haptoglobin (Hp) and serum amyloid A (SAA).

In this study, *O. stricta* consuming goats had multiple abscesses in the abomasum; and small and large intestines were full of pinkish red fluids. There was also a marked reduction in liver weight compared to goats which had not consumed *O. stricta*. Lesions in the abomasum and lack of ingested feed in the small and large intestines may have been the cause of low albumins in *O. stricta* consuming goats. Proteins may either not have been absorbed or they were lost due to diseased gastrointestinal tract as a result of injuries by *O. stricta* thorns and spines. Traumatic injuries caused by *O. stricta* thorns and spines, inflammation, ulcerative lesions on the lips and mouth and abomasa abscesses in goats which had consumed *O. stricta* may have contributed to increased levels of total proteins. The observed increased levels of total protein in goats which had not consumed *O. stricta* may have been contributed by *Anaplasma marginale* infection as reported in cattle by Coskun *et al*., (2012).

Elevation of creatine kinase is consistent with muscle injury. Any kind of muscle fiber injury (commonly skeletal, sometimes cardiac, and seldom smooth) is the basis for the discharge of creatine kinase from the damaged muscle fibers. Traumatic injuries such as intramuscular

injections, motor accidents and / or recumbence (as occur in horses and cattle) also increase the levels of creatine kinase. Inflammation of other body parts by microorganisms such as *Neospora sp*, bacterial, *Toxoplasma gondii* which may result to muscles injury also increases CK levels in the serum. Nutritional deficiency like vitamin E and selenium deficiency and degeneration such as hypoxia exertion and exertional rhabdomyolysis are other causes of increased levels of CK (Stockham and Scott, 2013; Neumann *et al*., 2005; Aktas *et al*., 1993). Besides skeletal muscles, creatine kinase is also found in the muscles of the heart, brain, urinary and reproductive systems, digestive system and thyroid gland. When there is a significant injury of these tissues, creatine kinase activities are increased and the type of the muscles or body part traumatized can be identified by ascertaining isoenzyme portions of creatine kinase (Lerma *et al*., 2018; Tietze, 2011; Fascetti *et al*., 1997). Creatine kinase (CK) is more dependable as a biomarker for muscle injury than AST for the reason that augmented AST amounts might occur in liver injury. An increase in serum AST and CK is consistent with muscle injury. The two are raised at the start and a high AST and decreasing CK would propose that muscle deterioration is not in progress. Acute diseases of muscles, especially the ones affecting muscle fibres leads to a higher aspartate aminotransferase (AST), creatine kinase (CK) and lactate dehydrogenase (LDH) levels (Constable *et al*., 2016; Kim *et al*., 2008). Creatine kinase levels are also elevated in high catabolic activities in the muscles (Fascetti *et al*., 1997). Coskun *et al*., (2012) reported that cattle naturally infected with *Anaplasma marginale* had marked increase in creatine kinase levels. The increased levels of creatine kinase in the *O. stricta* consuming goats may have been caused by traumatic injuries from thorns and spines in various tissues. Septic ulcerative lesions on the lips, mouth and tongue, and multiple abscesses in the abomasum represent inflammatory changes caused by microorganisms that were introduced into the tissues by thorns and spines of the *O.*

stricta (Nobel, 2002; Shackleton *et al*., 2017). These injuries could have caused the observed increase in creatine kinase in the affected animals. The marked elevation of creatine kinase in goats which had not consumed *O. stricta* may have been caused by *Anaplasma marginale* infection as reported in cattle by Coskun *et al*., (2012).

Alkaline phosphatase is produced commonly in the liver, bone, intestines, kidneys and placenta and secreted into bile. Diseases that affect biliary tract (liver, gall bladder and bile ducts) and conditions stopping the flow of bile either from within or outside liver cause rise in alkaline phosphatase (Petty *et al*., 2015; Kliegman *et al*., 2017). Elevation of serum alkaline phosphatase consistently occurs in injuries that reduce the flow of bile (cholestasis). Decreased alkaline phosphatase (ALP) can be caused by insufficient nutrition, reduced uptake of food in the gastrointestinal tract and lack of vitamin D among other conditions (Thompson, 2013). Low ALP therefore shows malnutrition due to either poor diet or by any condition that interferes with absorption of food. Alanine aminotransferase (ALT) and Aspartate aminotransferase (AST) originate from the cytoplasm of the liver cells and also from the bone muscles.

AST occurs in the cytoplasm and mitochondria of various cells, being most prominent in liver cells, while ALT is abundant in the cytoplasm of the liver cells. AST and ALT are discharged from the cell into plasma in cell injury. The scale at which ALT is raised in serum is normally larger than that of AST in liver cell damage. The reason is that ALT has elongated half-life while AST is firmly attached to the mitochondria (Kaneko *et al*., 2008; Suckow *et al*., 2012; Zoppini *et al.*, 2016; Faqi, 2016). AST is not as precise as ALT as indicators for liver damage because AST is manifested in other body parts like brain, heart muscles and skeletal muscles. Thus, increase in ALT in serum is consistent in liver disease. The ratio of AST to ALT is used in the clinical practice to assist in differentiating injuries from within the liver and those from outside the liver.

When the ratio of AST/ALT is 2:1, it is suggestive of severe and chronic liver damage and / or severe muscle damage (Gupta, 2016). In liver degeneration serum enzyme levels may decrease because of declining quantity of liver cells (hepatocytes). Hepatic ALT action is very little in horses, ruminants, pigs, and birds. Rise in serum ALT levels in these animals may indicate muscle damage than liver disease (Stockham and Scott, 2013; Duncan and Prasse, 1987). In the *O. stricta* consuming goats, alkaline phosphatase (ALP), aspartate aminotransferase (AST), alanine aminotransferase (ALT) were all lowered. Although lowered alkaline phosphatase may have been due to malnutrition as a result of reduced uptake of food in the gastrointestinal tract of goats consuming *O. stricta* (Thompson, 2013), it is not clear why aspartate aminotransferase (AST), alanine aminotransferase (ALT) were all lowered. The possibility that *O. stricta* has some biochemicals which are depressing production or release of these enzymes from the organs where they are produced is suggested as an important research question

Blood urea nitrogen (BUN) is analyzed to determine the levels of urea nitrogen in the blood and it may be influenced by the status of the body fluids, dietary protein intake and the rate of the breakdown of protein (Thomas, 2018). BUN and creatinine are the more frequently used markers of kidneys filtration and reabsorption function in mammals. Nevertheless, their sensitivity is not precise and therefore not reliable indicators of renal functions in severe renal damage. This is because they are affected by renal and non-renal factors (Peterson and Kutzler, 2010; Edelstein, 2016). When high BUN levels are encountered in patients with renal ailments, this is considered to be a result and not the origin of damaged kidney function (Engelking, 2014). Both BUN and the amounts of blood creatinine might be elevated in congestive heart failure, as a result of lowered filtration of fluids by the kidneys (DiBartola, 2011). The amounts of BUN and blood creatinine are usually raised in diabetic ketoacidosis (Feldman, 2014). Urea nitrogen

concentration in blood may decrease with reduced transformation of ammonia to urea by the liver. Nevertheless, blood urea amounts are not precise for hepatic disease. Reduced BUN also occurs in patients taking low amounts of protein. When ruminants have a low appetite or are on low protein diet rumen microbes utilize urea as a source of nitrogen for their own protein production. This causes reduction in serum BUN levels (Constable, 2016). *O. stricta* consuming goats were unable to feed due to ulcerative lesions on the lips, mouth and tongue and pain as a result of these lesions. This condition may have caused the observed low blood urea nitrogen in the affected goats.

The amounts of serum creatinine in the blood depend on dietary protein consumption, the bulkiness of muscles and the use of medicines like cimetidine and trimethoprim, which affects the renal creatinine management (Farrar *et al*., 2013). Substantial loss of muscle mass (muscular dystrophy) results to reduced serum creatinine while high serum creatinine levels occurs with reduced glomerular filtration (Willard and Tvedten, 2011). In young animals, low serum creatinine levels are frequently triggered by reduced muscle quantity as a result of muscular atrophy from inadequate use or food shortage (Peterson and Kutzler, 2011).

Severe economic loses to the livestock business in various parts of the world is caused by consumption of toxic foliage although there is no methodical way of accounting for the magnitude of these losses. Losses in livestock industry can be direct or indirect. Deaths, weight loss (emaciation), abortions, lengthened calving intervals, decreased efficiency and other effects on the animals are direct losses. Losses due to reduction in performance can be greater than losses due to deaths. In western countries, livestock deaths and some reproductive losses results to about $ 340,000,000 annually (Nielsen, 1978; James *et al*., 1992). In the current study, economic losses resulting from livestock deaths after consumption of *O. stricta* was enormous. It

ranged between Kenya shillings 193,635.60 – 634961.30 ($1936 – 6350) per year or between Ksh 16,208.30 – Kenya shillings 68,113.30 ($162 – $681) every month per household. This is much higher than what Shackleton *et al.,* (2017) had reported earlier from the study in the same area that the annual economic losses due to death of livestock from the effects of *O. stricta* ranged between US$ 500–1000 and US$100–500 per home.

Economic losses impacted by loss of body condition (emaciation) of live goats at livestock market was about ksh 2,089 ($ 20.89) per goat. At slaughter losses were between Kenya shillings 2488.50 – Kenya shillings 2765 ($24.885 – $27.65) per dressed carcass. Economic losses at slaughter could be even higher if frequent condemnation of whole goat carcasses and body organs due to multiple abscesses, hemorrhages and other effects such as presence of *O. stricta* thorns and spines in the muscles were accounted for. Similarly, Shackleton *et al., (2017)* reported that in US, national beef quality audit indicated that 22.5% of cattle had inflammation, protuberances and sores of lips, tongues and buccal cavities caused by the spikes and barbed bristle of the cactus. This condition specifically called pear mouth and cactus tongue made cattle unsuitable for sale and for people to eat.

Reduced milk production resulted in low growth rate and weight gain and higher mortalities of young goats. This together with increased calving/lambing/kidding to mating intervals and high culling rates of the affected breeding stock; reduced herd sizes per household, which was a great loss in a purely pastoral production system. Measures taken to avert losses to livestock poisonings by plants makes up the indirect losses. These includes building and maintaining of fences to manage livestock at risk due to poisonous plants; looking after livestock to avoid poisoning; supplementary feeding to avert poisoning; changed grazing programs which may result in higher costs or grazing inadequacy; therapeutic costs occasioned by poisoning; and loss

of forage because it cannot be reaped at the appropriate time or intensity. It is hard to account for these costs yet they exist (James *et al*., 1992). Costs of purchasing drugs from agro-veterinary outlets to manage *O. stricta* related conditions were massive. This study observed that wide range of veterinary drug are used to treat animals affected by *O. stricta* indicating misuse of antibiotics in the market and risk to antibiotic resistance.

8.2 Conclusions

1. *Opuntia stricta* variety *stricta* poses threat to the health of livestock and humans in Laikipia County and community living in the area have clear knowledge about its harmful effects.
2. The risk factors associated with the consumption of *Opuntia stricta* are environmental and include reduction of rangeland grasses and other forage plants and trees as a result of invasion of the prime grazing land by *Opuntia stricta.* Also, land degradation, overstocking and poor rangeland management and recurrent and prolonged droughts deplete other flora and facilitate *O. stricta* to invade rangelands in the study area.
3. *Opuntia stricta* affects haematological parameters of goats by causing neutrophilia accompanied by lymphophenia which is consistent with inflammatory and infectious injuries.
4. Consumption of *Opuntia stricta* by goats is associated with reduced: mean corpuscular hemoglobin (MCH), Hematocrits (PCV) and haemoglobin (Hb) levels. The plant causes anemia consistent with iron deficiency and depression of erythrocytes production.

5. Goats that had consumed *Opuntia stricta* had reduced levels of serum albumin, alkaline phosphatase (ALP), aspartate aminotransferase (AST), alanine aminotransferase (ALT), blood urea nitrogen (BUN) and creatinine.
6. Thorns and spines of *O. stricta* cause multiple abscesses on the skin of goats in the entire body and inflict severe ulcerative lesions on the lips, mouth and tongue and abscesses in the abomasum.
7. Lesions caused by *O. stricta* thorns and spines are multifocal foreign body granulomas located mainly in the skin especially at ears; and lips, tongue and abomasum. The lesions are infiltrated by mononuclear cell mainly macrophages, lymphocytes and a few plasma cells, and fibrosis that surrounded embedded thorns or spines.
8. Severe oral and abomasal lesions, blindness and injury-associated pain explain the loss of body condition that occurred in goats affected by *O. stricta* since they affected prehension and digestion of feed.
9. Consumption of *O. stricta* by goats and other livestock species causes enormous direct and indirect economic losses as a result of loss in live weight and carcass quality at slaughter that impact negatively on the livelihoods and survival of the communities living in Laikipia north.
10. Results of the present study show that no treatment or intervention measures can reverse the damage caused by many thorns and spines penetrating into body systems of goats consuming *O. stricta*.

8.3 Recommendations

1. Measures to reduce invasion of *O. stricta* in Laikipia north should be instituted in order to prevent losses in livestock production and the associated impacts on lives, livelihoods and insecurity of the people in the area.
2. There is an urgent need to rehabilitate the environment after reduction of *O. stricta* in the prime grazing areas by reseeding with range grass and planting range plants and trees.
3. Community living in Laikipia north should be sensitized on the dangers of overstocking livestock and cutting of available trees to avoid land degradation and subsequent invasion by undesired plant species like *O. stricta*

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10.0 APPENDICES

Appendix 1: Questionnaire on assessment of the economic losses and harmful effects of *Opuntia Stricta* variety *Stricta* in goats of Laikipia County, Kenya

UNIVERSITY OF NAIROBI

COLLEGE OF AGRICULTURE AND VETERINARY SCIENCE

DEPARTMENT OF VETERINARY PATHOLOGY, MICROBIOLOGY AND PARASITOLOGY

Date of interview .....…….. Tel. No. ..... Code……

QUESTIONNAIRE ON ASSESSMENT OF THE ECONOMIC LOSSES AND HARMFUL EFFECTS OF *OPUNTIA STRICTA* VARIETY *STRICTA* IN GOATS OF LAIKIPIA COUNTY, KENYA

[Information given will be treated with utmost confidentiality]

GPS coordinates: Eastings …….……Northings ……. Elevation……

SECTION 1: BACKGROUND INFORMATION

1) Sub-county .....Ward……Village.....

Location……

2) Name of the clan……

3) Name of group ranch ……

4) Name of household owner…….....

5) Contact details of household owner: Cell phone: ……..

6) Gender of the household owner: [1] Male [2] Female

7) Age of the owner (years) [1] 18-30 [2] 31-40 [3] 41-55 [4] Above 55

8) Main occupation of the owner ……

[1] Farming [2] Business [3] Salaried employee [4] Others specify…....

9) Education level of household head…….....

[1] No formal education [2] Primary level [3] Secondary level [4] Tertiary level

10) Who is responsible for the day to day management decisions of the animals?

[1] Owner [2] Spouse [3] Daughter [4] Son [5] Worker [6] Other (specify)……

11) What is the education level of the person responsible for day to day management decisions?

[1] No formal education [2] Primary level [3] Secondary level [4] Tertiary level

12) Name of the interviewee……

13) Contact details of interviewee: Cell phone: …….

14) Gender of interviewee [1] Male [2] Female

15) Age of interviewee?

[1] 18-30 years [2] 31-40 years [3] 41-50 years [4] > 50years

16) What is the education level of the interviewee?

[1] No formal education [2] Primary level [3] Secondary level [4] Tertiary level

17) Relationship of interviewee to household head.....

[1] Owner [2] Spouse [3] Daughter [4] Son [5] Worker [6] Other (specify) ….. ……

SECTION 2: INFORMATION OF THE HOUSEHOLD

1. Which livestock species do you keep?

Species	Tick appropriately	Number
1] Cattle		
2] Sheep		
3] Goats		
4] Camels		
5] Others (specify)		

2. What is the main reason for keeping the animals?

[1] Business [2] Subsistence [3] Culture [4] Prestige/hobby

[5] Other ……(specify)

3. What feeds are available to the goats during rainy and dry season?

Type of feed	Available in dry season	Available in rainy season
1) Grass		
2) Foliage		
3) Acacia		

4) Others specify		

4. Do you get any extension services from the veterinary and livestock production officers?

[1] Yes [2] No

5. If yes, list some of the extension services offered by the veterinary and livestock production officers?

No.	Service	Tick appropriately
1]	Vaccination	
2]	Deworming	
3]	Training on management	
4]	Treatment of clinical cases	
5]	Availing drugs	
6]	Other specify	

SECTION 3 – KNOWLEDGE ABOUT *OPUNTIA* PLANT

6. Do you know *Opuntia* plant? [1] Yes [2] No

7. What is its local name ……...

8. How long have you known *Opuntia* plant?

……

9. Does *Opuntia* plant have any benefit to?

a) Livestock [1] Yes [2] No

b) Humans [1] Yes [2] No

10. If yes give reasons for your answers in (9) above?

No.	Benefits to livestock	Benefits to humans
1]		
2]		
3]		
4]		
5]		
6]		

11. Does *Opuntia* plant have any harmful effect to?

a) Livestock [1] Yes [2] No

b) Humans [1] Yes [2] No

12. If yes give reasons for your answers in (11) above?

No.	Effects in livestock	Effects in humans
1]		
2]		
3]		
4]		
5]		
6]		

13. Which parts of the *Opuntia* plants are eaten by animals?

[1] Fruits [2] Stem [3] Leaves [4] Root [5] Flower [6 Other specify ….....

14. When do animals eat *Opuntia* plant?

[1] Rainy season [2] Dry season [3] Both [4] Other …… (specify)

15. Why do you think animals eat *Opuntia* plant in the season picked in (14) above?

[1] Lack of feeds [2] They like *Opuntia* plant [3] To supplement other feeds

[4] Others specify……

16. Which animal species are mostly affected/harmed by O*puntia* plant?

[1] Cattle [2] Sheep [3] Goats [4] Camels [5] Others…….specify

17. Which sex is mostly affected?

[1] Males [2] Females [3] Both males and females [4] Don't know

18. Which age group is mostly affected for animals listed below?

Species	Young	Adult	Old	All affected the same way
1) Cattle				
2) Sheep				
3) Goats				
4) Camels				
5) Others specify				

Key:

Cattle: (1) - Day 1-$1^{1/}_{2}$ years (young) (2) 2-5 years (adult) (3) Above 6 years (old)

Sheep: (1) - Day 1- 1 year (young) (2) $1^{1/}_{2}$ – 4years Adult (3) Above $4^{1/}_{2}$ years (old)

Goats: (1) - Day 1- 1 year (young) (2) $1^{1/}_{2}$ – 4years Adult (3) Above $4^{1/}_{2}$ years (old)

Camels: (1) - Day 1- $2^{1/}_{2}$ years (young) (2) 3 – 8 years (adult) (3) Above 9 years (old)

19. Which clinical signs do you associate with an animal that has eaten *Opuntia* plant? Give the first two observable signs.

No.	Clinical signs/symptoms	Tick appropriately	First two signs to appear
1]	Lack of appetite		
2]	Loss of body condition		
3]	Injuries in the mouth		
4]	Blindness		
5]	Others specify A]		
	B]		
	C]		

20. After how long are the clinical signs identified in 19 above from the time an animal consumes *Opuntia* plant appear?

[1] Few days [2] Few weeks [3] Few months [4] More than 1yr [5] immediately

21. Have you ever slaughtered an animal that is affected by *Opuntia* plant?

[Yes] [No]

22. Did any animal slaughtered as above show some abnormalities?

[Yes] [No]

23. If yes which parts of the body are affected in an animal that has consumed *Opuntia* plant?

No.	Body part	Tick appropriately	Effects
1]	Eyes		
2]	Lips		
3]	Mouth		
4]	Esophagus		
5]	Rumen		
6]	Reticulum		
7]	Omasum		
8]	Abomasum		
9]	Small intestines		
10]	Large intestines		
11]	Others specify		

24. Do some of the animals die from effects of *Opuntia* plant?

[1] Yes [2] No

25. If yes how long do the animals take to die after they presents with signs arising from consumption of *Opuntia* plant?

No.	Species	Time taken to die
1]	Cattle	

2]	Sheep	
3]	Goats	
4]	Camels	
5]	Others specify	

SECTION 4 – ECONOMIC LOSSES DUE TO DEATHS AND TREATMENT

1. What action do you take when your animal shows symptoms arising from consumption of *Opuntia* plant?

[1] Veterinary intervention [2] Self-treat [3] Cull for slaughter [4] Others specify

2. If self-treat, how do you treat the condition?

No.	Method of treatment	Specify trade name/local names of herbs
1]	Buy drugs from agro-veterinary outlets	
2]	Use herbal plants	
3]	Homemade therapy	
4]	Others specify	

3. Does the treatment regime given work? [1] Yes [2] No

4. If yes, how long does it take to recover? ----------

5. If no, how long does an animal take to die after treatment?

No.	Species	Time taken to die after treatment
1]	Cattle	
2]	Sheep	
3]	Goats	
4]	Camels	
5]	Others specify	

6. How many animals have you lost for the past one year due to effects of *Opuntia* plant? Give cost per animal.

No.	Species	Number of animals lost	Cost per animal in Ksh.
1]	Cattle		
2]	Sheep		
3]	Goats		
4]	Camels		
5]	Others specify		

SECTION 5 – ECONOMIC LOSSES DUE TO PRODUCTION AND REPRODUCTION

7. Does *Opuntia* plant have any effect on lactating animals?

[1] Yes [2] No

8. If yes, state the effects *Opuntia* plants have on lactating animals?

No.	Effects of *Opuntia* pant on:	Increases [1]	Decreases [2]	No effect [3]
1]	Milk production			
2]	Calving to mating interval in cattle			
3]	Lambing to mating interval in sheep			
4]	Kidding to mating interval in goats			
5]	Calving to mating interval in camel			
6]	Others specify a)			
	b)			
	c)			

9. Does *Opuntia* plant have any effect on suckling young ones?

[1] Yes [2] No

10. If yes, what effect does *Oputia* plant have on suckling young ones? (enter appropriate code as follows: [1] Decreases [2] Increases [3] No effect)

No.	Species	Growth rate	Weight gain	Death rate

1]	Calves (cattle)			
2]	Lambs			
3]	Kids			
4]	Calves (camel)			
5]	Others specify			

11. Do you have any other information you can share on *Opuntia* plant?

a) …….

b) …….

c) …….

d) …….

e) …….

……..……..…… Thank you…….……...

Appendix 2: Approval letter from the University of Nairobi, biosafety, animal use and ethics committee

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

P.O. Box 30197,
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Dr. Jackson Muriungi Ncebere
Dept of Vet. Pathology, Microbiology and Parassitology

REF: FVM BAUEC/2019/192

02/02/2019

Dear Dr. Ncebere,

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

Pathology, haematological and biochemical parameters of goats due to *Opuntia stricta variety stricta* in Laikipia County, Kenya.

By Dr. Jackson Ncebere (J56/ 6725/ 2017).

We refer to the above revised MSc. proposal and ethical clearence application submitted on 19/09/2018.

We have reviewed your MSc. proposal, particularly section 3.8 that involves use of goats as the animal model. We are satisfied that the proposed handling, sample collection and humane end points of the animals meets acceptable standards for animal welfare.
Furthermore, the numbers proposed are reasonable.
We have also noted that Dr. Waruiru (KVB registered vet surgeon) will supervise the animal experiments and humane end points.
We hereby give approval for you to proceed with the experiments as outlined in the proposal you submitted to the committee.

Yours sincerely

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

Appendix 3: Taking blood samples for haematology and biochemistry tests

Appendix 4: Haematological analysis at Karatina regional veterinary investigation laboratory

Appendix 5: Giemsa stain preparation and staining of blood smears at Karatina regional veterinary investigation laboratory

Appendix 6: Centrifuging and harvesting serum and plasma at Dol dol sub county hospital

Appendix 7: Individual goat haematological changes

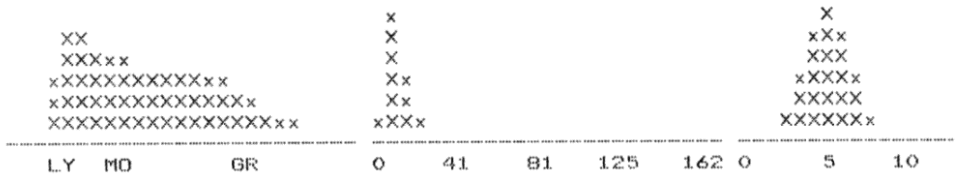
STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 3:23PM Sq : 0022

BANK : Goat
FILE : 20181123-S01
PATIENT : 01
COMMENT :

HEMATOLOGY				Normal Range
WBC	: +	13.91	m/mm3	4.0 - 13.0
Lym.	:M-	33.9	%	50.0 - 70.0
Mon.	:M+	5.0	%	1.0 - 4.0
Gra.	:M+	61.1	%	30.0 - 56.0
Lym#	:M-	4.71	m/mm3	2.0 - 9.1
Mon#	:M+	0.69	m/mm3	0.0 - 0.5
Gra#	:M+	8.51	m/mm3	1.2 - 7.2
RBC	:	11.11	M/mm3	8.0 - 18.0
MCV	: -	14.0	fl	16.0 - 25.0
Hct	: -	15.5	%	22.0 - 39.0
MCH	: -	4.0	pg	5.2 - 8.0
MCHC	:	29.0	g/dl	28.0 - 42.0
RDW	: +	18.0		8.0 - 12.0
RRg	:	0.0		
Hb	: -	4.5	g/dl	8.0 - 12.0
THR	:	278	m/mm3	200 - 600
MPV	:	5.5	fl	4.0 - 9.0
Pct	:	0.15	%	
PDW	: -	3.9		6.0 - 10.0

WBC HISTOGRAM RBC HISTOGRAM THR HISTOGRAM



STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

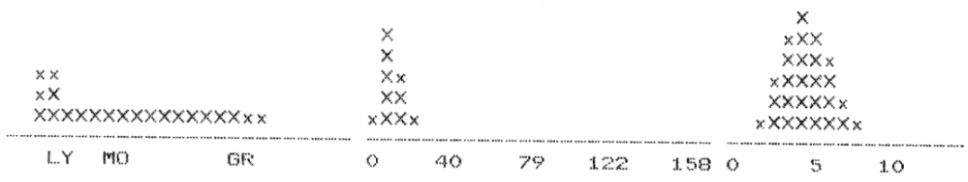
Nov. Fri 23,2018 2:26PM Sq : 0006

BANK : Goat
FILE : 20181123-SG2
PATIENT : 02
COMMENT :

HEMATOLOGY				Normal Range
WBC	:&-	3.32	m/mm3	4.0 - 13.0
Lym.	:L-	36.2	%	50.0 - 70.0
Mon.	:L	3.9	%	1.0 - 4.0
Gra.	:L+	59.9	%	30.0 - 56.0
Lym#	:L-	1.20	m/mm3	2.0 - 9.1
Mon#	:L	0.12	m/mm3	0.0 - 0.5
Gra#	:L+	2.00	m/mm3	1.2 - 7.2

RBC	:	10.75	M/mm3	8.0 - 18.0
MCV	: -	14.3	fl	16.0 - 25.0
Hct	: -	15.3	%	22.0 - 39.0
MCH	: -	4.0	pg	5.2 - 8.0
MCHC	:	28.1	g/dl	28.0 - 42.0
RDW	: +	18.8		8.0 - 12.0
RRg	:	0.0		
Hb	: -	4.3	g/dl	8.0 - 12.0
THR	:	425	m/mm3	200 - 600
MPV	:	5.0	fl	4.0 - 9.0
Pct	:	0.21	%	
PDW	: -	5.8		6.0 - 10.0

WBC HISTOGRAM RBC HISTOGRAM THR HISTOGRAM



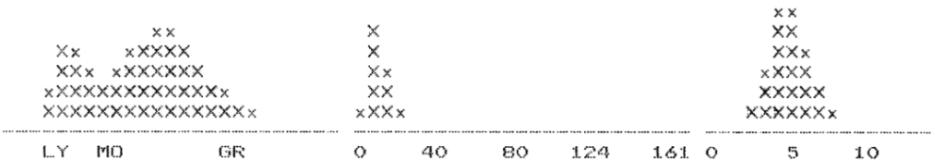
STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 2:29PM Sq : 0007

BANK : Goat
FILE : 20181123-SG3
PATIENT : 03
COMMENT :

HEMATOLOGY				Normal Range
WBC	: +	16.19	m/mm3	4.0 - 13.0
Lym.	: -	26.7	%	50.0 - 70.0
Mon.	:	3.3	%	1.0 - 4.0
Gra.	: +	70.0	%	30.0 - 56.0
Lym#	: -	4.32	m/mm3	2.0 - 9.1
Mon#	:	0.53	m/mm3	0.0 - 0.5
Gra#	: +	11.34	m/mm3	1.2 - 7.2
RBC	: +	18.75	M/mm3	8.0 - 18.0
MCV	: -	14.5	fl	16.0 - 25.0
Hct	:	27.1	%	22.0 - 39.0
MCH	: -	4.4	pg	5.2 - 8.0
MCHC	:	30.6	g/dl	28.0 - 42.0
RDW	: +	18.0		8.0 - 12.0
RRg	:	0.0		
Hb	:	8.3	g/dl	8.0 - 12.0
THR	:	415	m/mm3	200 - 600
MPV	:	5.4	fl	4.0 - 9.0
Pct	:	0.22	%	
PDW	: -	4.1		6.0 - 10.0

WBC HISTOGRAM RBC HISTOGRAM THR HISTOGRAM



STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 2:33PM Sq : 0008

BANK : Goat
FILE : 20181123-S04
PATIENT : 04
COMMENT :

HEMATOLOGY				Normal Range
WBC	:@+	28.71	m/mm3	4.0 - 13.0
Lym.	:L	63.1	%	50.0 - 70.0
Mon.	:L	1.7	%	1.0 - 4.0
Gra.	:L	35.2	%	30.0 - 56.0
Lym#	:L	18.11	m/mm3	2.0 - 9.1
Mon#	:L	0.48	m/mm3	0.0 - 0.5
Gra#	:L	10.12	m/mm3	1.2 - 7.2
RBC	:	16.26	M/mm3	8.0 - 18.0
MCV	:	17.0	fl	16.0 - 25.0
Hct	:	27.6	%	22.0 - 39.0
MCH	: -	4.7	pg	5.2 - 8.0
MCHC	: -	27.8	g/dl	28.0 - 42.0
RDW	: +	17.3		8.0 - 12.0
RRg	:	0.0		
Hb	: -	7.7	g/dl	8.0 - 12.0
THR	:	250	m/mm3	200 - 600
MPV	:	5.4	fl	4.0 - 9.0
Pct	:	0.13	%	
PDW	:	6.1		6.0 - 10.0

WBC HISTOGRAM RBC HISTOGRAM THR HISTOGRAM

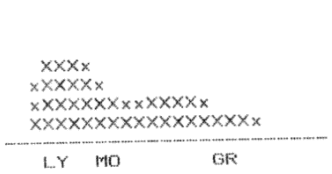
STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 2:42PM Sq : 0009

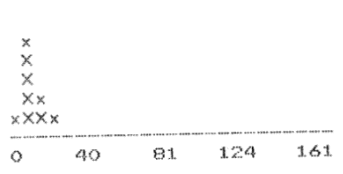
BANK : Goat
FILE : 20181123-SG5
PATIENT : 05
COMMENT :

HEMATOLOGY				Normal Range
WBC	: +	25.07	m/mm3	4.0 - 13.0
Lym.	: -	45.6	%	50.0 - 70.0
Mon.	: +	4.9	%	1.0 - 4.0
Gra.	:	49.5	%	30.0 - 56.0
Lym#	: -	11.43	m/mm3	2.0 - 9.1
Mon#	: +	1.22	m/mm3	0.0 - 0.5
Gra#	:	12.42	m/mm3	1.2 - 7.2
RBC	:	17.02	M/mm3	8.0 - 18.0
MCV	: -	13.9	fl	16.0 - 25.0
Hct	:	23.6	%	22.0 - 39.0
MCH	: -	4.3	pg	5.2 - 8.0
MCHC	:	31.3	g/dl	28.0 - 42.0
RDW	: +	16.2		8.0 - 12.0
RRg	:	0.0		
Hb	: -	7.4	g/dl	8.0 - 12.0
THR	:	371	m/mm3	200 - 600
MPV	:	5.5	fl	4.0 - 9.0
Pct	:	0.20	%	
PDW	: -	4.1		6.0 - 10.0

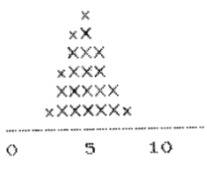
WBC HISTOGRAM



RBC HISTOGRAM



THR HISTOGRAM



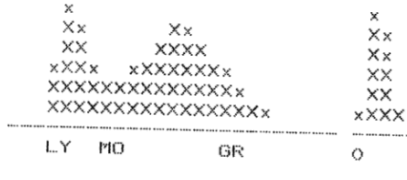
STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 2:45PM Sq : 0010

BANK : Goat
FILE : 20181123-SG6
PATIENT : 06
COMMENT :

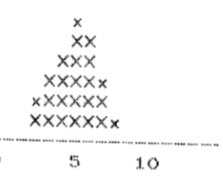
HEMATOLOGY				Normal Range
WBC	:	9.53	m/mm3	4.0 - 13.0
Lym.	: -	30.7	%	50.0 - 70.0
Mon.	:	2.4	%	1.0 - 4.0
Gra.	: +	66.9	%	30.0 - 56.0
Lym#	: -	2.92	m/mm3	2.0 - 9.1
Mon#	:	0.22	m/mm3	0.0 - 0.5
Gra#	: +	6.39	m/mm3	1.2 - 7.2
RBC	:	10.43	M/mm3	8.0 - 18.0
MCV	: -	15.6	fl	16.0 - 25.0
Hct	: -	16.2	%	22.0 - 39.0
MCH	: -	4.4	pg	5.2 - 8.0
MCHC	:	28.3	g/dl	28.0 - 42.0
RDW	: +	19.5		8.0 - 12.0
RRg	:	0.0		
Hb	: -	4.6	g/dl	8.0 - 12.0
THR	:	229	m/mm3	200 - 600
MPV	:	5.5	fl	4.0 - 9.0
Pct	:	0.13	%	
PDW	: -	5.7		6.0 - 10.0

WBC HISTOGRAM



RBC HISTOGRAM

THR HISTOGRAM



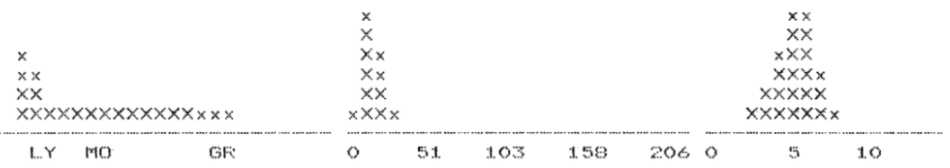
STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 2:21PM Sq : 0005

BANK : Goat
FILE : 20181123-SG7
PATIENT : 07
COMMENT :

HEMATOLOGY				Normal Range	
WBC	:@+	16.14	m/mm3	4.0 -	13.0
Lym.	:L-	44.4	%	50.0 -	70.0
Mon.	:L+	5.0	%	1.0 -	4.0
Gra.	:L	50.6	%	30.0 -	56.0
Lym#	:L-	7.16	m/mm3	2.0 -	9.1
Mon#	:L+	0.80	m/mm3	0.0 -	0.5
Gra#	:L	8.18	m/mm3	1.2 -	7.2
RBC	:&	9.52	M/mm3	8.0 -	18.0
MCV	:	19.4	fl	16.0 -	25.0
Hct	: -	18.4	%	22.0 -	39.0
MCH	:	6.3	pg	5.2 -	8.0
MCHC	:	32.6	g/dl	28.0 -	42.0
RDW	: +	17.2		8.0 -	12.0
RRg	:	0.0			
Hb	: -	6.0	g/dl	8.0 -	12.0
THR	:&	231	m/mm3	200	- 600
MPV	:	5.6	fl	4.0 -	9.0
Pct	:	0.13	%		
PDW	: -	4.3		6.0 -	10.0

WBC HISTOGRAM RBC HISTOGRAM THR HISTOGRAM



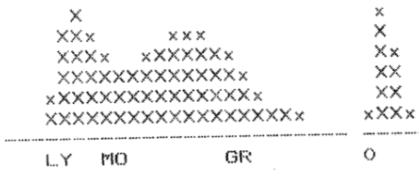
STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 2:48PM Sq : 0011

BANK : Goat
FILE : 20181123-S08
PATIENT : 08
COMMENT :

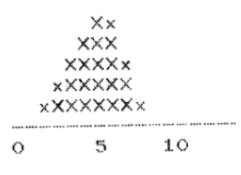
HEMATOLOGY				Normal Range
WBC	:	10.26	m/mm3	4.0 - 13.0
Lym.	: -	28.0	%	50.0 - 70.0
Mon.	:	3.9	%	1.0 - 4.0
Gra.	: +	68.1	%	30.0 - 56.0
Lym#	: -	2.87	m/mm3	2.0 - 9.1
Mon#	:	0.40	m/mm3	0.0 - 0.5
Gra#	: +	6.99	m/mm3	1.2 - 7.2
RBC	:	11.59	M/mm3	8.0 - 18.0
MCV	: -	15.0	fl	16.0 - 25.0
Hct	: -	17.3	%	22.0 - 39.0
MCH	: -	4.5	pg	5.2 - 8.0
MCHC	:	30.6	g/dl	28.0 - 42.0
RDW	: +	18.0		8.0 - 12.0
RRg	:	0.0		
Hb	: -	5.3	g/dl	8.0 - 12.0
THR	:	267	m/mm3	200 - 600
MPV	:	5.4	fl	4.0 - 9.0
Pct	:	0.14	%	
PDW	: -	5.6		6.0 - 10.0

WBC HISTOGRAM



RBC HISTOGRAM

THR HISTOGRAM



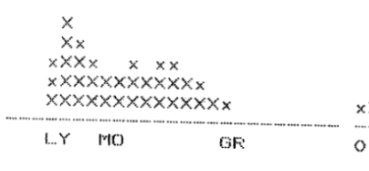
STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 2:50PM Sq : 0012

BANK : Goat
FILE : 20181123-S09
PATIENT : 09
COMMENT :

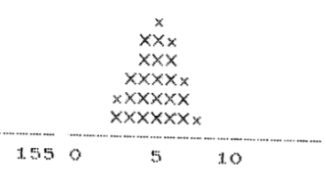
HEMATOLOGY				Normal Range
WBC	:	8.59	m/mm3	4.0 - 13.0
Lym.	: -	41.1	%	50.0 - 70.0
Mon.	: +	4.6	%	1.0 - 4.0
Gra.	:	54.3	%	30.0 - 56.0
Lym#	: -	3.53	m/mm3	2.0 - 9.1
Mon#	: +	0.39	m/mm3	0.0 - 0.5
Gra#	:	4.67	m/mm3	1.2 - 7.2
RBC	:	11.51	M/mm3	8.0 - 18.0
MCV	: -	15.2	fl	16.0 - 25.0
Hct	: -	17.4	%	22.0 - 39.0
MCH	: -	4.4	pg	5.2 - 8.0
MCHC	:	29.3	g/dl	28.0 - 42.0
RDW	: +	17.2		8.0 - 12.0
RRg	:	0.0		
Hb	: -	5.1	g/dl	8.0 - 12.0
THR	:	275	m/mm3	200 - 600
MPV	:	5.4	fl	4.0 - 9.0
Pct	:	0.15	%	
PDW	: -	5.5		6.0 - 10.0

WBC HISTOGRAM



RBC HISTOGRAM

THR HISTOGRAM



STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 2:53PM Sq : 0013

BANK : Goat
FILE : 20181123-S010
PATIENT : 10
COMMENT :

HEMATOLOGY				Normal Range	
WBC	:R	9.01	m/mm3	4.0 -	13.0
Lym.	:L-	38.2	%	50.0 -	70.0
Mon.	:L	2.7	%	1.0 -	4.0
Gra.	:L+	59.1	%	30.0 -	56.0
Lym#	:L-	3.44	m/mm3	2.0 -	9.1
Mon#	:L	0.24	m/mm3	0.0 -	0.5
Gra#	:L+	5.33	m/mm3	1.2 -	7.2
RBC	:	14.21	M/mm3	8.0 -	18.0
MCV	:	16.5	fl	16.0 -	25.0
Hct	:	23.4	%	22.0 -	39.0
MCH	: -	4.7	pg	5.2 -	8.0
MCHC	:	28.6	g/dl	28.0 -	42.0
RDW	: +	17.3		8.0 -	12.0
RRg	:	0.0			
Hb	: -	6.7	g/dl	8.0 -	12.0
THR	:	293	m/mm3	200 -	600
MPV	:	5.5	fl	4.0 -	9.0
Pct	:	0.16	%		
PDW	: -	4.1		6.0 -	10.0

WBC HISTOGRAM RBC HISTOGRAM THR HISTOGRAM

STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 2:57PM Sq : 0014

BANK : Goat
FILE : 20181123-SG11
PATIENT : 11
COMMENT :

HEMATOLOGY				Normal Range
WBC	:	10.81	m/mm3	4.0 - 13.0
Lym.	: -	38.1	%	50.0 - 70.0
Mon.	: +	4.9	%	1.0 - 4.0
Gra.	: +	57.0	%	30.0 - 56.0
Lym#	: -	4.11	m/mm3	2.0 - 9.1
Mon#	: +	0.52	m/mm3	0.0 - 0.5
Gra#	: +	6.18	m/mm3	1.2 - 7.2
RBC	:	14.77	M/mm3	8.0 - 18.0
MCV	: -	15.1	fl	16.0 - 25.0
Hct	:	22.3	%	22.0 - 39.0
MCH	: -	4.4	pg	5.2 - 8.0
MCHC	:	29.5	g/dl	28.0 - 42.0
RDW	: +	18.0		8.0 - 12.0
RRg	:	0.0		
Hb	: -	6.6	g/dl	8.0 - 12.0
THR	:	349	m/mm3	200 - 600
MPV	:	5.3	fl	4.0 - 9.0
Pct	:	0.18	%	
PDW	: -	5.0		6.0 - 10.0

WBC HISTOGRAM RBC HISTOGRAM THR HISTOGRAM

STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

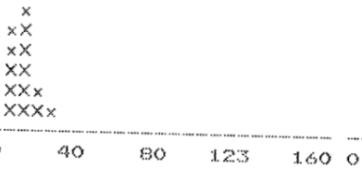
Nov. Fri 23,2018 2:59PM Sq : 0015

BANK : Goat
FILE : 20181123-SG12
PATIENT : 12
COMMENT :

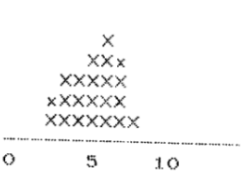
HEMATOLOGY				Normal Range
WBC	:	11.48	m/mm3	4.0 - 13.0
Lym.	: -	27.7	%	50.0 - 70.0
Mon.	:	3.2	%	1.0 - 4.0
Gra.	: +	69.1	%	30.0 - 56.0
Lym#	: -	3.17	m/mm3	2.0 - 9.1
Mon#	:	0.36	m/mm3	0.0 - 0.5
Gra#	: +	7.95	m/mm3	1.2 - 7.2
RBC	:	11.33	M/mm3	8.0 - 18.0
MCV	:	17.6	fl	16.0 - 25.0
Hct	: -	19.9	%	22.0 - 39.0
MCH	: -	4.7	pg	5.2 - 8.0
MCHC	: -	27.1	g/dl	28.0 - 42.0
RDW	: +	16.0		8.0 - 12.0
RRg	:	0.0		
Hb	: -	5.4	g/dl	8.0 - 12.0
THR	: -	165	m/mm3	200 - 600
MPV	:	5.6	fl	4.0 - 9.0
Pct	:	0.09	%	
PDW	:	6.0		6.0 - 10.0

WBC HISTOGRAM

RBC HISTOGRAM



THR HISTOGRAM



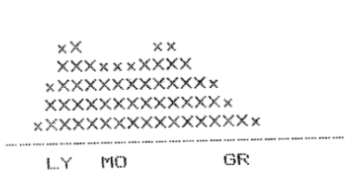
STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 3:03PM Sq : 0016

BANK : Goat
FILE : 20181123-SG13
PATIENT : 13
COMMENT :

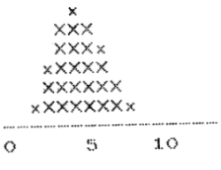
HEMATOLOGY				Normal Range
WBC	:	12.28	m/mm3	4.0 - 13.0
Lym.	: -	30.7	%	50.0 - 70.0
Mon.	: +	4.6	%	1.0 - 4.0
Gra.	: +	64.7	%	30.0 - 56.0
Lym#	: -	3.76	m/mm3	2.0 - 9.1
Mon#	: +	0.56	m/mm3	0.0 - 0.5
Gra#	: +	7.96	m/mm3	1.2 - 7.2
RBC	:	9.89	M/mm3	8.0 - 18.0
MCV	:	19.2	fl	16.0 - 25.0
Hct	: -	18.9	%	22.0 - 39.0
MCH	:	5.4	pg	5.2 - 8.0
MCHC	:	28.5	g/dl	28.0 - 42.0
RDW	: +	19.9		8.0 - 12.0
RRg	:	0.0		
Hb	: -	5.4	g/dl	8.0 - 12.0
THR	:	374	m/mm3	200 - 600
MPV	:	5.1	fl	4.0 - 9.0
Pct	:	0.19	%	
PDW	:	6.7		6.0 - 10.0

WBC HISTOGRAM



RBC HISTOGRAM

THR HISTOGRAM



STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 3:05PM Sq : 0017

BANK : Goat
FILE : 20181123-SG14
PATIENT : 14
COMMENT :

HEMATOLOGY				Normal Range	
WBC	:	11.14	m/mm3	4.0 -	13.0
Lym.	: -	19.8	%	50.0 -	70.0
Mon.	:	3.5	%	1.0 -	4.0
Gra.	: +	76.7	%	30.0 -	56.0
Lym#	: -	2.20	m/mm3	2.0 -	9.1
Mon#	:	0.38	m/mm3	0.0 -	0.5
Gra#	: +	8.56	m/mm3	1.2 -	7.2
RBC	: -	5.30	M/mm3	8.0 -	18.0
MCV	: -	14.8	fl	16.0 -	25.0
Hct	: -	7.8	%	22.0 -	39.0
MCH	: -	4.1	pg	5.2 -	8.0
MCHC	:	28.2	g/dl	28.0 -	42.0
RDW	: +	21.3		8.0 -	12.0
RRg	:	0.0			
Hb	: -	2.2	g/dl	8.0 -	12.0
THR	:	388	m/mm3	200	- 600
MPV	:	5.2	fl	4.0 -	9.0
Pct	:	0.20	%		
PDW	: -	5.1		6.0 -	10.0

WBC HISTOGRAM RBC HISTOGRAM THR HISTOGRAM

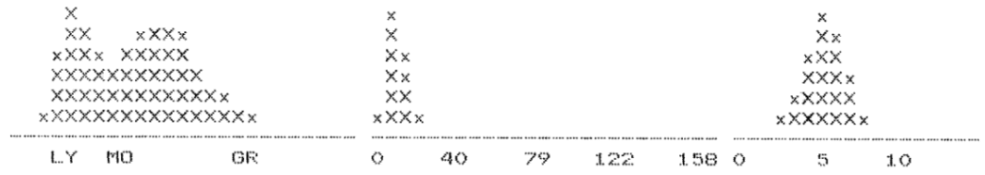
STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 3:08PM Sq : 0018

BANK : Goat
FILE : 20181123-SG15
PATIENT : 15
COMMENT :

HEMATOLOGY				Normal Range
WBC	:	11.43	m/mm3	4.0 - 13.0
Lym.	: -	37.0	%	50.0 - 70.0
Mon.	:	4.0	%	1.0 - 4.0
Gra.	: +	59.0	%	30.0 - 56.0
Lym#	: -	4.22	m/mm3	2.0 - 9.1
Mon#	:	0.45	m/mm3	0.0 - 0.5
Gra#	: +	6.76	m/mm3	1.2 - 7.2
RBC	:	11.19	M/mm3	8.0 - 18.0
MCV	: -	14.9	fl	16.0 - 25.0
Hct	: -	16.6	%	22.0 - 39.0
MCH	: -	4.8	pg	5.2 - 8.0
MCHC	:	32.5	g/dl	28.0 - 42.0
RDW	: +	18.0		8.0 - 12.0
RRg	:	0.0		
Hb	: -	5.4	g/dl	8.0 - 12.0
THR	:	226	m/mm3	200 - 600
MPV	:	5.7	fl	4.0 - 9.0
Pct	:	0.13	%	
PDW	: -	3.5		6.0 - 10.0

WBC HISTOGRAM RBC HISTOGRAM THR HISTOGRAM



STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

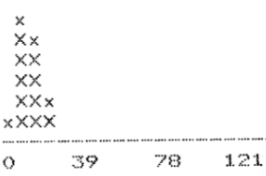
Nov. Fri 23,2018 3:11PM Sq : 0019

BANK : Goat
FILE : 20181123-SG16
PATIENT : 16
COMMENT :

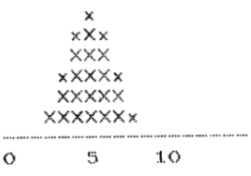
HEMATOLOGY				Normal Range
WBC	:	10.70	m/mm3	4.0 - 13.0
Lym.	:M-	33.7	%	50.0 - 70.0
Mon.	:M+	5.1	%	1.0 - 4.0
Gra.	:M+	61.2	%	30.0 - 56.0
Lym#	:M-	3.60	m/mm3	2.0 - 9.1
Mon#	:M+	0.54	m/mm3	0.0 - 0.5
Gra#	:M+	6.56	m/mm3	1.2 - 7.2
RBC	:	10.74	M/mm3	8.0 - 18.0
MCV	:	16.0	fl	16.0 - 25.0
Hct	: -	17.1	%	22.0 - 39.0
MCH	: -	4.7	pg	5.2 - 8.0
MCHC	:	29.8	g/dl	28.0 - 42.0
RDW	: +	18.7		8.0 - 12.0
RRg	:	0.0		
Hb	: -	5.1	g/dl	8.0 - 12.0
THR	:	268	m/mm3	200 - 600
MPV	:	5.5	fl	4.0 - 9.0
Pct	:	0.15	%	
PDW	: -	4.2		6.0 - 10.0

WBC HISTOGRAM

RBC HISTOGRAM



THR HISTOGRAM



STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 3:14PM Sq : 0020

BANK : Goat
FILE : 20181123-SG17
PATIENT : 17
COMMENT :

HEMATOLOGY				Normal Range
WBC	:	9.30	m/mm3	4.0 - 13.0
Lym.	: -	30.0	%	50.0 - 70.0
Mon.	: +	4.3	%	1.0 - 4.0
Gra.	: +	65.7	%	30.0 - 56.0
Lym#	: -	2.79	m/mm3	2.0 - 9.1
Mon#	: +	0.39	m/mm3	0.0 - 0.5
Gra#	: +	6.12	m/mm3	1.2 - 7.2
RBC	:	11.17	M/mm3	8.0 - 18.0
MCV	:	19.0	fl	16.0 - 25.0
Hct	: -	21.2	%	22.0 - 39.0
MCH	:	5.2	pg	5.2 - 8.0
MCHC	: -	27.8	g/dl	28.0 - 42.0
RDW	: +	16.1		8.0 - 12.0
RRg	:	0.0		
Hb	: -	5.9	g/dl	8.0 - 12.0
THR	:	222	m/mm3	200 - 600
MPV	:	5.3	fl	4.0 - 9.0
Pct	:	0.12	%	
PDW	:	7.2		6.0 - 10.0

WBC HISTOGRAM RBC HISTOGRAM THR HISTOGRAM

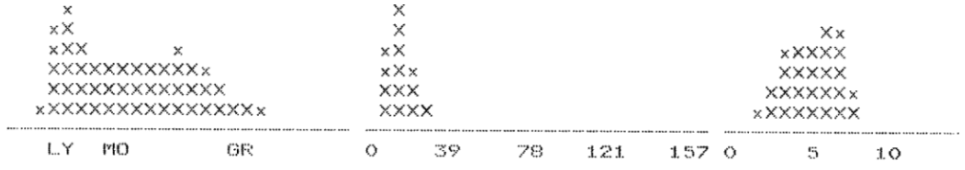
STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Fri 23,2018 3:17PM Sq : 0021

BANK : Goat
FILE : 20181123-S018
PATIENT : 18
COMMENT :

HEMATOLOGY				Normal Range	
WBC	: +	15.24	m/mm3	4.0 -	13.0
Lym.	: -	39.0	%	50.0 -	70.0
Mon.	: +	4.3	%	1.0 -	4.0
Gra.	: +	56.7	%	30.0 -	56.0
Lym#	: -	5.94	m/mm3	2.0 -	9.1
Mon#	: +	0.65	m/mm3	0.0 -	0.5
Gra#	: +	8.65	m/mm3	1.2 -	7.2
RBC	:	9.11	M/mm3	8.0 -	18.0
MCV	:	19.1	fl	16.0 -	25.0
Hct	: -	17.4	%	22.0 -	39.0
MCH	:	6.2	pg	5.2 -	8.0
MCHC	:	32.7	g/dl	28.0 -	42.0
RDW	: +	16.1		8.0 -	12.0
RRg	:	0.0			
Hb	: -	5.7	g/dl	8.0 -	12.0
THR	: -	114	m/mm3	200 -	600
MPV	:	5.6	fl	4.0 -	9.0
Pct	:	0.06	%		
PDW	:	6.9		6.0 -	10.0

WBC HISTOGRAM RBC HISTOGRAM THR HISTOGRAM



STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

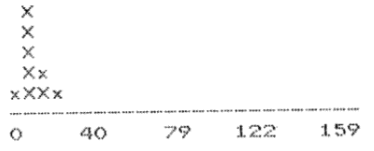
Nov. Sun 25,2018 1:34PM Sq : 0024

BANK : Goat
FILE : 20181125-S019
PATIENT : 19
COMMENT :

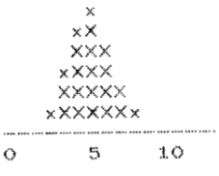
HEMATOLOGY				Normal Range
WBC	: +	15.49	m/mm3	4.0 - 13.0
Lym.	:M-	38.8	%	50.0 - 70.0
Mon.	:M+	5.1	%	1.0 - 4.0
Gra.	:M+	56.1	%	30.0 - 56.0
Lym#	:M-	6.01	m/mm3	2.0 - 9.1
Mon#	:M+	0.78	m/mm3	0.0 - 0.5
Gra#	:M+	8.70	m/mm3	1.2 - 7.2
RBC	:	17.15	M/mm3	8.0 - 18.0
MCV	: -	13.7	fl	16.0 - 25.0
Hct	:	23.4	%	22.0 - 39.0
MCH	: -	4.4	pg	5.2 - 8.0
MCHC	:	32.4	g/dl	28.0 - 42.0
RDW	: +	16.2		8.0 - 12.0
RRg	:	0.0		
Hb	: -	7.6	g/dl	8.0 - 12.0
THR	:	475	m/mm3	200 - 600
MPV	:	5.5	fl	4.0 - 9.0
Pct	:	0.26	%	
PDW	: -	3.9		6.0 - 10.0

WBC HISTOGRAM

RBC HISTOGRAM



THR HISTOGRAM



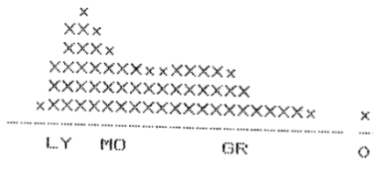
STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Sun 25,2018 1:37PM Sq : 0025

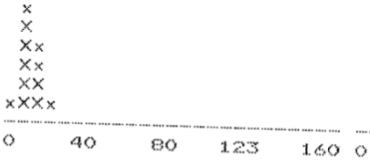
BANK : Goat
FILE : 20181125-SG20
PATIENT : 20
COMMENT :

HEMATOLOGY				Normal Range
WBC	:&	10.38	m/mm3	4.0 - 13.0
Lym.	: -	34.9	%	50.0 - 70.0
Mon.	: +	4.5	%	1.0 - 4.0
Gra.	: +	60.6	%	30.0 - 56.0
Lym#	: -	3.62	m/mm3	2.0 - 9.1
Mon#	: +	0.46	m/mm3	0.0 - 0.5
Gra#	: +	6.30	m/mm3	1.2 - 7.2
RBC	:	15.36	M/mm3	8.0 - 18.0
MCV	: -	15.1	fl	16.0 - 25.0
Hct	:	23.1	%	22.0 - 39.0
MCH	: -	4.6	pg	5.2 - 8.0
MCHC	:	31.1	g/dl	28.0 - 42.0
RDW	: +	18.0		8.0 - 12.0
RRg	:	0.0		
Hb	: -	7.2	g/dl	8.0 - 12.0
THR	:	282	m/mm3	200 - 600
MPV	:	5.5	fl	4.0 - 9.0
Pct	:	0.16	%	
PDW	: -	4.7		6.0 - 10.0

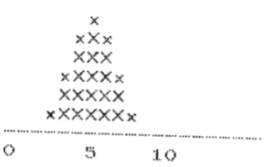
WBC HISTOGRAM



RBC HISTOGRAM



THR HISTOGRAM



STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Sun 25,2018 1:40PM

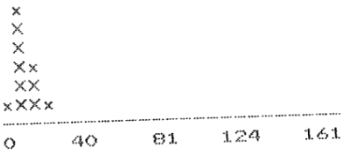
Sq : 0026

BANK : Goat
FILE : 20181125-SG21
PATIENT : 21
COMMENT :

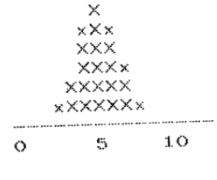
HEMATOLOGY				Normal Range	
WBC	:@+	23.88	m/mm3	4.0 -	13.0
Lym.	:L-	40.8	%	50.0 -	70.0
Mon.	:L	1.8	%	1.0 -	4.0
Gra.	:L+	57.4	%	30.0 -	56.0
Lym#	:L-	9.74	m/mm3	2.0 -	9.1
Mon#	:L	0.42	m/mm3	0.0 -	0.5
Gra#	:L+	13.72	m/mm3	1.2 -	7.2
RBC	: +	20.02	M/mm3	8.0 -	18.0
MCV	: -	15.2	fl	16.0 -	25.0
Hct	:	30.4	%	22.0 -	39.0
MCH	: -	5.0	pg	5.2 -	8.0
MCHC	:	33.5	g/dl	28.0 -	42.0
RDW	: +	17.2		8.0 -	12.0
RRg	:	0.0			
Hb	:	10.2	g/dl	8.0 -	12.0
THR	:	274	m/mm3	200 -	600
MPV	:	5.6	fl	4.0 -	9.0
Pct	:	0.15	%		
PDW	: -	3.7		6.0 -	10.0

WBC HISTOGRAM

RBC HISTOGRAM



THR HISTOGRAM



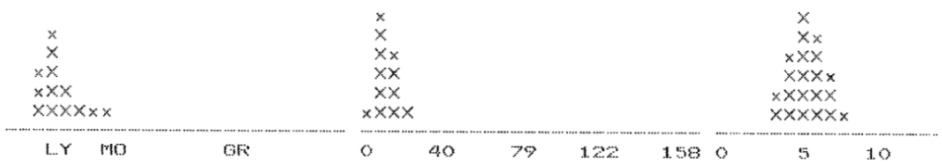
STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Sun 25,2018 1:43PM Sq : 0027

BANK : Goat
FILE : 20181125-SG22
PATIENT : 22
COMMENT :

HEMATOLOGY				Normal Range
WBC	:R+	39.43	m/mm3	4.0 - 13.0
Lym.	:L+	74.7	%	50.0 - 70.0
Mon.	:L	2.4	%	1.0 - 4.0
Gra.	:L-	22.9	%	30.0 - 56.0
Lym#	:L+	29.45	m/mm3	2.0 - 9.1
Mon#	:L	0.94	m/mm3	0.0 - 0.5
Gra#	:L-	9.04	m/mm3	1.2 - 7.2
RBC	:	17.69	M/mm3	8.0 - 18.0
MCV	: -	15.5	fl	16.0 - 25.0
Hct	:	27.4	%	22.0 - 39.0
MCH	: -	5.1	pg	5.2 - 8.0
MCHC	:	33.2	g/dl	28.0 - 42.0
RDW	: +	18.0		8.0 - 12.0
RRg	:	0.0		
Hb	:	9.1	g/dl	8.0 - 12.0
THR	:	236	m/mm3	200 - 600
MPV	:	5.8	fl	4.0 - 9.0
Pct	:	0.14	%	
PDW	: -	3.6		6.0 - 10.0

WBC HISTOGRAM RBC HISTOGRAM THR HISTOGRAM



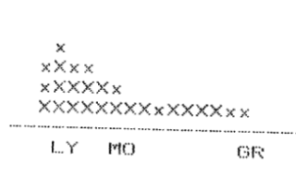
STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

Nov. Sun 25,2018 1:46PM Sq : 0028

BANK : Goat
FILE : 20181125-S023
PATIENT : 23
COMMENT :

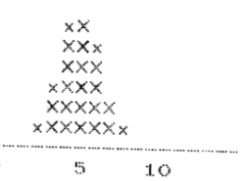
HEMATOLOGY				Normal Range	
WBC	:@+	16.82	m/mm3	4.0 -	13.0
Lym.	:	58.0	%	50.0 -	70.0
Mon.	: +	4.8	%	1.0 -	4.0
Gra.	:	37.2	%	30.0 -	56.0
Lym#	:	9.75	m/mm3	2.0 -	9.1
Mon#	: +	0.80	m/mm3	0.0 -	0.5
Gra#	:	6.27	m/mm3	1.2 -	7.2
RBC	:	18.03	M/mm3	8.0 -	18.0
MCV	: -	14.2	fl	16.0 -	25.0
Hct	:	25.6	%	22.0 -	39.0
MCH	: -	4.6	pg	5.2 -	8.0
MCHC	:	32.8	g/dl	28.0 -	42.0
RDW	: +	17.1		8.0 -	12.0
RRg	:	0.0			
Hb	:	8.4	g/dl	8.0 -	12.0
THR	:	406	m/mm3	200	- 600
MPV	:	5.5	fl	4.0 -	9.0
Pct	:	0.22	%		
PDW	: -	3.9		6.0 -	10.0

WBC HISTOGRAM



RBC HISTOGRAM

THR HISTOGRAM



STATE DEPARTMENT OF LIVESTOCK
DIRECTORATE OF VETERINARY SERVICES
RVIL KARATINA BOX 402-10101 KRT
TEL-0614572721/0202083169

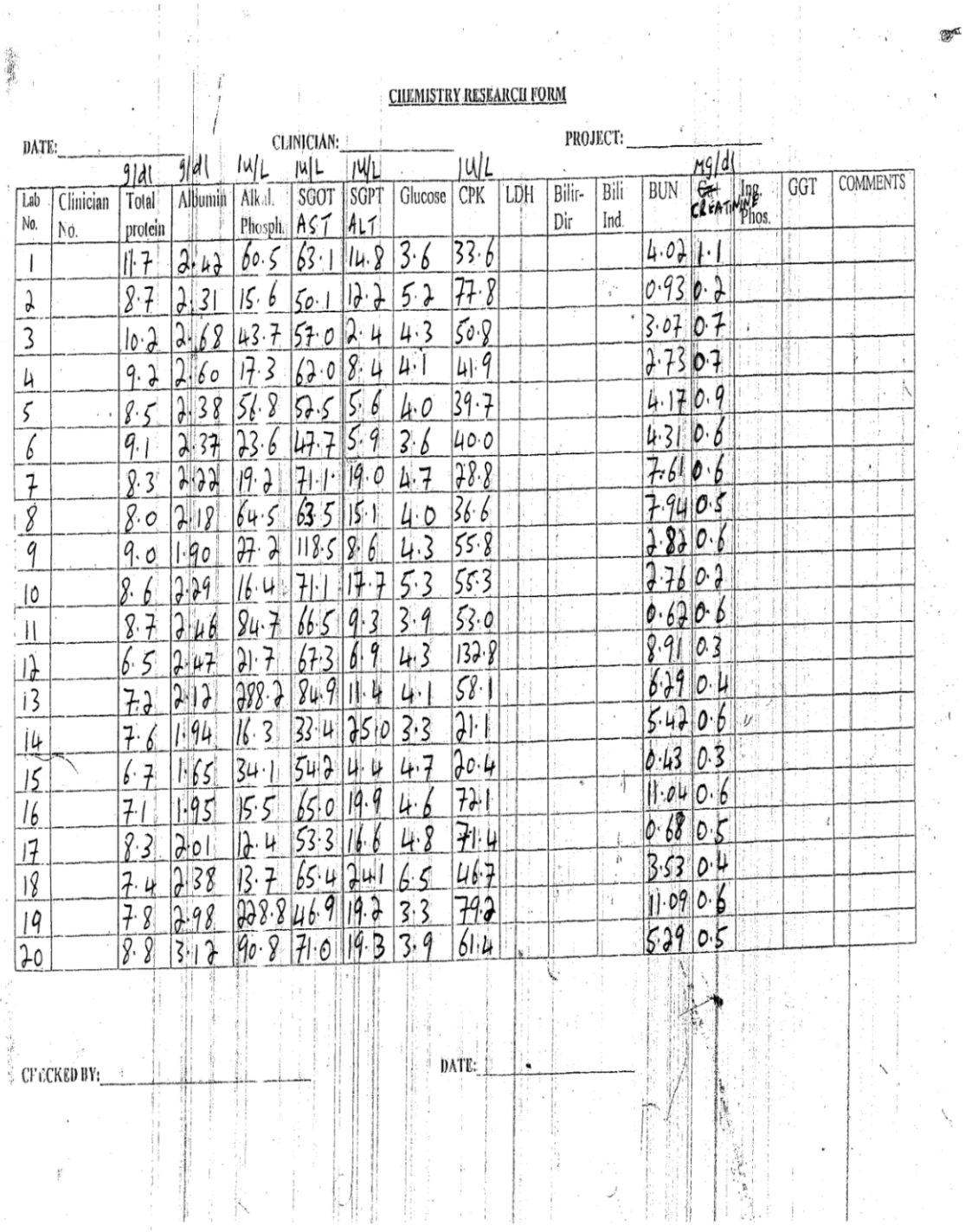
Nov. Sun 25,2018 1:49PM Sq : 0029

BANK : Goat
FILE : 20181125-SG24
PATIENT : 24
COMMENT :

HEMATOLOGY				Normal Range	
WBC	:	10.89	m/mm3	4.0 -	13.0
Lym.	: -	47.2	%	50.0 -	70.0
Mon.	: +	4.8	%	1.0 -	4.0
Gra.	:	48.0	%	30.0 -	56.0
Lym#	: -	5.14	m/mm3	2.0 -	9.1
Mon#	: +	0.52	m/mm3	0.0 -	0.5
Gra#	:	5.23	m/mm3	1.2 -	7.2
RBC	:	16.32	M/mm3	8.0 -	18.0
MCV	: -	15.1	fl	16.0 -	25.0
Hct	:	24.6	%	22.0 -	39.0
MCH	: -	4.7	pg	5.2 -	8.0
MCHC	:	31.3	g/dl	28.0 -	42.0
RDW	: +	17.2		8.0 -	12.0
RRg	:	0.0			
Hb	: -	7.7	g/dl	8.0 -	12.0
THR	:	271	m/mm3	200 -	600
MPV	:	5.6	fl	4.0 -	9.0
Pct	:	0.15	%		
PDW	: -	4.1		6.0 -	10.0

WBC HISTOGRAM RBC HISTOGRAM THR HISTOGRAM

Appendix 8: Individual goat biochemical changes



CHEMISTRY RESEARCH FORM

DATE: _____ CLINICIAN: _____ PROJECT: _____

		g/dl	g/dl	IU/L	IU/L	IU/L		IU/L				mg/dl				
Lab No.	Clinician No.	Total protein	Albumin	Alk. Phosph.	SGOT AST	SGPT ALT	Glucose	CPK	LDH	Bilir-Dir	Bili Ind.	BUN	~~Cr~~ CREATININE	Ing. Phos.	GGT	COMMENTS
1		11.7	2.42	60.5	63.1	14.8	3.6	33.6				4.02	1.1			
2		8.7	2.31	15.6	50.1	12.2	5.2	77.8				0.93	0.2			
3		10.2	2.68	43.7	57.0	2.4	4.3	50.8				3.07	0.7			
4		9.2	2.60	17.3	62.0	8.4	4.1	41.9				2.73	0.7			
5		8.5	2.38	56.8	52.5	5.6	4.0	39.7				4.17	0.9			
6		9.1	2.37	23.6	47.7	5.9	3.6	40.0				4.31	0.6			
7		8.3	2.22	19.2	71.1	19.0	4.7	28.8				7.61	0.6			
8		8.0	2.18	64.5	63.5	15.1	4.0	36.6				7.94	0.5			
9		9.0	1.90	27.2	118.5	8.6	4.3	55.8				2.82	0.6			
10		8.6	2.29	16.4	71.1	17.7	5.3	55.3				2.76	0.2			
11		8.7	2.46	84.7	66.5	9.3	3.9	53.0				0.67	0.6			
12		6.5	2.47	21.7	67.3	6.9	4.3	132.8				8.91	0.3			
13		7.2	2.12	288.2	84.9	11.4	4.1	58.1				6.29	0.4			
14		7.6	1.94	16.3	33.4	2510	3.3	21.1				5.42	0.6			
15		6.7	1.65	34.1	542	4.4	4.7	20.4				0.43	0.3			
16		7.1	1.95	15.5	65.0	19.9	4.6	72.1				11.04	0.6			
17		8.3	2.01	12.4	53.3	16.6	4.8	71.4				0.68	0.5			
18		7.4	2.38	13.7	65.4	241	6.5	46.7				3.53	0.4			
19		7.8	2.98	228.8	46.9	19.2	3.3	79.2				11.09	0.6			
20		8.8	3.12	90.8	71.0	19.3	3.9	61.4				5.29	0.5			

CHECKED BY: _____ DATE: _____

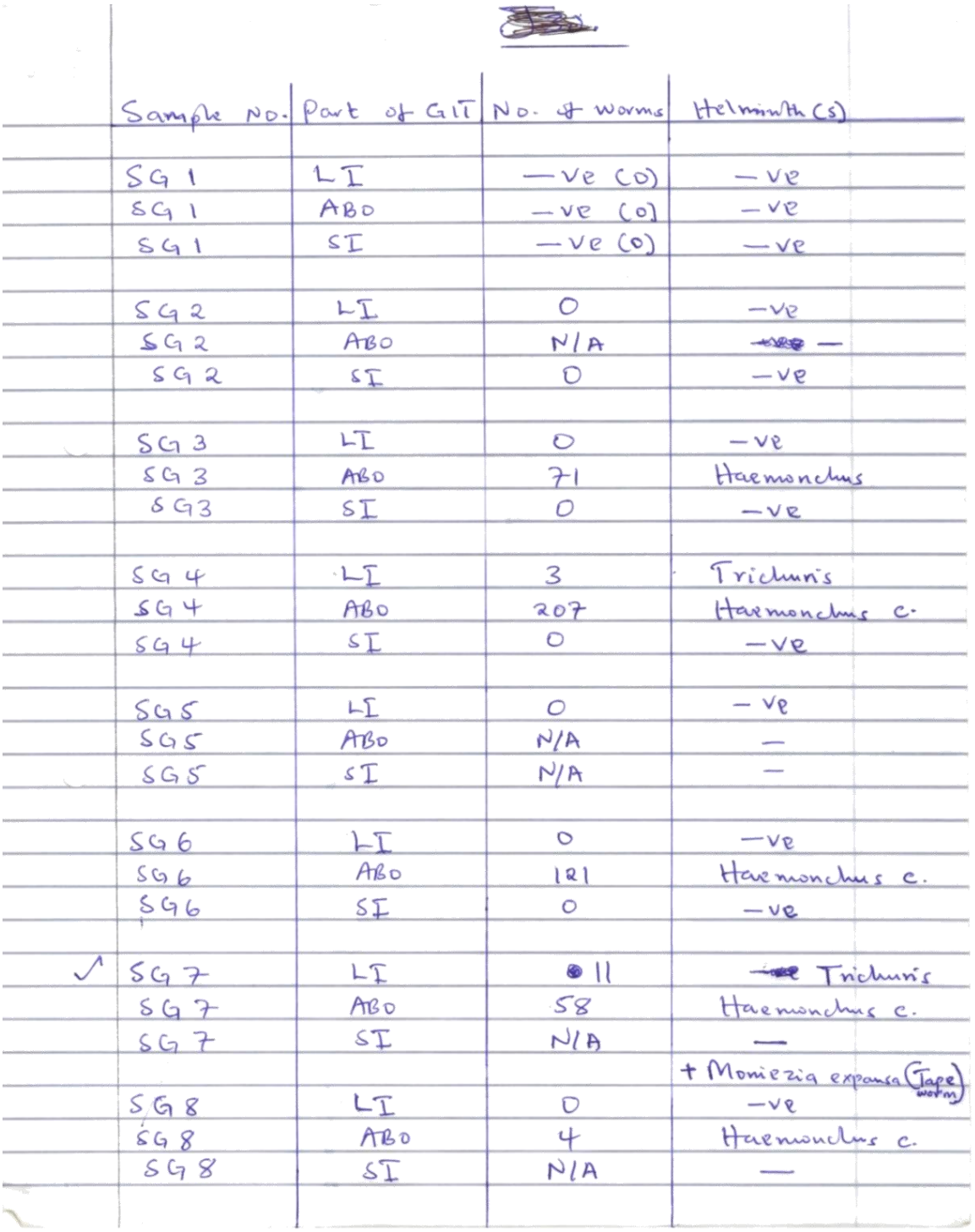
CHEMISTRY RESEARCH FORM

DATE:_____ CLINICIAN:_____ PROJECT:_____

Lab No.	Clinician No.	Total protein	Albumin	Alkal. Phosph.	SGOT AST	SGPT ALT	Glucose	CPK	LDH	Bilir-Dir	Bili Ind.	BUN	~~Cr~~ CREATININE	Ing. Phos.	GGT	COMMENTS
21		11.0	2.91	108.5	71.1	26.9	3.8	91.0				5.01	0.6			
22		7.0	3.11	104.8	70.7	34.0	3.2	115.7				5.08	0.5			
23		8.1	3.38	127.2	62.9	23.8	4.0	89.4				6.45	0.5			
24		8.1	3.36	211.9	90.6	28.5	4.1	118.0				4.54	0.7			

CHECKED BY:_____ DATE:_____

Appendix 9: Individual goat Worm Count Results



Sample No.	Part of GIT	No. of worms	Helminth(s)
SG 1	LI	—ve (0)	—ve
SG 1	ABO	—ve (0)	—ve
SG 1	SI	—ve (0)	—ve
SG 2	LI	0	—ve
SG 2	ABO	N/A	—
SG 2	SI	0	—ve
SG 3	LI	0	—ve
SG 3	ABO	71	Haemonchus
SG3	SI	0	—ve
SG 4	LI	3	Trichuris
SG 4	ABO	207	Haemonchus c.
SG 4	SI	0	—ve
SG 5	LI	0	—ve
SG 5	ABO	N/A	—
SG 5	SI	N/A	—
SG 6	LI	0	—ve
SG 6	ABO	121	Haemonchus c.
SG 6	SI	0	—ve
✓ SG 7	LI	11	Trichuris
SG 7	ABO	58	Haemonchus c.
SG 7	SI	N/A	—
			+ Moniezia expansa (Tape worm)
SG 8	LI	0	—ve
SG 8	ABO	4	Haemonchus c.
SG 8	SI	N/A	—

Sample No.	Part of GIT	No. of worms	Helminth (s)
SG 9	LI	1	Oesophagostomum c.
SG 9	ABO	53	Haemonchus c.
SG 9	SI	0	-ve
SG 10	LI	0	-ve
SG 10	ABO	87	Haemonchus c.
SG 10	SI	0	-ve
SG 11	LI	5	Oesophagostomum c.
SG 11	ABO	68	Haemonchus c.
SG 11	SI	0	-ve
SG 13	LI	17	Trichuris
SG 13	ABO	N/A	—
SG 13	SI	N/A	—
SG 14	LI	N/A	—
SG 14	ABO	Over 200	Haemonchus c.
SG 14	SI	N/A	—
SG 15	LI	0	-ve
SG 15	ABO	67	Haemonchus c.
SG 15	SI	0	-ve
SG 16	LI	53	Trichuris
SG 16	ABO	N/A	0
SG 16	SI	N/A	0
SG 17	LI	21	Oesophagostomum c.
SG 17	ABO	96	Haemonchus c.
SG 17	SI	N/A	—

Sample No.	Part of GIT	No. of worms	Helminth(s)
SG 18	LI	6	Trichuris
SG 18	ABO	18	Haemonchus c.
SG 18	SI	N/A	—
SG 19	LI	N/A	—
SG 19	ABO	178	Haemonchus c.
SG 19	SI	0	-ve
SG 20	LI	0	-ve
SG 20	ABO	193	Haemonchus c.
SG 20	SI	0	-ve
SG 21	LI	0	-ve
SG 21	ABO	0	-ve
SG 21	SI	0	-ve
SG 22	LI	3	Oesophagostomum c.
SG 22	ABO	153	Haemonchus c.
SG22	SI	0	-ve
SG 23	LI	2	Oesophagostomum c.
SG 23	ABO	29	Haemonchus c.
SG 23	SI	0	-ve
SG 24	LI	0	-ve
SG 24	ABO	113	Haemonchus c.
SG 24	SI	0	-ve
SG 12	LI	0	-ve
SG 12	ABO	11	Haemonchus c.
SG 12	SI	0	-ve