SERO-PREVALENCE OF PESTES DES PETIT RUMINANTS AND OCCURRENCE OF CAMEL SUDDEN DEATH IN SELECTED COUNTIES IN KENYA

A THESIS SUBMITTED TO THE UNIVERSITY OF NAIROBI IN PARTIAL FULFILLMENT OF REQUIREMENTS OF THE MASTER OF SCIENCE DEGREE IN APPLIED MICROBIOLOGY (VIROLOGY OPTION)

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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 goes to my family, I truly appreciate you for all the support and encouragement. You have molded me into the person I am today. I will forever be indebted to you. May God richly bless you.

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List of Abbreviations

AGDT- Agar Gel Diffusion Test

ASALs – Arid and Semi-Arid Lands

c-ELISA- Competitive Enzyme linked immuno absorbent assay

CIEP- Counter immunoelectrophoresis

CPE- Cytopathic effects

CSD- Camel Sudden Death

ELISA- Enzyme linked immuno absorbent assay

KALRO- Kenya Agricultural and Livestock Research Organization

KCA- Kenya Camel Association

OIE- Organizational International Epizootic

PPR- Peste des Petits Ruminants

PPRV- Peste des Petits Ruminants Virus

RPLRP- Regional Pastoral Livelihood Resilience Project

RT-PCR- Reverse Transcriptase Polymerase Chain Reaction

ABSTRACT

Camels are significant livestock species largely kept by pastoral communities to support their socio-economic needs. Peste des petit ruminants (PPR) disease is thought to be of great economic impact, and mainly known to affect sheep and goats. Recent serological surveys have detected Peste des petit ruminants' virus (PPRV) antibodies in camels in Sudan and Ethiopia. Investigations conducted on fatal disease in camels characterized by sudden death in Sudan and Ethiopia gave positive results for PPR. Cases of Camel sudden death (CSD) outbreak have been reported in Kenya, with the first outbreak reported in 2007. Therefore, in an effort to find out the status of CSD in Kenya, a cross-sectional study was conducted to assess pastoralists' knowledge on CSD and determine previous exposure to PPRV; as the health of livestock and the household and community economic welfare are closely linked in livestock-dependent pastoralists the study was completed by determining the socio-economics of camels in the northern region of Kenya (Isiolo, Marsabit, Wajir and Mandera counties). A total of 36 questionnaires were administered for socio-economics and pastoralists knowledge assessment, and 398 serum samples were collected for serology. The socio-economics issues examined were; household characteristics, livelihood activities, livestock production and benefits, camel and camel product sales and income. The results showed camels were the major source of livelihood and nutrition in the pastoral community. Sale of camel milk and camels were cited to be major benefits derived from camels, 92% and 86% respectively. The study also indicated rising of market price for camel products because of increasing demand for the products.

Issues assessed regarding pastoralists' knowledge included; CSD awareness, Age group and sex of camels affected by CSD and actions taken when camels die of CSD. The results indicated that a significant number of the local pastoralists (89%) in the region were aware of existence of

CSD. The study showed that CSD mostly affected camels less than 2 years old (indicated by 36% of the respondents), followed by 2-4 years old camels (stated by 32% of the respondents). Camels older than 4 years and pregnant ones were the least affected by CSD. CSD affected both males and females, with female camels being the most affected (52%) than the male camels (44%). Most pastoralists (63.3%) reportedly were eating carcasses of camels that died of CSD.

Competitive Enzyme-Linked Immunosorbent Assay (C-ELISA-) technique was used to determine PPR sero-prevalence, using INGEZIM PPR COMPAC, 13.PPR, K3 kit from Spain. The study revealed camels are susceptible to PPRV; the results gave overall sero-prevalence of 3.02% with sero-prevalence by county ranging from 0% to 7%. Sex (P=0.013) and location (P=0.068) by county showed to be significant risk factor for PPR sero-prevalence.

The study established existence of relationship between CSD and PPR; the camel keepers indicated CSD mostly affected camels less than 4 years old which compares with serology findings that adult camels were the least affected compared to middle aged camels and calves.

Presence of PPRV antibodies in camels suggests camels may be involved in the circulation of PPRV and PPR might be possible cause of CSD; therefore, underscoring the need for more research to determine the epidemiological role of camels in a multi-host environment and to confirm causative agent of CSD paying attention to

CHAPTER ONE: INTRODUCTION

1.0 BACKGROUND INFORMATION

Arid and semi-arid lands (ASALs) are estimated to cover 80% of land in Kenya (Kitalya et al, 2002); it is made up of about 12 million (30%) of the country's population. These ASALs are suitably utilized through extensive livestock production, mainly through pastoralism (Behnke and Scoones, 1993). It is projected that Kenya's livestock found in ASALs is over 60% of all livestock (KNBS, 2010). The camel (C*amelus dromedaries*), is an important livestock species exceptionally adapted to hot ASALs and mainly kept by pastoralists (Dowelmadina et al, 2015). Camels are multiuse animals in nomadic pastoral production structures of north eastern, Kenya (Noor, 2013), with the overall purpose of producing milk, meat, provision of transport and social and cultural roles (Kaufman and Binder, 2002).

According to Farah et al. (2007), the World camel population is estimated at 19 M. The immense majority of these (approximately 79%) found in Africa and about 4 million in Asia. Kenya is the third African country with largest camel population (3,091,200 camels). The annual worth of camel meat and milk in Kenya is approximately US$ 11,000,000 (Musinga and Kivolonzi, 2008).

PPR is a disease of great economic impact since it causes great livestock losses (OIE, 2009). It is caused by PPRV, in the family *Paramyxoviridae* and genus *Morbillivirus*, (Balamurugan et al., 2012). PPR primarily affects goats and sheep. The disease is acutely characterized by oral erosions and pneumonia and mortality and morbidity are at 90–100% in naive population of sheep and goats (Munir, 2015). Camels are known to be affected by many diseases. Never-the less, few viral agents are known to inflict diseases in this resilient animal. Although there are

limited data on PPR in camels, some serological studies have indicated that camels are susceptible to the virus. Khalafalla et al (2010) reported positive results for PPR virus with virus isolation in cell culture and Agar gel diffusion test (AGDT) after an outbreak of fatal disease in camels, marked by sudden death in Sudan.

CSD is an emerging disease in camels with unidentified causative agent (Gluecks et al, 2010); it is characterized by collapse, dyspnea and rapid death within 1hour after collapse. It first started in Ethiopia In December 2005 then Somalia in 2006 and in 2007 it was reported in Kenya. The disease mainly affected adult camels, especially lactating and pregnant females, breeding bulls and pack camels (Gluecks et al, 2010). In late 2015 and early 2016 CSD was again reported in the north eastern pastoral regions of Kenya, including, Mandera, Marsabit, Wajir and Isiolo counties. Mortality rates were estimated at 6.8 % and 3.7% for Kenya and Somalia, respectively (Gluecks et al, 2010). Investigations of CSD outbreaks carried out in Ethiopia by Wernery et al. (2006), and in Kenya and Somalia by Gluecks and Younan, (2010) failed to establish any causative agent. An attempted virus isolation and histology results carried out in Kenya indicated involvement of a viral agent (Gluecks et al, 2010). Despite these field and laboratory investigations, the causative agent of CSD is not yet determined and awareness among farmers, clinicians, veterinarians and policymakers also remains limited.

With the positive results for PPR virus with Agar gel diffusion test (AGDT) and Reverse Transcriptase-Polymerase Chain Reaction (RT-PCR) after a fatal disease outbreak in camels, characterized by sudden death in Sudan (Khalafalla et al, 2010); This study, therefore, established previous exposure to PPRV in camels through antibody detection in serum and documents the knowledge of camel keepers in reference to CSD in 4 selected counties in north

eastern, Kenya. Results of this study will contribute in understanding relationship between PPR and CSD and eventually aid in designing the disease management and control policy.

1.1 HYPOTHESIS

1. Camels have no antibodies against Peste des petits ruminants and value chain actors have no knowledge on camel Sudden Death CSD in northern Kenya.

2. There will be no relationship between Peste des petits ruminants and camel Sudden Death

1.2 OBJECTIVES

1.2.1 General objective

1. To investigate PPR Sero-prevalence in Camels and to assess Knowledge, Attitudes and Practices among camel keepers to Camel Sudden Death Syndrome in North-eastern, Kenya

1.2.3 Specific objectives

1. To determine the socio-economic importance of the camel among camel keepers in the study counties
2. To assess knowledge, Attitudes and Practices of camel keepers on camel sudden death in the study counties
3. To estimate PPR sero-prevalence in camels in the study counties

1.3 JUSTIFICATION

Camels in Kenya are significant livelihood assets for wealth creation and food security in the ASALs (Noor, 2013). Camels provide income to the household through sale of meat, milk, hides, riding and tourism which is crucial to pastoral subsistence economy (Njanja, 2007). Despite their significant impact to economy, Camel production is under immense pressure as a result of numerous variations in the production environment (Farah et al. 2004), Diseases being the key factor affecting traditional Camel production. CSD is responsible for marked economic losses in the north eastern pastoral communities of Kenya. Although CSD was first reported in Kenya in 2007, it is has had devastating effects on Camel production and it is not clear what the camel keepers understand about the disease. The etiological agent of the disease is also not yet determined and PPRV is one the suspect. It is, therefore, important to establish the status of CSD and find out camel susceptibility to PPRV through detection of antibodies, this will eventually help in; determining the evolution of the CSD and designing control, management and surveillance policy for the disease.

CHAPTER TWO: LIRTERATURE REVIEW

2.1 Camel production and importance

World's camel population is projected at 19 million (Farah et al., 2007). The vast majority of camel population estimated at about 15 million is found in Africa. In Asia, camel population is estimated to be at 4 million (Farah et al., 2007). The largest population of camel in the World is found in Somalia (over 6 million camels), perhaps representing one-third of all dromedary camels (Farah et al., 2007). Kenya is the third African country with high camel population (3,091,200 camels) (FAOSTAT. 2013). They are normally found in the north-eastern part of Kenya (54%), the former eastern province comprising Marsabit, Moyale and Isiolo Districts (29%), Rift Valley (13%) and coast province (4%).

The dromedary camel in Kenya is a multiuse animal, which is principally kept for meat and milk production (Kaufman and Binder, 2002). The camel is also used for transportation. Its unique physiological, anatomical and ecological adaptations enable the camel to produce milk to pastoral households through the year (Farah, 1996). The species is also an asset to the family or a financial reserve as well as a security against losses such as drought for pastoralists. The camel in Kenya plays a significant role in wealth and social status (Guliye, 2006). The species also provide blood, fibre, leather, urine as disinfectant, and bones for manufacture of jewelry (Guliye, 2006). The numerous changes affecting the ASAL environment has put Camel production under immense pressure (Farah et al. 2004). Diseases, growing human population pressure on pastoral grazing lands and unavailability of veterinary services are aspects badly affecting camel production (Desta and Coppock, 2004).

2.2 Camel sudden death syndrome

2.2.1 Background information

Camel sudden death syndrome (CSD) is a new disease entity in camels with unknown causative agent; the disease presents with no clinical signs, low morbidity and almost 100% case fatality rate in adult camels (Wernery et al. 2006, Dawo 2010). Several names have been given to the disease lately, in reference to its nature of quick onset and short course (Gluecks and Younan, 2010).

Table 1: Disease names given by pastoralists

	Traditional name	**Meaning in English**
Somali	*Babta*	collapsed immediately
Borana	*Habaad*	Bullet
	Maal oo dhaaf	Milk and abandon
Swahili	*Risasi*	Bullet

2.2.2 History

CSD was first reported in Ethiopia in December 2005(Wernery et al. 2006), it was then described in Somalia in 2006 and defined in Kenya in 2007 (Gluecks and Younan, 2010, Dawo 2010). In late 2015 and early 2016 CSD was again reported in the north eastern pastoral regions of Kenya, including, Mandera, Marsabit, Wajir and Isiolo counties.

2.2.3 Epidemiology

Herd mortality of 3.7% and 6.6 % was realized in Somalia and Kenya, respectively (Gluecks and Younan, 2010). The mean number of cases per herd was; 2.0 in Somalia and 6.8 in Kenya. Within herds females are most affected (74% in Somalia and 88% in Kenya), of females affected 41% are lactating females and 59% are dry and pregnant (Gluecks and Younan, 2010). A study by Dawo (2010) found the mean age of affected camels to be 6.5 years. Mostly the camels are found dead in the morning (45%) with no symptoms prior to death (Dawo, 2010).

2.2.4 Clinical signs

In most cases there is no prior clinical course, but some cases show clinical signs before death (Gluecks and Younan, 2010). These signs include; collapse, dyspnea and death; in some cases non-specific prodromal signs are observed in less than 6 hours. Sometimes neurological signs, vocalization and neck extension (in dead camels) are observed (Dawo, 2010).

2.2.5 Pathology

Post mortem findings as described by Dawo (2010) are; lungs darkening, pericardial rupture, intestinal inflammation, gas in large intestine, jaundice, blood clotting is delayed and rigor mortis. Other pathological signs are; Oedema and massive foam in the lungs, severe haemorrhages on the tracheal mucosa and Petechial haemorrhages on the Myocardium (Gluecks and Younan, 2010).

2.2.6 Laboratory findings

Laboratory tests done on post mortem samples and blood for agents of various diseases did not confirm any commonly known animal disease agents (Gluecks and Younan, 2010). Isolation of virus on Vero Cells showed a positive CPE in three cases, indicating possibility of viral agent involvement as cause of CSD (Gluecks and Younan, 2010). A study by Khalafalla et al (2010)

on a disease presenting as CSD in Sudan, reported positive results for PPR virus with Agar gel diffusion test (AGDT) and Reverse Transcriptase-Polymerase Chain Reaction (RT-PCR) with Agar gel diffusion test (AGDT) and Reverse Transcriptase-Polymerase Chain Reaction (RT-PCR).

2.3 PESTES DES PETIT RUMINANTS

2.3.1 Etiology

PPR is caused by PPRV. PPRV belong to the genus Morbillivirus, *Paramyxoviridae* family and in the order *Mononegavirales* (Murphy et al., 1999). PPRV is negative sense RNA, single stranded, linear, non-segmented virus with a nucleo-capsid and a characteristic herring-bone appearance. The genome of the virus is divided into 6 transcriptional units encoding six structural proteins and two non-structural proteins (V and C protein) (Barrett et al, 1999).

PPRV is believed to have one serotype and has been grouped into four lineages according to geographical distribution (Shaila et al., 1996; Dhar et al., 2002). Lineage 1 consist of viruses isolated in Africa. Lineage 2 represent viruses isolated in West Africa in the late 1980s. Third lineage is made up of Sudan and Ethiopia isolates (Roeder et al., 1994). PPRV causing disease in the entire East African region is thought to belong to lineage 3. Lineage 4 of PPR virus is found in Asia. Recently, it was also described in Turkey and isolated in Sudan (Ozkul et al., 2002).

2.3.2 History

First discovery of PPR was in Côte d'Ivoire (Gargadennec and Lalanne, 1942). Later, it was established in Nigeria, Senegal and Ghana, and then reported in East Africa (Sudan) (Diallo, 1988). Since 1993, PPR was reported in the Middle East, the Arabian Peninsula (Housawi et al., 2004) and major parts of the India (Dhar et al., 2002). Currently, PPR is extensively distributed across Africa, Middle East and South Asia (Munir, 2015). PPR was suspected as early as 1992 in Kenya but the clinical cases were first reported to the OIE in 2006.Tanzania reported PPR in the northern part of the country in 2008. Presently, PPR is endemic in the whole East African region (Banyard et al., 2010).

2.3.3 Epidemiology

PPR predominantly affects small ruminants. Sheep are usually affected by mild form while goats are affected severely (Lefèvre and Diallo, 1990). PPRV also infects several other domestic and wild species. There is also evidence that camels are susceptible to PPR infection. PPRV is transmitted through direct contact with infected animal (Braide, 1981). Large amounts of the virus are found in discharges as well as the loose faeces (Abubakar et al., 2008).

2.3.4 Clinical signs

The major form of PPR is the acute form, where clinical signs present 3-6 days after exposure to infection. It is accompanied by a sudden fever (39.5 - 41°C). Affected animals display rapid and difficult breathing and pneumonia, discharge of serous nature from the nose, eyes and later from the mouth, with secondary bacterial infection the discharge becomes mucopurulent. Profuse and bloody diarrhoea begins 3-4 days after onset of fever (Roeder and Obi, 1999). There are also cases of abortion (Radostits et al., 2000). The subacute form of the disease is less marked with recovery seen within two weeks.

2.3.5 Pathology

The dominating pathology affects the gastro-intestinal tract presented as necrotizing and ulcerative lesions (Roeder et al., 1994).Swollen lips marked with scabs and erosions, dried-up discharges in the nose and eyes. Gum erosions which extend to the tongue, soft and hard palate, congestion of the nasal cavity yellow exudates and erosions. The lung becomes firm and purple. Lymph nodes become soft and swollen. The omasum has defined erosions mostly with oozing blood and abomasum appears haemorrhagic and congested. There are small strips of hemorrhages in the small intestines and the terminal ileum and duodenum have erosions. Congestion of large intestine around the ileocecal valve is evident. There are "zebra stripes" the colon and the rectum. The respiratory system presents several pathology including; lung consolidation, bronchopneumonia and atelectasis.

2.3.6 Diagnosis

PPR diagnosis can be done through detection of antibodies and viral antigens, molecular techniques and virus isolation.

2.3.6.1 Virus isolation

PPR virus is best isolated when the disease is at acute stage, while clinical signs are quiet apparent. Samples used for isolation include; Swabs (eye, nasal, mouth and rectal linings) whole blood and clotted blood. Spleen and lymph node biopsies could also be used. It is best to sample live animals before diarrhea has stared and in high temperatures(Lefèvre, 1987). Samples collected at postmortem are; alimentary tract mucosa, lymphnodes and spleen.

Primary cultures of, sheep kidney, bovine kidney, goat lung and kidney cells are most extensively used cell culture for PPR isolation and propagation (Taylor, 1984; Lefèvre and

Diallo, 1990; Hashimoto et al., 2002). Presently, Vero cell line (African green monkey kidney) is commonly used for PPRV owing to its continuity and low contamination.

PPRV produce several cytopathic effects (CPE) in Vero cells, this include; cell rounding, giant cells, grape-like clusters and small syncytia (Hamdy et al., 1976).

2.3.6.2 Serological Techniques

Conventional serological techniques for example agar gel immunodiffusion (AGID), counter immunoelectrophoresis (CIEP) and indirect ELISA have been used for diagnosis of Rinderpest in the past (White, 1958; Scott, 1967). Nevertheless, they became outdated owing to its incapacity to distinguish PPR from Rinderpest infections (Obi et al., 1990).

2.3.6.2.1 Competitive Elisa

Monoclonal antibody based ELISAs were established in early 1990s for diagnosis of PPR antigen and antibodies. Production of monoclonal antibodies against PPRV hemagglutinin protein have been used either in c-ELISA (Anderson and McKay, 1994) or blocking ELISA (Saliki et al., 1993) for differentiation of Rinderpest and PPRV antibodies. The c-ELISA is the most popular test used for diagnosis of PPR and is presently used as commercial kits in PPR endemic countries. C-ELISA and Virus Neutralization Test compares very well, they have high sensitivity (92.4%) and specificity (98.4%) (Singn et al, 2004). With the high sensitivity and specificity of c-ELISA, it was deemed the best serological test for this study.

2.3.7 PPR in camels

Camel was not known as a probable host to PPR up until PPRV antibodies were detected in Egyptian camels (Ismail et al., 1992). Serological reviews have shown camels are susceptible to PPRV (Abubakar et al., 2008). Recent study in Sudan reported that camels are severely affected with PPR with highest severity in adult camels (Khalafalla et al., 2010). PPRV has been assumed to have been the cause of an epizootic disease characterized by sudden death in camels in

Ethiopia that affected camels in 1995-1996 (Rogers et al, 2001). Studies indicate that the disease in camels is described by sudden death of actually well animals, also yellowish diarrhea which later turns bloody and cases of abortion are reported (Khalafalla et al., 2010). Signs of submandibular swelling and subcutaneous oedema, difficulty in breathing, coughing, chest pain and weight loss, decreased milk production, and increased consumption of water are reported. Studies of PPR in the camel indicate variations in the outcome from asymptomatic to severe clinical syndrome.

Abraham et al, (2005) recorded PPR sero-prevalence was 3% in Ethiopian camels. However, the results were lower likened to those reported by Ismail et al., (1992) in Egypt and Roger et al., (2001) of 7.9% in Ethiopia. Following CSD outbreaks in Sudan and Ethiopia, PPRV antibodies were detected in camels (Roger et al., 2001; Haroun et al., 2002; Khalafalla et al., 2010), this suggests PPRV as the causative agent of CSD

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study Area

The study was carried out in four counties in Kenya; Mandera, Marsabit, Isiolo and Wajir counties. The four counties are part of hot ASALs of Kenya where they record minimal rainfall between 300-500 mm per year, and the temperatures experienced range from 13°C to 30°C. The vegetation consists of acacia trees and shrubs (Kenya Soil Survey, 2001`). The soil is generally sandy and saline, with low water holding capacity, making it almost impossible to engage in agricultural activities (Kenya Soil Survey, 2001). They practice extensive livestock production, through nomadic pastoralism and camel is the main livestock kept (Otolo and Wakhungu, 2013). The site was purposively selected based on the large population of camels which are reared closely with sheep and goats and had previously reported CSD outbreaks.

Figure 1: Map showing Marsabit, Mandera, Wajir and Isiolo counties

3.2 Study design

Cross-sectional study was conducted, involving the use of semi-structured questionnaires and direct observations to collect data which was used to assess knowledge, attitudes and practices of camel keepers, with respect to CSD camels. Enzyme-linked immuno-sorbent assay (ELISA) was also used to detect antibodies against PPR in the serum of the sampled camels. Questionnaires were administered to the farmers whose camel herds were bled for serum samples to enable matching of the respective results. The design gives self-reported facts about respondents, their opinions, feelings, attitudes, and habits (Kombo and Tromp, 2007). The study design was selected because of its low costs and ability for quick completion.

3.3 Sample size

The four counties were assumed as one population. As the population of camels is more than 10000, the camel population was assumed as infinite (large population). Therefore, to estimate prevalence of previous exposure, and for large populations, the formula yielding a representative sample for proportions was developed by Cochran:

$$n = 1.96^2 \frac{p(1-p)}{e^2}$$

Where n is the sample size, 1.96 is the z value for the desired confidence level (95%), p is an estimate of the probable prevalence of PPR antibodies, and e is the level of precision. A proportion of 0.5 indicates the maximum variability in a population, and it is often used in determining a more conservative sample size. This yielded a sample of 385 camels.

The 385 samples were proportionally allocated to the 4 counties based on camel population in the counties. From each county, two sub-counties that had previously experienced an outbreak of

CSD were purposively sampled. Camel herds were conveniently sampled along the roads and watering points.

3.4 Questionnaires construction and administration

A total of 36 questionnaires were administered. Data collection was done using semi-structured questionnaires. It was administered through in person interviews and interview guides to enable probing by interviewers and In-depth interviews. The answers were prudently recorded in the questionnaire as the interview continued and confirmed well filled before proceeding to the next respondent. Important household and herd-level data collected included; household characteristics, livelihood activities, livestock production and benefits, camel and camel product sales and income, actors and markets in camel value chains, expenditure of camel incomes, camel diseases & epidemiology, camel health interventions, impacts of disease on camel benefits. Sampling units were the heads of household or any responsible adult in the household at the time whether male or female.

3.5 Blood collection, processing and serum storage

Each camel was well restraint and using plain vacutainer tube with well fitted needle (Becton Dickson, UK), blood was collected from the jugular vein until it filled ¾ of the vacutainer tube. Codes defining specific animal were used to label each sample. To allow clotting, the tubes were set tilted on a table at room temperature overnight. The clotted blood was then centrifuged (at 3000 g for 20 min) and clear serum obtained. The serum was then stored at -20°C until their analysis. A sample of 399 samples of 400 camel sera were realized despite the logistical difficulties and the existing drought.

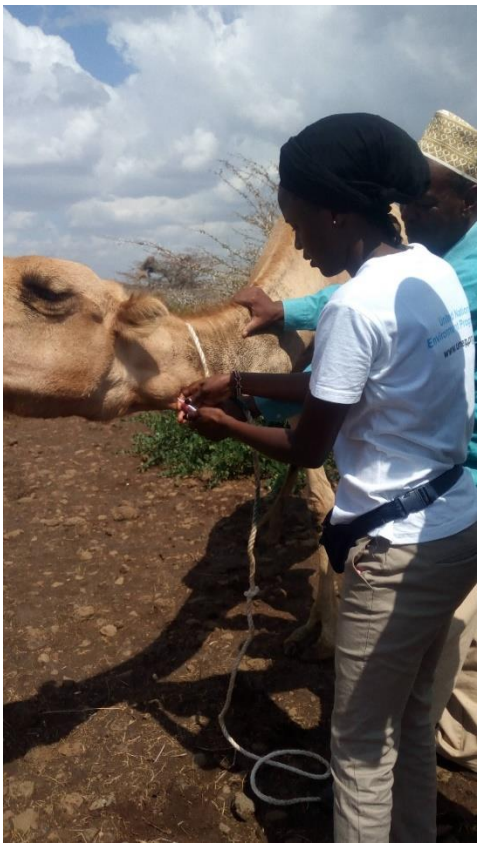

Figure 2: Blood sample collection through the jugular vein

3.6 Serology

A sero-prevalence survey was done using competitive Enzyme-Linked Immunosorbent Assay c-ELISA at Kenya Agricultural and Livestock Research Organization (KALRO), Muguga.

3.6.1 c-ELISA Procedure

All reagents were allowed to come to room temperature before use. Eighty microliters of diluent were added to all the wells. Twenty microliters of serum samples were dispensed to each well and the plate shaken carefully for homogenization, 100 microliters of positive and negative

controls were then added in duplicated wells and plate incubated for 45 min at 37 degrees Celsius, after which it was washed 3 times. 100 microliters of conjugate were dispensed to all wells and the plate incubated for 30 min at room temperature, which was then washed 6 times.

Hundred microliters of substrate was added to all wells and plate incubated at room temperature, in a dark place. 100 microliters of stop solution were dispensed to each well, and the optical density (OD) of each was read at 450nm absorbency wavelength with spectrophotometer within 5 min, after addition of stop solution (INGEZIM PPR COMPAC, 13.PPR, K3-Technical guide).

3.6.2 c-ELISA validity test

The test was determined valid when the ratio of OD (positive control)/OD (negative control) was lower than 0.3 and OD of negative control greater than 0.8 (INGEZIM PPR COMPAC, 13.PPR, K3-Technical guide).

3.6.3 c-ELISA results interpretation

The relative level of antibodies (Blocking %) of each sample was calculated as follows (INGEZIM PPR COMPAC, 13.PPR, K3-Technical guide):

$$\text{Blocking \%} = 100 - [(\text{OD sample} / \text{OD negative control}) \times 100]$$

All samples with blocking % higher or equal than 50 were considered positive and those with blocking % lower than 50 were considered negative.

3.7 Data management and analysis

3.7.1 Questionnaire data Analysis

The data collected were entered in a database prepared in Microsoft Excel®. The data was then transferred to the Statistical Package for Social Science (SPSS) in a worksheet format from where the data cleaning process was carried out. Analysis was done using the SPSS software. The major analysis outputs from the analysis included tables and charts, which are useful in the interpretation of the findings.

3.7.2 Serology Analysis

The sero-prevalence of PPR was calculated using Bennette et al., (1991) formula;

Prevalence (%) = number of seropositive samples/total number of serum examined× 100

This formula was used to work out the overall sero-prevalence and sero-prevalence by sex, age and county. To test variances in sero-prevalence, chi-square test was used.

The association between PPRV antibody prevalence and individual risk factors for PPRV sero-positivity was assessed by running univariable models. The risk factors evaluated comprised sex, age and county. The significance level was put at $P \leq 0.1$. The risk factors included in the model were analysed through backward elimination to select factors that were associated with PPRV using the probability ratio test ($P < 0.05$). Estimation of the strength of association between the risk factor and PPRV sero-positivity was done using odds ratios (OR) which were derived from the coefficient estimates from the logistic regression models.

CHAPTER FOUR: RESULTS

4.1 KNOWLEDGE, ATTITUDES AND PRACTICES AMONG VALUE CHAIN ACTORS ON CAMEL SUDDEN DEATH SYNDROME

4.1.1 Socio-demographic characteristics

4.1.1.1 Distribution of questionnaire respondents by county

Thirty-six questionnaires were administered in the four counties. The distribution of questionnaires is shown in Table 2.

Table 2: Distribution of questionnaire respondents by county

County	Frequency	Proportion
Mandera	10	27.8
Isiolo	8	22.2
Marsabit	4	11.1
Wajir	14	38.9
Total	36	100

4.1.1.2 Distribution of questionnaire respondents by gender

Of all 36 respondents 97% were men and 3% were women (Figure 3).

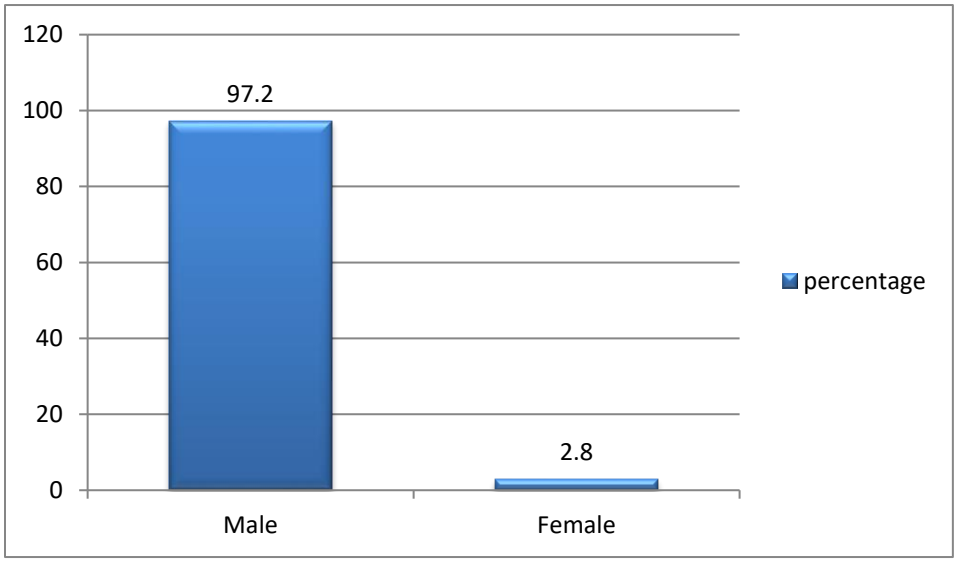

Figure 3: Gender distribution of respondents

4.1.1.3 Education level of questionnaire respondents

Figure 4 shows the education level of the respondents. 83% of the respondents had no formal education.

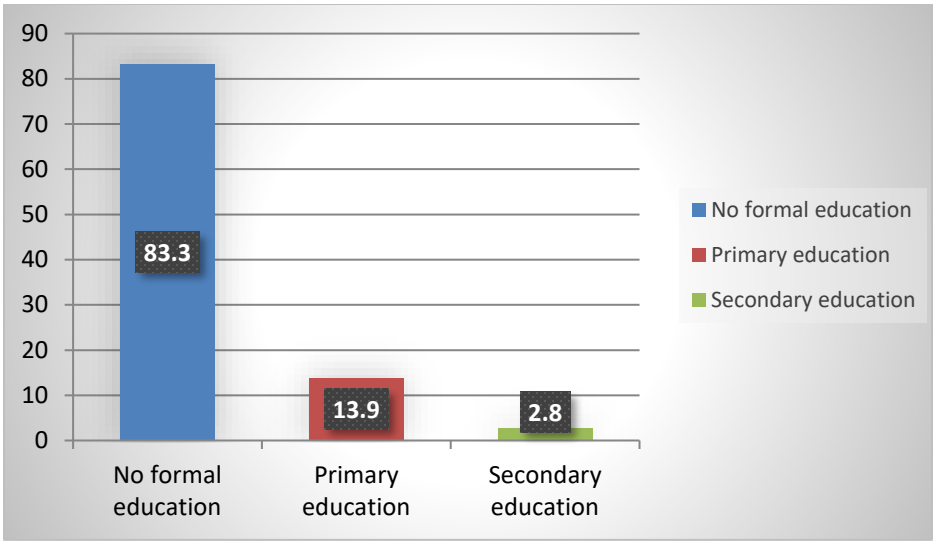

Figure 4: Education level of respondents

4.1.1.4 Major source of income for questionnaire respondents

Figure 5 reveals that majority of household head depend on livestock for income. 94%, 3% and 3% of the household head rely on livestock, formal employment and informal employment for income respectively.

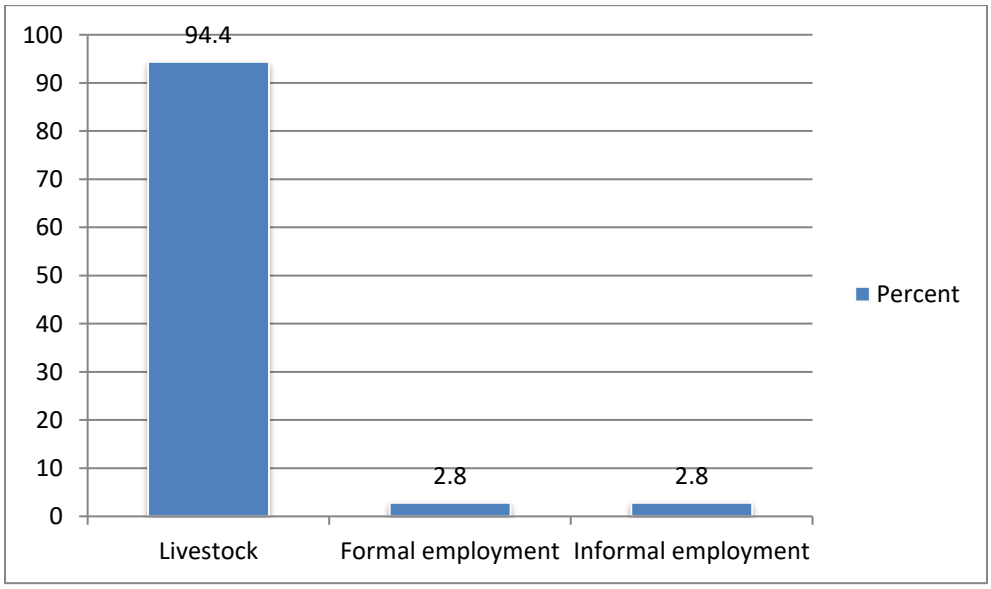

Figure 5: Major source of income for respondents

4.1.2 Livestock production and benefits derived from camels

4.1.2.1 Distribution of livestock species reared by county

Table 3 shows the distribution of livestock species reared by county. All households in the four counties kept camels. All households in Isiolo County reared sheep and goats while Mandera County had the highest number of respondents keeping donkeys.

Table3: Distribution of livestock specie reared by county

Livestock Species	County	Number of households keeping the livestock species	Number of households not keeping the livestock species
Cattle	Mandera	6 (60.0%)	4 (40.0%)
	Isiolo	7 (87.5%)	1 (12.5%)
	Marsabit	4 (100%)	0.0 (0%)
	Wajir	2 (14.3%)	12 (85.7%)
Sheep and goats	Mandera	9 (90.0%)	1 (10.0%)
	Isiolo	8 (100%)	0 (0%)
	Marsabit	4 (100%)	0 (0%)
	Wajir	12 (85.7%)	2 (14.3%)
Camels	Mandera	10 (100%)	0 (0%)
	Isiolo	8 (100%)	0 (0%)
	Marsabit	4 (100%)	0 (0%)
	Wajir	14 (100%)	0 (0%)
Donkey	Mandera	9 (90%)	1 (10%)
	Isiolo	7 (87.5%)	1 (12.5%)
	Marsabit	2 (50%)	2 (50%)
	Wajir	10 (71.4%)	4 (28.6%)

5.1.2.2 Benefits derived from camels by questionnaire respondents

Sale of camel milk was reported by all respondents as the main benefit derived from camels. About 92% of respondents reported benefiting from sale of camels and 86% of respondents reported using camels in payment of dowry. Other benefits included draught power and provision of meat (Figure 6).

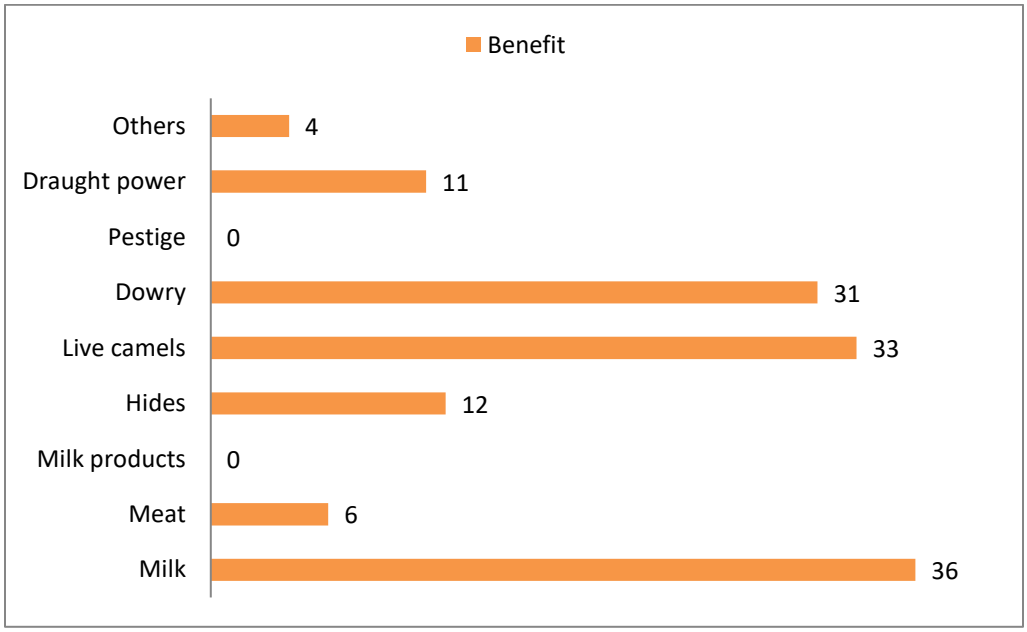

Figure 6: Benefits derived from camels according to pastoralists.

4.1.2.3 Reasons for selling camels

Support of livelihood was reported by 22 (61.1%) respondents as reason for selling, 14 respondents (38.9%) indicated they sold camels to help them pay school fees, 11 respondents (30.6) sold camels to help them finance social activities, 8 respondents (22.2%) sold camels to

boost their financial status and 5 respondents (13.9%) sold camels as a result of drought (Figure 7).

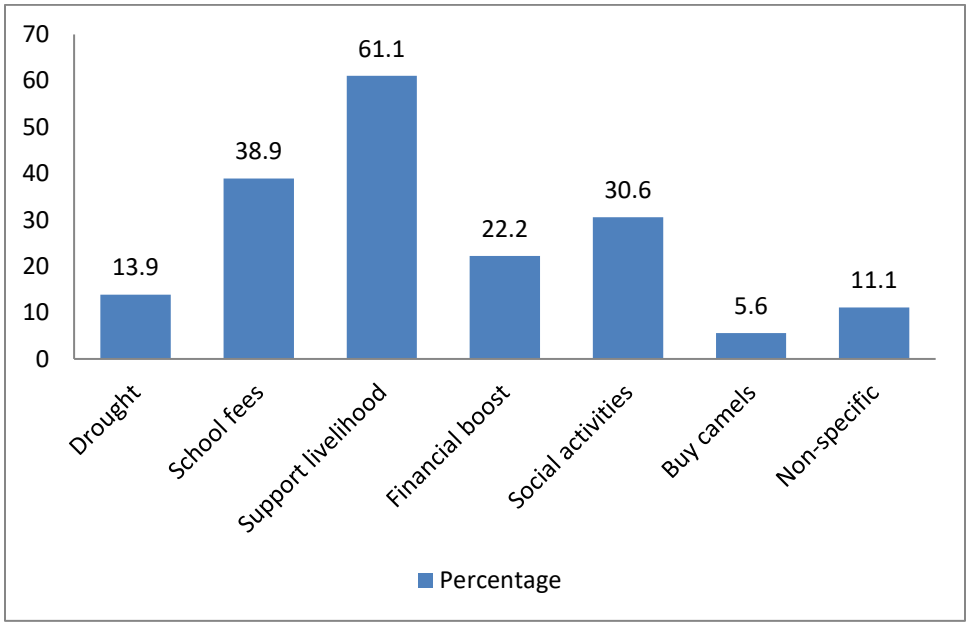

Figure 7: Reasons for selling camels

4.1.2.4 Nearest Camel market

Majority of the respondents 17(47.2%) indicated that the nearest accessible camel market was about 50KM, 15 (41.6%) respondents approximated the nearest camel market was 50-100KM, 2 (5.6) respondents approximated the nearest camel market to be 151-200KM (Table 4).

Table 4: Distance to the nearest camel market

Distance in KM	Frequency	Percentage
<50	17	47.2
50-100	15	41.6
101-150	1	2.8
151-200	2	5.6
201-250	1	2.8
Total	36	100

4.1.2.5 Camel milk production and sale

Data on milk production was sought in "good" season - season when there are no major challenges of production, e.g. diseases or drought and "bad" season - season when there are major challenges of production, e.g. diseases or drought. The mean milk production in "good" season was 4.8 liters with a median of 3.5 liters. The minimum and maximum production reported was 1.4 and 15 liters respectively. The mean milk production in "bad" season was 2.5 liters with a median of 1.8 liters. The minimum and maximum production reported was 0.35 and 10 liters respectively. Data on milk sale was also sought in the same manner. The mean milk selling price in "good" season was Ksh 56 with a median of Ksh 50. The minimum and maximum selling price in "good" season was Ksh 20 and Ksh150 respectively. The mean milk selling price in "bad" season was Ksh 39 with a median of Ksh 30. The minimum and maximum selling price in "bad" season was Ksh 10 and Ksh100 respectively. Data on camel sale was also sought in the same manner. The mean camel selling price in "good" season was Ksh 71,515 with a median of Ksh 70,000. The minimum and maximum selling price in "good" season was Ksh 20,000 and Ksh150,000 respectively. The mean camel selling price in "bad" season was Ksh 38150 with a median of Ksh 30000. The minimum and maximum selling price in "bad" season was Ksh 10,000 and Ksh100000 respectively.

4.1.2.5 Constraints faced in camel production and in sale of camel and camel products

Constraints faced in camel production from all respondents included diseases, drought and lack of pastures and water, lack of markets, unavailability of markets, unavailability of animal health services, predation and insecurity. 26 out of 36 respondents (72.2%) listed diseases as the most important challenge. Most of the respondents (33 out of 36 which equals 91.7%) did not find unavailability of veterinary services as important challenge. (Figure 8).

Constraints faced in sale of camel and camel products included mainly drought and associated lack of pastures and water, and lack of ready markets and to a lesser extent insecurity. Diseases that have affected camels in last one year in the study area included trypanosomiasis, haemorrhagic septicaemia, camel pox, mange, camel abscesses, sudden death syndrome and pneumonia. Vaccinations were not being done to prevent any of these diseases.

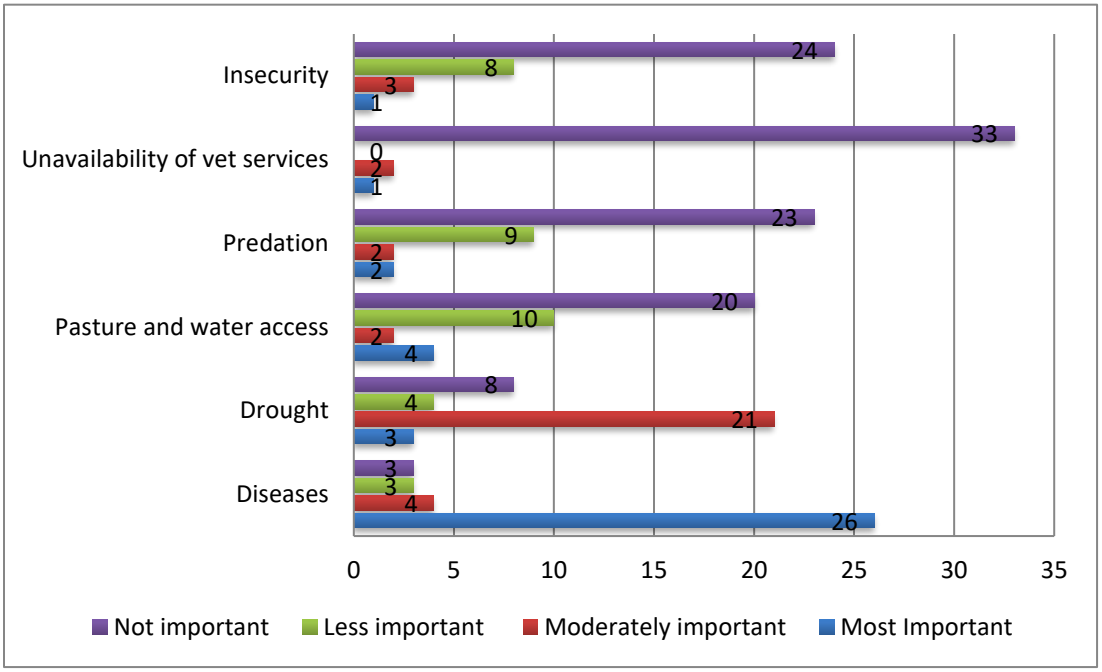

Figure 8: Challenges experienced in camel production

4.1.3 CAMEL SUDDEN DEATH SYNDROME

4.1.3.1 Pastoralists' Knowledge and Awareness of CSD

Thirty-two (89%) pastoralists were aware of CSD and four (11%) pastoralists were unaware of the disease (Figure 9). 77.27% of the interviewed pastoralists indicated that camels died suddenly without presenting any clinical sign and 22.73% of pastoralists indicated that camels presented clinical signs and died after a short time (6 hours- 1day). The signs included; swollen neck, nasal discharge, inappettance and recumbence.

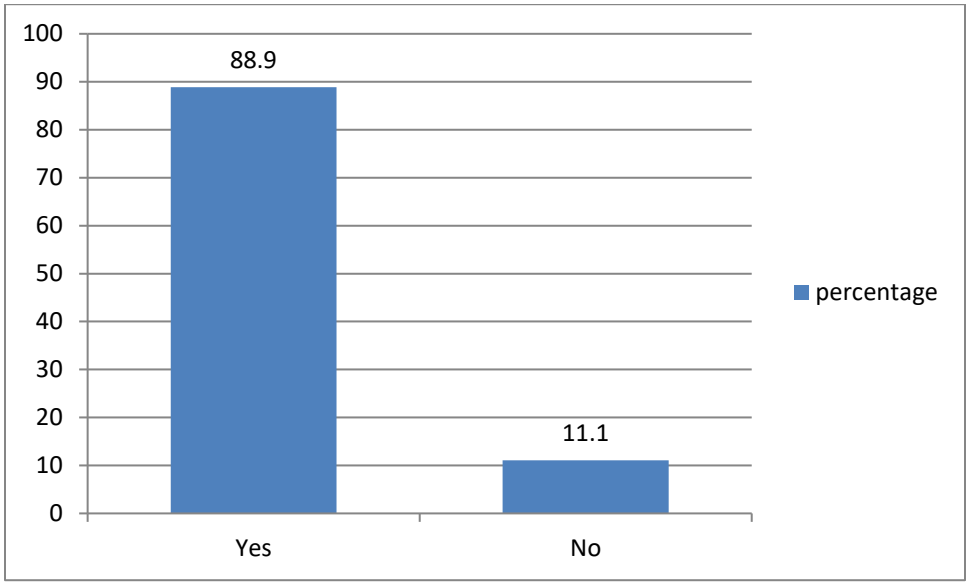

Figure 9: Respondents' awareness on CSD

4.1.3.2 Distribution of CSD by age

36% of the respondents indicated CSD affect camels less than 2 years old, 32% of the respondents stated the disease affect camels 2-4 years of age and 16% of respondents indicated the disease affects lactating camels. Camels older than 4 years and pregnant ones are the least affected by CSD (Figure 10).

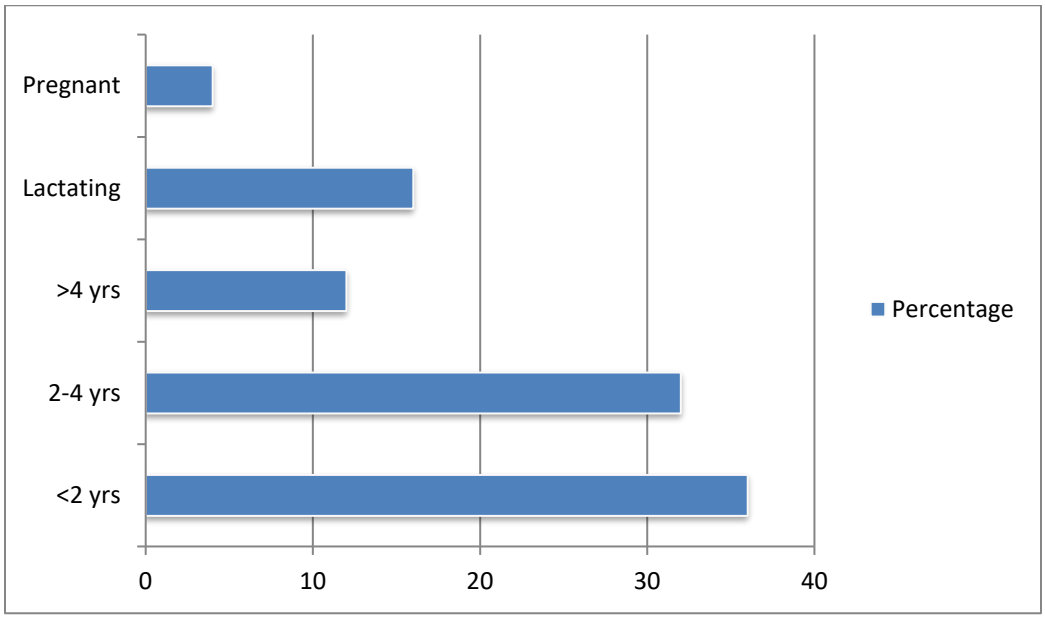

Figure 10: Distribution of CSD by age

4.1.3.3 Distribution of CSD by sex

52% of the respondents indicated CSD affects mostly females, 44% of the respondents stated CSD affects male and 4% indicated the disease affects both sexes equally (Figure 11).

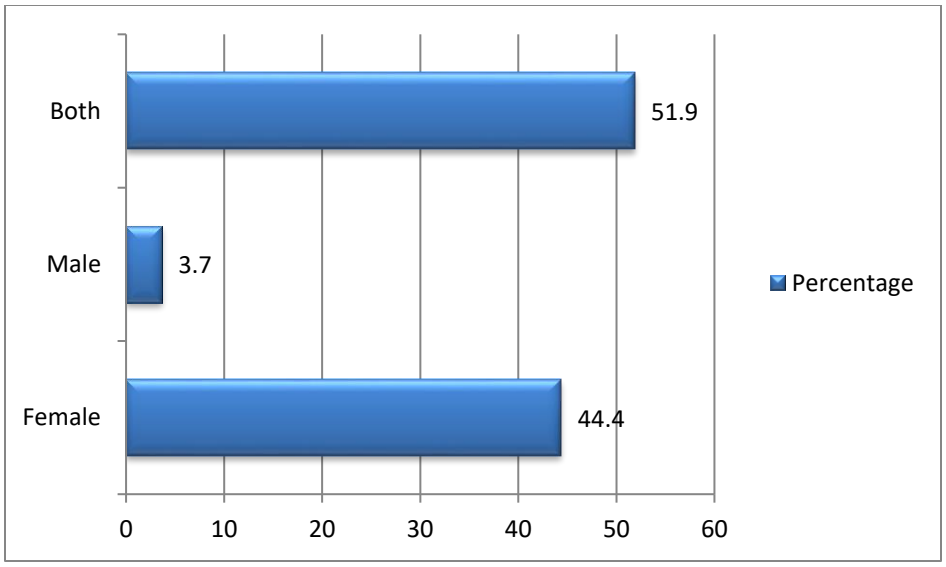

Figure 11: Distribution of CSD by sex

4.1.3.4 Actions taken when camels die of CSD

63% of the respondents' slaughter dead camels for meat, 22.2% of respondents abandon the dead camels in the fields. Few respondents burned or buried carcasses of camels that died of CSD (Figure 12).

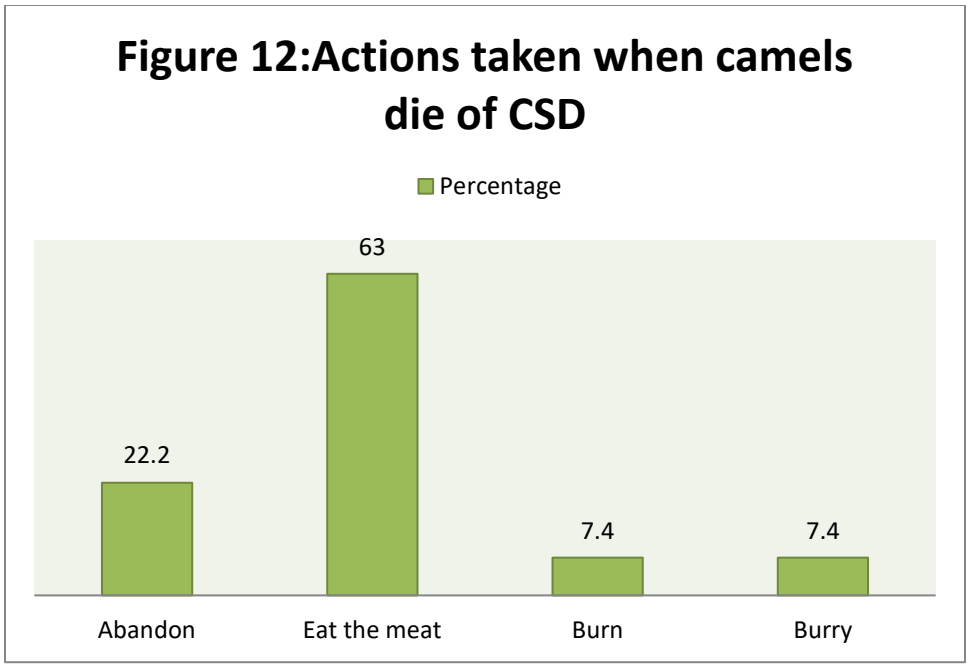

Figure 12: Actions taken when camels die of CSD

4.2 PPR Sero-prevalence

4.2.1 Characteristics of sampled camels

A total of 398 camels were sampled, with Isiolo county recording the highest number of camels sampled (120 out of 398). Majority of sampled camels were adults (59%). The proportion of sampled females was higher than that of males (Table 5).

Table 5: Characteristics of sampled camels

Variable	Frequency	Percentage (%)
Sex		
Male	107	26.88
Female	291	73.12
Age		
Calf	70	17.59
Middle age	91	22.86
Adult	237	59.55
County		
Isiolo	120	30.15
Marsabit	88	22.11
Wajir	105	26.38
Mandera	85	21.36

4.2.3 PPR sero-prevalence by Age group

Sero-prevalence by age group was ranging from 2% to 5%. The sero-prevalence was increasing from adults (2.11%) to calves (5.71%), (Table 6).

Table 6: PPR Sero-prevalence by age

Age	Frequency	Sero-positive	Sero-prevalence (%)
Calf	70	4	5.71
Middle Age	91	3	3.30
Adults	237	5	2.11
Total	398	12	3.11

4.2.4 PPR Sero-Prevalence by Sex

PPR sero-prevalence was higher in males (6.54%) compared to females (1.72%), (Table 7).

Table 7: PPR Sero-prevalence by sex

Sex	Frequency	Sero-positive	Sero-Prevalence (%)
Male	107	7	6.54
Female	291	5	1.72
Total	398	12	3.02

4.2.3 PPR Sero-Prevalence by County

PPR sero-prevalence by counties ranged from 0% to 6.81%, with overall sero-prevalence of 3.02%. Marsabit County recorded the highest sero-prevalence while Mandera County recorded the lowest (Table 8)

Table 8: PPR Sero-prevalence by county

County	Frequency	Sero-positive	Sero-prevalence (%)
Isiolo	120	3	2.50
Marsabit	88	6	6.81
Wajir	105	3	2.86
Mandera	85	0	0.00
Total	398	12	3.02

CHAPTER FIVE: DISCUSSION

5.1 Socio-economics

Thirty-six questionnaires were administered to pastoralists in the four study counties. 38.9% (14 out of 36) were administered in Wajir county, 27.8% (10 out of 36) in Mandera county, 22.2% (8 out of 36) were administered in Isiolo county and 11.1% (4 out of 36) in Marsabit County. The few numbers of questionnaires administered in Marsabit County was attributed to insecurity cases in the region during the field study.

The study found that 97% of the questionnaire respondents were men and 3% were women. This reveals that women are not actively involved in the daily management of camel herds maybe because it involves moving far away from the homesteads in search of pasture and water.

The study revealed that literacy level in the population is poor, this is indicated by the fact that majority of the respondents (n=36, 83%) had no formal education and none attained tertiary education. This agrees with the findings of a study in Isiolo County by Elhadi Y. et al (2015) that reported most of the respondents had no formal education (81.2%), whereas only 1.5% attained tertiary education. Possible explanation for the poor education level of the respondents can be the inaccessibility of education services in the area, given its pastoral ASAL nature and the belief that the livestock management doesn't need special skills. Also the poor income from livestock keeping is not enough to afford higher levels of education.

Njanja (2007) and Guliye (2006) indicated that in Kenya camels are significant livelihood assets for food security and making wealth in the pastoral ASALs. This is similar to the findings of this study which showed that majority of the population in all the areas depended on livestock as main source of income; thirty-four respondents (94%) indicated that livestock was the only

source of income. Only one respondent had in addition to livestock, informal employment as a source of income. The dependence on livestock could be attributed by the nature of the area (ASAL) which does not allow crop farming and there are no available employment opportunities. Also the poor education level makes them unqualified for most formal jobs.

The study found that Camels were kept by all households in the four counties. All households in Isiolo County reared sheep and goats while Mandera County had the highest number of respondents keeping donkeys (90%). This agrees with Dowelmadina et al (2015) that camels are largely kept by pastoralists as they are remarkably adapted to hot ASALs.

The study found out that the camel keepers derived many benefits from the camels, the main benefit being Sale of milk (100%). 92% of respondents benefited from sale of camels and 86% of respondents used camels in payment of dowry. Other benefits included draught power and provision of meat to a lesser extent, there is no farmer that keeps camel for prestige and none derives benefit directly from camel milk products. This corresponds with findings of Noor (2013) and Farah (1996) which stated that camels were primarily kept for production of milk and meat and also used for transportation and socio-cultural functions.

The study found that the pastoralists sold camels for various reasons. Most respondents (61.1%) cited that they sold camels to support livelihood, 38.9% of the respondents indicated they sold camels to help them pay school fees, 11 respondents (30.6) sold camels to help them finance social activities, 22.2% of the respondents sold camels to boost their financial status and 13.9% of respondents sold camels as a result of drought. To a lesser extent there were no specific reasons for selling camels and other respondents sold camels to buy more camels. This relates

with Noor et al (2013) findings that Camels were sold to cater for livelihood wants and raise money for other investments.

The study revealed that camel markets were quite far from the pastoral communities. Majority of the respondents (47.2%) indicated that the nearest accessible camel market was <50KM, 41.6% of the respondents approximated the nearest camel market to be between 50-100KM, 2 (5.6%) respondents approximated the nearest camel market to be 151-200KM. This agrees with present finding, Noor et al (2013) reported that pastoralists missed adequate market information because they are generally far-off the urban markets.

The study provides evidence that the mean camel milk production in "good" season is higher (4.8 litres) than the camel mean milk production in "bad" season (2.5 litres). Where "good" season refer to times when there are no major challenges of production, e.g. diseases or drought and "bad" season refer to times when there are major challenges of production.

The study established that the mean camel selling price in "good" season was Ksh 71,515, while mean camel selling price in "bad" season was Kshs 38150. The mean milk selling price in "good" season was Ksh 56 while mean camel selling price in "bad" season was Kshs 39 Where "good" season refer to times when there are no major market challenges and "bad" season refer to times when there are major market challenges. On comparison with the findings of (KCA 2009) that prices of camel in Kenya ranged between Ksh. 17,000 and Ksh. 35,000, it is explicable that camels have fetched better market prices with time, this can be explained with the increasing demand for camels as a result of increasing consumption of camel meat among the pastoralists and non-pastoral communities. On the other hand, camel and camel products prices

depended on several factors, including body condition, demand and market supply (KCA 2009), which agrees with the findings of this study.

The study indicated that constraints faced in sale of camel and camel products included mainly drought and associated lack of pastures and water, and lack of ready markets and to a lesser extent insecurity. This agrees with Noor (1999) who reported several obstacles affecting livestock market in the ASALs of Kenya; insecurity, poor roads, unreliable market information and lack of reliable livestock marketing policies.

The study found that constraints faced in camel production included diseases, drought and lack of pastures and water, unavailability of markets, unavailability of veterinary services, predation and insecurity. 26 out of 36 respondents (72.2%) listed diseases as the most important challenge. This coincides with findings reported by Farah et al. (2004) that lack of veterinary services and diseases are among the factors that undesirably affect camel production.

5.2 Camel diseases and Camel Sudden Death Syndrome

The study found out that the diseases that have affected camels in last one year in the study area included trypanosomiasis, haemorrhagic septicaemia, camel pox, mange, camel abscesses, sudden death syndrome and pneumonia. Vaccinations were not being done to prevent any of these diseases.

A significant number (89%) of the respondents were aware of existence CSD and 11% (4 out of 36) of the respondents were unaware of the disease. In agreement with Gluecks et al (2010) that CSD is an emerging disease in camels, the study identified that the local pastoralists had no traditional name for CSD. 77.27% of the respondents indicated that camels died suddenly without presenting any clinical signs and 22.73% indicated that camels presented clinical signs and died after a short time (6 hours- 1day). The signs included; swollen neck, nasal discharge, inappettance and recumbence.

The study showed that CSD mostly affected camels less than 2 years old (indicated by 36% of the respondents), followed by 2-4 years old camels (stated by 32% of the respondents) and lactating camels (indicated by16% of respondents). Camels older than 4 years and pregnant ones are the least affected by CSD. This is in agreement with a report that the disease claimed camels of ages between 2-5 years by Wajir times (2016)

The study found CSD affected both males and females, with female camels being the most affected (52%) than the male camels (44%). This relates with Gluecks et al (2010) that CSD Mainly affected females (88% in Kenya and 74% in Puntland) within herds.

Most pastoralists (63.3%) indicated to eat carcasses of camels that died of CSD, 22.2% of respondents abandon the dead camels in the fields. Few respondents burned or buried carcasses of camels that died of CSD.

5.3 PPR Sero-prevalence

PPR is mainly a disease of sheep and goats. Although the clinical manifestation of the disease is not pronounced in camels, PPR antibodies have been detected in camels' sera (Roger et al., 2001; Haroun et al., 2002; Khalafalla et al., 2010). The sera samples tested in this study gave an overall sero-prevalence of 3.02%, which relates to findings by (Abraham et al., 2005) which recorded PPR sero-prevalence was 3% in Ethiopian camels. However, the results were lower compared to those reported by Ismail et al., (1992) in Egypt and Roger et al., (2001) of 7.9% in Ethiopia. The camels tested were never vaccinated against PPR, this results therefore indicate that the camels have had natural exposure to the disease, and there could be possibility of natural transmission of the disease between camels and sheep and goats.

Sero-prevalence by age group was ranging from 2% to 5%. Unexpectedly, the adult age group recorded low sero-prevalence in comparison with the middle age group and calf age group. This finding is in contrast with other studies (Kihu et al., 2015) where sero-prevalence in sheep and goats adults was high. The high sero-prevalence noticed in the middle age group may be as a result of natural exposure to infection as they grow. The high sero-prevalence in calf age group may be attributed to maternal antibodies or exposure to the virus at a young age. We hypothesize the low sero-prevalence detected in the adult age may be due to waning of antibodies against PPRV with age in camels. In contrast with (Waret et al., 2008; Munir et al., 2013; Kihu et al., 2015), age did not show to be important risk factor for PPR sero-prevalence (P=0.296).

Sex unexpectedly was a significant risk factor for PPR sero-prevalence (P=0.013). While male camels had high sero-prevalence compared to female camels, the opposite holds true for PPR in goats (Kihu et al., 2015). In goats, the explanation for this finding was straightforward about population structuring and turnover (Kihu et al., 2015). The females were 75% not likely to have PPRV antibodies compared to males. There is no known sex-related factor that can be attributed to such differences, and this calls for concerted empirical inquiry in to camel husbandry practices that would expose camels of separate sexes differently or physiological mechanisms that lead to such variation in epidemiology between sexes.

Sero-prevalence by county was ranging from 0% to 7%, with Marsabit County recording the highest sero-prevalence and Mandera County recording the lowest. With logistic regression, Marsabit County showed to be 2 times more likely to have camels with PPRV antibodies compared to Isiolo County. These variations in PPRV sero-prevalence between the counties suggest spatial variations in exposure between counties. Socio-ecological factors may be responsible for PPRV sero-prevalence (Kihu et al., 2015).

5.4 Overall discussion

PPR is mainly a disease of goats and sheep (Munir, 2015). Although the clinical manifestation of the disease is not pronounced in camels, this study found that camels in Kenya are indeed exposed to PPRV, meaning camels are susceptible to the disease. CSD is an emerging fatal disease of the camels (Gluecks et al 2010). Even though the disease is not well understood among the camel keepers and animal health experts this study showed that camel keepers are aware of the disease. Recent studies investigating CSD outbreaks in Sudan and Ethiopia have linked CSD to PPR (Roger et al., 2001; Haroun et al., 2002; Khalafalla et al., 2010); correspondingly this study established relationship between CSD and PPR; the camel keepers indicated CSD mostly affected camels less than 4 years old which is related with serology findings that adult camels were the least affected compared to middle aged and calves.

PPR /CSD can affect the health of camel directly or indirectly and therefore impacting on household nutrition and socio-economic needs. This study completed the picture by collecting socio-economic information. The study found out that camel keeping was major source of livelihood and nutrition. Camel milk was found to be the main source of income for buying food with fibre, since vegetables are not grown in the region. Furthermore, the study found out that the milk prices kept fluctuating, experiencing low prices when there are major market challenges. The seasonal milk prices may lead to fluctuating provisions affecting socio-economic constant needs and fluctuating nutritional provisions to the community.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSI0NS

1. It can be concluded that camels were main source of income and livelihood support in the four pastoral counties, also camels are important in social and cultural events. We can also deduce that there was increasing demand for camel products like meat and milk, thus camel was fetching good market price. With the rising demand for camel products and the dependency on camels for livelihood in the pastoral communities, good husbandry and production measures should be put in place and implemented.
2. It was established that camels were susceptible to PPRV. The study also showed that risk factors related to PPR sero-prevalence include; sex, age and location of the camels. The detection of PPRV antibodies in camels in the study, suggests possible transmission of PPRV between camels and sheep and goats, therefore camels could be major role players in the epidemiology of PPR infection. Microbiological, epidemiological and pathological studies should be done, to give a clearer picture of PPR in camels. This will greatly aid in coming up with control and eradication strategies for the disease.
3. It can be stated that camel keepers were aware of existence of CSD but had no traditional name for the disease, concluding the disease is a new entity in the region. The study also indicated that the camels died shortly after presenting with swollen neck, nasal discharge, inappetance and recumbence. With camels in this region being closely reared with sheep and goats, the main hosts of PPRV, and detection of PPRV antibodies in camels in this study; we can infer that PPRV is a possible causative agent of CSD.

4. It is concluded that there is possible linkage between PPR and CSD in the region; therefore, further research should be conducted to confirm the etiological agent of CSD with special attention to PPRV.
5. The relationship between livestock health and socio-economics is complex, and there is need for further studies to understand it in quantitative to develop improved livelihoods and animal health interventions.

6.2 RECOMMENDATIONS

1. Good husbandry and production measures for camel production should be put in place and implemented in pastoral regions.
2. Microbiological, epidemiological and pathological studies should be done, to give a clearer picture of PPR in camels
3. Research should be conducted to find out if there is transmission of PPR between camels and sheep and goats
4. Further researches should be conducted to confirm the causative agent of CSD, paying attention to PPRV
5. Education and awareness creation among pastoralists regarding zoonoses that may occur following eating meat of dead animals.

CHAPTER SEVEN: REFERENCES

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APPENDICES

Appendix1. Pastoralist Questionnaire

A. Background information

Name (Optional)……...

County..... Sub-county.....

Ward..... Village.....

GPS readings: Eastings..... Northings/southings..... Elevation.....

B. Biodata

1. Gender of the respondent?
[1] Male
[2] Female

2. Age of respondent?

Age	Tick as appropriate
[1] 18-25	
[2] 26-35	
[3] 36-45	
[4] 46 and above	
[5] Others specify	

3. Education level of the respondent?
[1.]No formal education
[2] Primary education
[3] Secondary education
[4] Tertiary education
[5] Others specify

4. Name of the respondent? ……

5. Relationship of respondent to household head

(1) Owner (2) Spouse (3) daughter (4) Son (5) Worker (6) Other

Specify ……

6. Who is responsible for the day to day management decisions of the farm?

(1) Owner (2) Spouse (3) daughter (4) Son (5) Worker (6) Other Specify……

7. 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

8. How many camels do you keep? ……

C. Knowledge, attitudes and practices on camel management and diseases

9. Rate the importance of the following management practices

Practices	**Important**	**Less important**	**Not important**
1. Timely feeding			
2. Provision of clean drinking water			
3. Timely medical attention for the sick			
4. Proper housing			
5. Others specify			

10. What are the challenges you experience in camel production?

Challenges	**Tick appropriately**
1. Diseases	
2. Drought	
3. Cost of drugs/vaccines	
4. availability of veterinary services	
5. Lack of market	
6. Predation	
7. Theft	
8. Others, specify	

11. Rank the main diseases that affect camels?

Diseases	**Major**	**Minor**	**Not a problem**

1. Camel pox			
2. Trypanosomiasis			
3. Contagious ecthyma			
4. Haemorrhagic septcaemia			
5. Foot and mouth disease			
6. Rift valley fever			
7. Plant poisoning			
8. Camel mange			
9. Respiratory diseases			
10. Anthrax			
11. Camel sudden death			
12. Others, specify			

12. Are you aware of camels suddenly dying without showing any sign of disease?
[1] Yes
[2] No

13. If yes, what local name is given to the disease causing it?
.....

14. How many camels have you lost to sudden camel death? ……

15. Which age group is mostly affected?

[1] 0-2yrs
[2] 3-5yrs
[3] 6-8yrs
[4] 9-11yrs
[5] >11yrs

9. Which sex of camels is mostly affected? [1] Male [2] Females

10. What clinical signs do you observe before death?

Clinical signs	**Tick as appropriate**
1. No prior clinical signs	
2. Submandibular edema	
3. Recumbence	
4. Respiratory signs	
5. Corneal opacity	
6. Pale mucus membranes	
7. Diarrhoea	
8. Enlarged lymph nodes	
9. Others, specify	

11: How long does it take for camel to die after showing clinical signs?

1. <1hr
2. 1-4hrs
3. 5-8hrs
4. 9-12hrs
5. 12hrs and above

12: Does the disease spread to other camels in contact with sick ones? [1] Yes [2] No

13: If yes, how soon does one observe the clinical signs after contact.....?

14: Are you aware of any recent outbreak in this region?
[1] Yes
[2] No

15: If yes, when did the outbreak occur?
.....

16. What do you think causes camel sudden death?
.....

17: How do you prevent the disease?

[1] Vaccinations

[2] Preventive treatment

[3] Separating the health herd from sick camels

[4] Others, specify……

18: What do you do when camels show signs suggesting camel sudden death syndrome?

	Tick as appropriate
1. Administer treatment by self	
2. Call Veterinary doctor	
3. Separate from heard	
4. Slaughter	
5. Do nothing	
6. Others, specify	

19: What do you do when camels die of sudden death?

[1] Eat the meat
[2] Burn
[3] Bury

[4] Others specify.....

20. Do you report cases of sudden death to the veterinary department? [1] Yes [2] No

D. CAMEL VALUE CHAIN

21. What is your main reason for keeping camels?
    1. Home consumption
    2. Business
    3. Prestige
    4. Socio-cultural purposes
    5. Others specify

22: which camel products do you sell?

Product	**Tick as appropriate**
1. Milk	
2. Meat	
3. Hide	
4. Manure	
5. Live camels	
6. Others, specify	

23: who do you sell the products to? (*Tick as appropriate*)

Products	**] Local retail traders**	**] Local consumers**	**Urban retail traders**	**Processing facilities**	**Others specify**
1. Milk per litre					
2. Meat per kg					
3. Hide each					
4. Manure kg					
5. Others, specify					
6. live camels each					

24: How many liters of milk do you sell per day?

.....

26: How does camel sudden death affect camel production?

1. Reduced production
2. Loss of breeding stock
3. Reduced reproduction
4. Loss of replacement stock
5. Others specify

Appendix 2: Enyzme Linked Immunosorbent Assay Raw Data

ELISA plate 1

C-ELISA FOR CAMEL PPR

Date…14/08/2017…… Plate #……1……..Animal Species……CAMEL……Wavelength (λ)…450 nm…….

	1	2	3	4	5	6	7	8	9	10	11	12
A	**C++ 0.547**	MR/05/1 **1.630**	MR/13/1 **1.991**	MR/21/1 **2.127**	MR/29/1 **2.413**	MR/36/1 **2.189**	MR/45/1 **2.200**	MR/54/1 **2.362**	MR/62/1 **1.604**	MR/70/1 **2.425**	MR/78/1 **2.373**	MR/86/1 **0.616**
B	**C++ 0.489**	MR/06/1 **2.296**	MR/14/1 **2.077**	MR/22/1 **2.263**	MR/30/1 **1.986**	MR/37/1 **1.987**	MR/46/1 **0.999**	MR/55/1 **1.523**	MR/63/1 **1.206**	MR/71/1 **2.320**	MR/79/1 **1.637**	MR/87/1 **2.077**
C	**C- 1.728**	MR/07/1 **1.709**	MR/15/1 **1.778**	MR/23/1 **2.272**	MR/31/1 **1.805**	MR/39/1 **1.971**	MR/47/1 **2.319**	MR/56/1 **0.923**	MR/64/1 **1.407**	MR/72/1 **1.606**	MR/80/1 **1.425**	MR/88/1 **2.173**
D	**C- 1.777**	MR/08/1 **2.242**	MR/16/1 **2.345**	MR/24/1 **0.992**	MR/21/1 **2.092**	MR/40/1 **2.053**	MR/48/1 **2.287**	MR/57/1 **1.985**	MR/65/1 **2.035**	MR/73/1 **2.371**	MR/81/1 **1.932**	EMPTY
E	MR/01/1 **1.585**	MR/09/1 **1.744**	MR/17/1 **2.199**	MR/25/1 **2.270**	MR/33/1 **2.390**	MR/41/1 **1.914**	MR/49/1 **1.787**	MR/58/1 **2.264**	MR/66/1 **1.653**	MR/74/1 **2.141**	MR/82/1 **2.223**	EMPTY
F	MR/02/1 **1.096**	MR/10/1 **2.154**	MR/18/1 **0.685**	MR/26/1 **1.495**	MR/34/1 **1.622**	MR/42/1 **2.230**	MR/50/1 **2.386**	MR/59/1 **1.812**	MR/67/1 **2.286**	MR/75/1 **2.328**	MR/83/1 **2.432**	EMPTY
G	MR/03/1 **1.602**	MR/11/1 **2.317**	MR/19/1 **2.171**	MR/27/1 **2.370**	MR/35/1 **1.077**	MR/42/1 **1.152**	MR/51/1 **2.283**	MR/60/1 **2.205**	MR/68/1 **1.808**	MR/76/1 **1.961**	MR/84/1 **2.379**	EMPTY
H	MR/04/1 **1.859**	MR/12/1 **1.618**	MR/20/1 **0.601**	MR/28/1 **2.363**	MR/35/1 **1.073**	MR/43/1 **2.446**	MR/53/1 **1.835**	MR/61/1 **2.372**	MR/69/1 **2.177**	MR/77/1 **2.343**	MR/85/1 **2.337**	EMPTY

ELISA plate 2

C-ELISA FOR CAMEL PPR

Date……16/08/2018…… Plate #……3……..Animal Species……CAMEL……Wavelength (λ)…450nm…….

	1	2	3	4	5	6	7	8	9	10	11	12
A	**C++ 0.518**	WJ/98/1 **2.718**	WJ/106/1 **2.557**	MN/01/1 **2.432**	MN/09/1 **2.222**	MN/17/1 **2.481**	MN/25/1 **2.373**	MN/33/1 **2.437**	MN/41/1 **2.233**	MN/49/1 **1.742**	MN/58/1 **2.101**	MN/66/1 **2.513**
B	**C++ 0.502**	WJ/99/1 **2.514**	WJ/107/1 **2.575**	MN/02/1 **2.258**	MN/10/1 **2.142**	MN/18/1 **2.245**	MN/26/1 **2.277**	MN/34/1 **2.209**	MN/42/1 **2.459**	MN/51/1 **2.491**	MN/59/1 **2.176**	MN/67/1 **2.445**
C	**C- 1.833**	WJ/100/1 **2.293**	SHEEP1 **0.873**	MN/03/1 **2.397**	MN/11/1 **2.242**	MN/19/1 **2.137**	MN/27/1 **2.218**	MN/35/1 **2.109**	MN/43/1 **2.504**	MN/52/1 **2.156**	MN/60/1 **2.423**	MN/68/1 **2.452**
D	**C- 1.950**	WJ/101/1 **2.226**	SHEEP2 **0.864**	MN/04/1 **2.600**	MN/12/1 **2.450**	MN/20/1 **2.078**	MN/28/1 **2.310**	MN/36/1 **2.385**	MN/44/1 **2.487**	MN/53/1 **2.579**	MN/61/1 **2.539**	MN/69/1 **2.501**
E	WJ/93/1 **2.493**	WJ/102/1 **2.428**	SHEEP3 **0.468**	MN/05/1 **2.605**	MN/13/1 **2.443**	MN/21/1 **2.035**	MN/29/1 **2.351**	MN/37/1 **2.359**	MN/45/1 **2.430**	MN/54/1 **2.626**	MN/62/1 **2.247**	MN/70/1 **1.855**
F	WJ/95/1 **2.332**	WJ/103/1 **2.410**	GOAT1 **0.786**	MN/06/1 **2.395**	MN/14/1 **2.380**	MN/22/1 **2.366**	MN/30/1 **1.979**	MN/38/1 **2.295**	MN/46/1 **2.316**	MN/55/1 **1.932**	MN/63/1 **2.475**	MN/71/1 **2.299**
G	WJ/96/1 **2.512**	WJ/104/1 **2.208**	GOAT2 **1.122**	MN/07/1 **2.126**	MN/15/1 **2.506**	MN/23/1 **2.353**	MN/31/1 **2.280**	MN/39/1 **2.331**	MN/47/1 **2.575**	MN/56/1 **1.795**	MN/64/1 **2.372**	MN/72/1 **2.440**
H	WJ/97/1 **2.781**	WJ/105/1 **2.236**	GOAT3 **1.640**	MN/08/1 **2.236**	MN/16/1 **2.700**	MN/24/1 **2.544**	MN/32/1 **2.620**	MN/40/1 **2.234**	MN/48/1 **2.054**	MN/57/1 **2.373**	MN/65/1 **2.736**	MN/73/1 **1.422**

ELISA plate 3

C-ELISA FOR CAMEL PPR

Date……16/08/2018…… Plate #……3……..Animal Species……CAMEL……Wavelength (λ)…450nm…….

	1	2	3	4	5	6	7	8	9	10	11	12
A	**C++ 0.518**	WJ/98/1 **2.718**	WJ/106/1 **2.557**	MN/01/1 **2.432**	MN/09/1 **2.222**	MN/17/1 **2.481**	MN/25/1 **2.373**	MN/33/1 **2.437**	MN/41/1 **2.233**	MN/49/1 **1.742**	MN/58/1 **2.101**	MN/66/1 **2.513**
B	**C++ 0.502**	WJ/99/1 **2.514**	WJ/107/1 **2.575**	MN/02/1 **2.258**	MN/10/1 **2.142**	MN/18/1 **2.245**	MN/26/1 **2.277**	MN/34/1 **2.209**	MN/42/1 **2.459**	MN/51/1 **2.491**	MN/59/1 **2.176**	MN/67/1 **2.445**
C	**C- 1.833**	WJ/100/1 **2.293**	SHEEP1 **0.873**	MN/03/1 **2.397**	MN/11/1 **2.242**	MN/19/1 **2.137**	MN/27/1 **2.218**	MN/35/1 **2.109**	MN/43/1 **2.504**	MN/52/1 **2.156**	MN/60/1 **2.423**	MN/68/1 **2.452**
D	**C- 1.950**	WJ/101/1 **2.226**	SHEEP2 **0.864**	MN/04/1 **2.600**	MN/12/1 **2.450**	MN/20/1 **2.078**	MN/28/1 **2.310**	MN/36/1 **2.385**	MN/44/1 **2.487**	MN/53/1 **2.579**	MN/61/1 **2.539**	MN/69/1 **2.501**
E	WJ/93/1 **2.493**	WJ/102/1 **2.428**	SHEEP3 **0.468**	MN/05/1 **2.605**	MN/13/1 **2.443**	MN/21/1 **2.035**	MN/29/1 **2.351**	MN/37/1 **2.359**	MN/45/1 **2.430**	MN/54/1 **2.626**	MN/62/1 **2.247**	MN/70/1 **1.855**
F	WJ/95/1 **2.332**	WJ/103/1 **2.410**	GOAT1 **0.786**	MN/06/1 **2.395**	MN/14/1 **2.380**	MN/22/1 **2.366**	MN/30/1 **1.979**	MN/38/1 **2.295**	MN/46/1 **2.316**	MN/55/1 **1.932**	MN/63/1 **2.475**	MN/71/1 **2.299**
G	WJ/96/1 **2.512**	WJ/104/1 **2.208**	GOAT2 **1.122**	MN/07/1 **2.126**	MN/15/1 **2.506**	MN/23/1 **2.353**	MN/31/1 **2.280**	MN/39/1 **2.331**	MN/47/1 **2.575**	MN/56/1 **1.795**	MN/64/1 **2.372**	MN/72/1 **2.440**
H	WJ/97/1 **2.781**	WJ/105/1 **2.236**	GOAT3 **1.640**	MN/08/1 **2.236**	MN/16/1 **2.700**	MN/24/1 **2.544**	MN/32/1 **2.620**	MN/40/1 **2.234**	MN/48/1 **2.054**	MN/57/1 **2.373**	MN/65/1 **2.736**	MN/73/1 **1.422**

ELISA plate 4

C-ELISA FOR CAMEL PPR

Date……16/08/2017…… Plate #……4……..Animal Species……CAMEL……Wavelength (λ)…450nm…….

	1	2	3	4	5	6	7	8	9	10	11	12
A	**C++ 0.574**	MN/78/1 **2.519**	MN/86/1 **2.069**	IS/06/1 **2.042**	IS/14/0 **2.490**	IS/21/0 **2.407**	IS/29/0 **2.413**	IS/37/0 **2.135**	IS/45/0 **2.171**	IS/53/0 **2.477**	IS/61/0 **1.425**	IS/69/0 **2.315**
B	**C++ 0.515**	MN/79/1 **1.758**	GOAT 2 **1.162**	IS/07/1 **1.971**	IS/15/0 **1.582**	IS/22/0 **0.758**	IS/30/0 **2.416**	IS/38/0 **1.941**	IS/46/0 **1.592**	IS/54/0 **1.817**	IS/62/0 **2.029**	IS/70/0 **2.370**
C	**C- 1.578**	MN/80/1 **2.098**	GOAT 4 **0.415**	IS/08/1 **2.205**	IS/16/0 **1.633**	IS/23/0 **1.964**	IS/31/0 **2.003**	IS/39/0 **2.323**	IS/47/0 **2.422**	IS/55/0 **1.989**	IS/63/0 **2.093**	IS/71/0 **2.204**
D	**C- 1.847**	MN/81/1 **2.253**	IS/01/1 **2.348**	IS/09/1 **1.892**	IS/17/0 **1.813**	IS/24/0 **2.343**	IS/32/0 **2.374**	IS/40/0 **2.479**	IS/48/0 **1.838**	IS/56/0 **2.347**	IS/64/0 **1.896**	IS/72/1 **2.185**
E	MN/74/1 **2.507**	MN/82/1 **2.151**	IS/02/1 **1.233**	IS/10/1 **2.303**	IS/18/0 **1.932**	IS/25/0 **1.618**	IS/33/0 **1.492**	IS/41/0 **1.860**	IS/49/0 **2.050**	IS/57/0 **2.089**	IS/65/0 **2.127**	IS/73/1 **2.389**
F	MN/75/1 **2.356**	MN/83/1 **2.175**	IS/03/1 **2.095**	IS/11/0 **2.041**	IS/19/0 **2.469**	IS/26/0 **1.555**	IS/34/0 **2.057**	IS/42/0 **1.536**	IS/50/0 **1.935**	IS/58/0 **2.434**	IS/66/0 **0.962**	IS/74/1 **0.620**
G	MN/76/1 **2.498**	MN/84/1 **2.284**	IS/04/1 **1.818**	IS/12/0 **2.462**	IS/20/0 **2.113**	IS/27/0 **1.915**	IS/35/0 **2.017**	IS/43/0 **2.320**	IS/51/0 **2.011**	IS/59/0 **2.014**	IS/67/0 **2.170**	IS/75/1 **2.021**
H	MN/77/1 **2.247**	MN/85/1 **2.236**	IS/05/1 **1.751**	IS/13/0 **2.319**	IS/21/0 **2.086**	IS/28/0 **2.207**	IS/36/0 **2.346**	IS/44/0 **1.745**	IS/52/0 **1.979**	IS/60/0 **2.240**	IS/68/0 **2.391**	IS/76/1 **2.261**

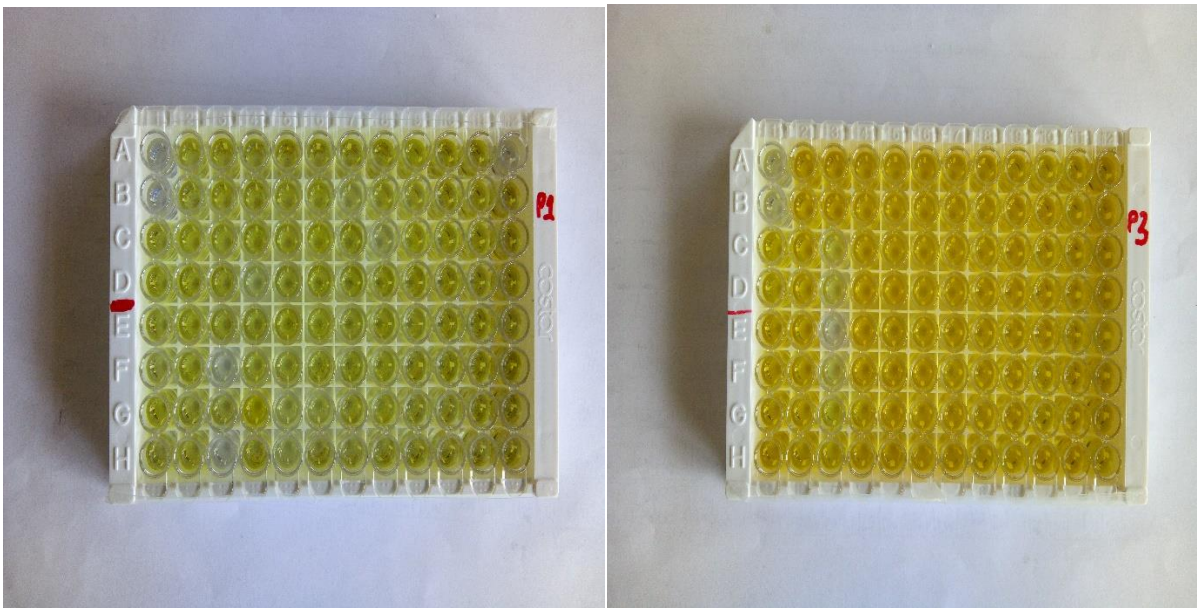
ELISA plate 5

C-ELISA FOR CAMEL PPR

Date……18/08/2017…… Plate #……5……..Animal Species…CAMEL……Wavelength (λ)……450nm…….

	1	2	3	4	5	6	7	8	9	10	11	12
A	**C++ 0.592**	IS/81/1 **2.192**	IS/89/1 **1.357**	IS/97/1 **2.221**	IS/105/1 **2.250**	IS/113/1 **2.306**	BAR1 **2.215**	BAR7 **1.951**	BAR14 **2.171**	KUL5 **2.036**	KUL11 **2.352**	EMPTY
B	**C++ 0.575**	IS/82/1 **2.159**	IS/90/1 **2.072**	IS/98/1 **1.959**	IS/106/1 **1.572**	IS/114/1 **2.323**	BAR2 **2.385**	BAR8 **2.346**	BAR14 **2.257**	KUL6 **1.609**	KUL11 **2.376**	EMPTY
C	**C- 1.918**	IS/83/1 **1.956**	IS/91/1 **2.313**	IS/99/1 **2.032**	IS/107/1 **2.312**	IS/115/1 **1.879**	BAR3 **2.203**	BAR8 **2.405**	BAR15 **2.272**	KUL6 **1.677**	KUL12 **1.920**	EMPTY
D	**C- 1.919**	IS/84/1 **2.286**	IS/92/1 **2.231**	IS/100/1 **2.247**	IS/108/1 **1.959**	IS/116/1 **1.711**	BAR4 **2.247**	BAR9 **1.875**	KUL1 **1.837**	KUL7 **2.369**	KUL13 **2.382**	EMPTY
E	IS/77/1 **1.812**	IS/85/1 **2.250**	IS/93/1 **2.336**	IS/101/1 **2.215**	IS/109/1 **2.146**	IS/117/1 **2.081**	BAR5 **1.377**	BAR10 **1.548**	KUL2 **2.174**	KUL8 **2.370**	KUL14 **2.452**	EMPTY
F	IS/78/1 **2.301**	IS/86/1 **1.306**	IS/94/1 **2.337**	IS/102/1 **2.188**	IS/110/1 **2.312**	IS/118/1 **1.811**	BAR5 **1.424**	BAR11 **1.807**	KUL3 **2.055**	KUL9 **2.386**	KUL14 **2.442**	EMPTY
G	IS/79/1 **1.946**	IS/87/1 **1.939**	IS/95/1 **1.865**	IS/103/1 **1.976**	IS/111/1 **2.091**	IS/119/1 **2.085**	BAR6 **2.264**	BAR12 **2.372**	KUL4 **2.308**	KUL10 **2.344**	KUL15 **2.016**	EMPTY
H	IS/80/1 **2.326**	IS/88/1 **2.058**	IS/96/1 **2.380**	IS/104/1 **1.854**	IS/112/1 **2.262**	IS/120/1 **1.917**	BAR6 **2.155**	BAR13 **2.351**	KUL4 **2.209**	KUL10 **1.953**	KUL15 **2.145**	EMPTY

Appendix 3: ELISA Plates showing processed samples



Appendix 4: Logistic Regression results

Logistic Regression results showing County as risk factor for PPR sero-positivity

County

2 2.853659 2.05927 1.45 0.146 .6936717 11.73951

3 1.147059 .9493723 0.17 0.868 .2265072 5.808839

4 1 (empty)

_cons .025641 .0149924 -6.27 0.000 .0081514 .0806561

Logistic Regression results showing Sex as risk factor for PPR sero-positivity

. Logistic pprseropositivity i.Sex

Logistic regression Number of obs = 398

LR chi2 (1) = 5.41

Prob > chi2 = 0.0200

Log likelihood = -51.130519 Pseudo R2 = 0.0503

PPR seropositivity Odds Ratio Std. Err. Z P>z [95% Conf. Interval]

2. Sex .2497502 .1490893 -2.32 0.020 .0775136 .8046996

_cons .07 .0273679 -6.80 0.000 .0325315 .1506232