

DEDICATION

To my teachers in all fields throughout my life

&

To the soul of my father: Professor *Ahmed Ali Ismail*

With great

Appreciation

I dedicate this work

Abdallami  **Friday, February 13, 2015**

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my supervisors, Professor *Ahmed Ali Ismail* and Dr. *Tamador Elkhansa Elnour Angara* for their intensive advises, encouragement and continuous support during this study which might have not been completed without their supervision. I am also indebted to Dr. *Osman Mukhtar Osman*, Head Department of Parasitology in the Veterinary Research Institute (VRI) for his continuous follow up during this work. I would also like to thank the research group of the project entitled: Compliance with WHO agreement by formulating long term brucellosis control strategy in Khartoum State for their valuable collaboration during this Study. My deep appreciation to Professor *Mohamed Abdel-Salam* and the Research Council, College of Veterinary Medicine, Sudan University of Science and Technology (CVMA/SUST) for their un-limited official help during this study. I am also pleased to thank Dr. *Seham Elias*, Dr. *Hisham Ismail Seri* for their continuous support with relevant reports concerning this study. I would also like to express my sincere gratitude to my colleagues in the University of Bahri, West Kordofan University and the University of Nyala for their continuous follow up and encouragement during this work. I greatly appreciate the frequent assistance afforded by the staff members and technicians of the Research Lab. of Parasitology, (CVMA/SUST) including Mrs. *Reem Moaz*, Mrs. *Ferial* and Mr. *Sarmad*. Hereafter, great thanks to Professor *Mohamed Tag-Eldin* for his assistance in the statistical analysis of the data.

The deeper more and more thanks belong to my family and all friends for their patience and help. Particular thanks to my brothers abroad (Professor *Nasreldin* and Dr. *Adlan*) for their valuable help in hard currency required for the diagnostic kits and publication fees. Special thanks and appreciation belong to my Mother (*Sara*), wife (*Entisar*) and my children who accompanied me through good and bad times during this work.

ABSTRACT

Toxoplasma gondii and *Neospora caninum* are closely related intracellular parasites which cause reproductive failure in man and animals worldwide. The aim of this study was to determine the sero-epidemiology of these parasites in dairy cows, and the co-herded camel, sheep and goats in the Sudan. Serological survey to detect antibodies against these parasites was carried out using different serological tests. The possible potential risk factors and the association between the seropositivity of these parasites and *B. abortus* infection were also analyzed using questionnaire and the available data of brucellosis from the concurrent research project. The present study is the first large scale report on serological evidence of both *T. gondii* and *N. caninum* infection associated with *B. abortus* infection in dairy farms from the Sudan as well as the risk factors associated with their seropositivity. The study revealed that, the overall seroprevalence of *T. gondii* infection at herd level of dairy animals in the State was 92.7%. The within herd seroprevalence was ranging from 8% up to 100% with mean of $51.3 \pm 24.3\%$ in different herds of different dairy animals species in the State. The differences between the three districts, the seven localities and the four animal species were statistically highly significant ($p < 0.01$). The overall sero-prevalence of *T. gondii* infection in dairy animals –at individual level- was 45.3%. Sheep scored the highest seroprevalence rate (75.0%) followed by goats (64.0%), camels (54.1%) and cattle (40.9%) with high statistically significant differences ($p < 0.01$). The highest level of antibody titration (1:128) was reported in sheep and goats. The LAT and ELISA tests detected relatively similar proportion of *Toxoplasma* positive serum samples of dairy cows. The level of agreement between the two tests as well as the area under the ROC curve was found to be fair

and associated with the level of antibody titration recorded by LAT. The univariate analysis included region, herd type, source of fodder, source of water, neosporosis, keeping cats, stray cats, keeping both dogs and cats and presence of both stray dogs and cats as risk factors associated with positive status of *T. gondii* infection. However, the multivariate analysis indicated region (Omdurman, $p=0.000$ and Bahri, $p=0.044$), Animal species (sheep, $p=0.006$) as the significant ($p<0.05$) risk factors of *T. gondii* seropositivity.

The overall seroprevalence of *N. caninum* at herd and individual level of dairy animals in the present work was 32.2% (56/174) and 8.8% (80/906) respectively. The within herd seroprevalence was ranging from 7% up to 75% with mean of 27.2 ± 15.4 in different herds of different dairy animals species. The highest percent inhibition (pi) recorded was 93% with mean of 38.7 ± 12.3 and 39.3 ± 13.9 at herd and individual level respectively. The highest prevalence rate, frequency distribution of the prevalence rate and the pi was reported in cattle at both herd and individual level followed by camel, goats and sheep respectively. Interestingly, camel was relatively similar to cattle in the occurrence of *N. caninum* infection in this study. There were no significant differences in the seroprevalence of *N. caninum* among the three districts, the seven localities and the four animal species ($p>0.05$). The univariate analysis included Production system, source of concentrate, keeping dogs, other diseases (Toxoplasmosis) as risk factors associated with cELISA positive status of *N. caninum* infection. The multivariate analysis indicated only production system (Intensive, $p=0.019$) and source of concentrate (Readymade, $p=0.007$) as the statistically significant ($p<0.05$) risk factors of being Neospora cELISA positive.

Mix-infection was observed in 176 heads (19.7%) out of all 895 seropositive animals and in 149 (47.9%) out of the 311 *B. abortus*

seropositive ones. Out of these 9 (6.04%) animals harbour the antibodies of the three abortifacient agents (*T. gondii*, *N. caninum* and *B. abortus*). Additionally 39 (48.8%) animals out of the 80 *N. caninum* seropositive animals have mix-infection with *T. gondii*. The univariate analysis showed no significant ($p>0.05$) association between *B. abortus* seropositivity and the two protozoal abortifacients. However, significant ($p=0.041$) association was observed between *N. caninum* seropositivity and *T. gondii* infection. Increasing odds ratios without significant ($p>0.05$) associations were observed in the multivariate analysis.

Different reproductive problems (abortion and repeated abortion, repeat breeding, stillbirth and neonatal mortalities) were reported during interview with the owners of the investigated dairy herds. Interestingly, 58% of the interviewed farmers send their dairy animals with reproduction problems to slaughter houses. With the exception of *B. abortus* the other causes of reproduction failure were neglected. Generally, this is the first comprehensive data explaining the association between *N. caninum*, *T. gondii*, their risk factors and *B. abortus* seropositivity in dairy animals from the Sudan. In addition, this study documents for the first time the existence of antibody against *N. caninum* in camels, sheep and goats in the Sudan. **In conclusion**, the results obtained in this study confirm the wide spread nature of *T. gondii* and *N. caninum* exposure together with *B. abortus* among dairy animals in the Sudan. This indicates the need for further work to identify appropriate bio-security measures to prevent transmission to human and industrial animals, thus reducing the economical consequences of these abortifacient agents in the country.

المستخلص

تناولت هذه الدراسة طفيليين متشابهين هما التوكسوبلازما والنيوسبورا (and T. gondii N. caninum) ويسببان فشل الولادة في الإنسان والحيوان. وعليه صمم هذا البحث لدراسة وبائية هذين الطفيليين في أمصال أبقار مزارع الألبان والحيوانات الأخرى (إبل؛ ضأن؛ ماعز) المتواجده في هذه المزارع باستخدام أنواع مختلفه من الإختبارات المصلية. ناقشت الدراسة أيضاً العوامل التي يمكن أن يكون لها إرتباط بحدوث الإصابة بالإضافة الى علاقتها بوجود إصابه بالبروسيلة. الدراسة الحالية هي الأوسع والأولى من نوعها عندما جمعت بين حدوث الإصابة بهذين الطفيليين مع الإصابة بمرض البروسيلة زائداً العوامل المؤثره على الإصابة في مزارع الألبان. بلغت مجمل نسبة الإصابة بالتوكسوبلازما في القطعان المفحوصه 92.7% بمعدلات مختلفه تراوحت من 8% الى 100% (متوسط $51.3 \pm 24.3\%$) في المزارع المختلفه بالولايه. سجلت الدراسة فروقات إحصائية ذات دلالة معنويه عاليه ($p < 0.01$) بين مناطق الولايه الثلاث ومحليات الولايه المختلفه وكذلك بين أنواع الحيوانات المختلفه. أما مجمل نسبة الإصابة بالتوكسوبلازما في جميع الحيوانات المفحوصه فبلغت 45.3% و كان الضأن الأكثر إصابة (75.0%) بهذا الطفيل يليه الماعز (64.0%) فالإبل (54.1%) ثم الأبقار (40.9%) بإختلاف إحصائي معنوي عالي ($p < 0.01$). كما أن معايرة الأجسام المضاده الأعلى (1:128) فسجلت في مصل الضأن والماعز. نسبة الإصابة باستخدام الاختبارين المصليين المتاحين أو الأكثر استعمالاً في البلاد (LAT and ELISA) كانت متساويه تقريباً؛ خاصةً وأن دقة وحساسية وتوافق الاختبارين كانت معقوله ولها علاقه بالتخفيفات المختلفه لاختبار التلازن (LAT). التحليل الأولي أدخل المنطقه؛ نوع القطيع؛ مصادر الأعلاف والماء؛ وجود القطط والكلاب؛ والإصابة بالنيوسبورا كعوامل مرتبطه بالإصابة بالتوكسوبلازما ($p < 0.05$). أما التحليل اللوجستي فقد أثنى على إختلاف المنطقه ونوع الحيوان كمؤثرات مرتبطه بالإصابة وبدرجه معنويه ($p < 0.05$) إحصائياً.

أما مجمل نسبة الإصابة بالنيوسبورا في القطعان المفحوصه فبلغت 32.2% و في جميع الحيوانات 8.8% بمعدلات مختلفه تراوحت من 7% الى 75% (متوسط % 15.4±5527.2) في المزارع المختلفه بالولايه. أعلى نسبة تثبيط (π) في الإختبار

المناعي المرتبط بالانزيم التنافسي (cELISA) كانت 93% بمتوسط 13.9 ± 39.3 % في الحيوانات المختلفه. الأبقار هي الأكثر إصابةً و الأكثر قابليةً للإصابة بالنيوسبورا يليها الإبل ثم الماعز فالضأن. ليس هناك إختلافات إحصائية معنويه ($p > 0.05$) بين مناطق الولاية الثلاث ومحليات الولاية و أنواع الحيوانات المختلفه. التحليل الأولي أدخل نمط الرعايه؛ مصادر المركزات؛ وجود الكلاب؛ والإصابة بالتوكسوبلازما كعوامل مرتبطة بالإصابة بالنيوسبورا ($p < 0.05$). أما التحليل اللوجستي فقد أثنى على النمط المكتف والمركزات الجاهزه كمؤثرات معنويه ($p < 0.05$) إحصائياً.

من الملاحظ إزدواجية الإصابة بواقع 19.7%؛ كما أن 48.8% من الحيوانات المصابه بالنيوسبورا تحمل أيضاً أجسام مضاده للتوكسوبلازما و 47.9% من الحيوانات المصابه بالبروسيلا تحمل أيضاً أجسام مضاده لأحد أو لهذين الطفيليين. الجدير بالذكر أن 6.04% من الحيوانات تحمل أجسام مضاده لمسببات الإجهاض الثلاث (توكسوبلازما؛ نيوسبورا؛ وبروسيلا). لم يظهر التحليل أي إرتباط إحصائي معنوي ($p > 0.05$) بين الإصابة بالطفيليين ووجود الإصابة بالبروسيلا. إلا أنه ظهر إرتباط إحصائي معنوي ($p < 0.05$) بين الإصابة بالنيوسبورا ووجود الإصابة بالتوكسوبلازما.

خلال المقابلات (الإستبيان) تلاحظ كثرة مشاكل الخصوبه والإجهاض وتكرار الإجهاض بالإضافة الى موت المواليد في مزارع الألبان. أكثر من نصف الأبقار الفاشله في الإنتاج والولاده أو متدنية الخصوبه (58%) يتم بيعها للجزارين (السلخانه). أغلبية المربين يجهلون مسببات الإجهاض؛ والقليل منهم ذكر البروسيلا كمسبب للإجهاض. عموماً فإن هذه الدراسه هي الأولى والأوسع التي تشرح العلاقة بين طفيلي التوكسوبلازما والنيوسبورا والبروسيلا؛ والعوامل المرتبطه بحدوثهما. كما أنها الشاهد الأول لوجود الأجسام المضاده لطفيل النيوسبورا في الإبل والماعز والضأن بالسودان.

هذا وقد خلصت هذه الدراسه إلى أن تعرض حيوانات المزرعه لطفيلي التوكسوبلازما والنيوسبورا كثير الإنتشار وبنفس مستوى إنتشار البروسيلا في مزارع الألبان. وعليه فإن الأمر يتطلب إجراء مزيد من الدراسات في مجال السلامه الحيويه لوقاية الإنسان والحيوان مما يقلل من الأثار الصحيه والإقتصادييه لمسببات الإجهاض في إنسان وحيوان السودان.

TABLE OF CONTENTS

Item	Page
Dedication	I
Acknowledgement	II
Abstract	III
Arabic abstract	VI
Table of contents	VIII
List of tables	XII
List of figures	XV
List of plates	XV
CHAPTER ONE: INTRODUCTION	
1.1. Background	
1.2. Statement of the problem	7
OBJECTIVES	
1.3. The objectives	9
1.3.1. Over all objectives	9
1.3.2. Specific objectives	10
CHAPTER TWO: LITERATURE REVIEW	
2.1. <i>Toxoplasma gondii</i>	12
2.1.1. History of <i>T. gondii</i>	12
2.1.2. Biology of <i>T. gondii</i>	13
2.1.2.1. Transmission of <i>T. gondii</i>	13
2.1.2.2. Source of Infection of <i>T. gondii</i>	15
2.1.2.2.1. Transmission and source of <i>T. gondii</i> Infection for Humans	16
2.1.2.3. Life Cycle of <i>T. gondii</i>	17
2.1.2.3.1. Development of <i>T. gondii</i> in the Final Host	17
2.1.2.3.2. Development of <i>T. gondii</i> in the Intermediate Hosts	18
2.1.2. 4. Pathogenesis of <i>T. gondii</i> Infection	19
2.1.2.4.1. Pathology of <i>T. gondii</i> Infection	20
2.1.3. Toxoplasmosis or (<i>T. gondii</i> infection)	21
2.1.3.1. Animal Toxoplasmosis	21
2.1.3.2. Human Toxoplasmosis	22
2.1.3.3. Clinical Manifestation of Toxoplasmosis	23
2.1.3.3.1. Clinical Manifestation in Sheep	24
2.1.3.3.2. Clinical Manifestation in Cats	25
2.1.3.3.3. Clinical Signs of Human Toxoplasmosis	25

2.1.3.4. Economic Importance of Toxoplasmosis	26
2.1.3.4.1. Socio-economic Importance of Human Toxoplasmosis	27
2.1.3.5. Epidemiology of Toxoplasmosis	28
2.1.3.5.1. Risk factors Associated with Toxoplasmosis	30
2.1.3.6. Diagnosis of Toxoplasmosis	32
2.1.3.6.1. Serological Techniques	33
2.1.3.6.2. Bioassay	34
2.1.3.6.3. Histopathology	35
2.1.3.6.4. Impression Smears	35
2.1.3.6.5. Immunohistochemistry	35
2.1.3.6.6. Molecular Technique	36
2.1.3.6.7. Diagnosis of Cat Toxoplasmosis	36
2.1.4. Sero-prevalence of <i>T. gondii</i>	36
2.1.4.1 Sero-prevalence of <i>T. gondii</i> Antibodies in Cattle	37
2.1.4.1.1. Seroprevalence of <i>T. gondii</i> Antibodies in Cattle from the Sudan	38
2.1.4.2. Sero-prevalence of <i>T. gondii</i> Antibodies in Sheep	39
2.1.4.2.1. Seroprevalence of <i>T. gondii</i> Antibodies in Sheep from the Sudan	42
2.1.4.3. Sero-prevalence of <i>T. gondii</i> Antibodies in Goats	43
2.1.4.3.1. Seroprevalence of <i>T. gondii</i> Antibodies in Goat from the Sudan	44
2.1.4.4. Seroprevalence of <i>T. gondii</i> antibodies in Equine	44
2.1.4.4.1. Seroprevalence of <i>T. gondii</i> Antibodies in Equine in the Sudan	44
2.1.4.5. Seroprevalence of <i>T. gondii</i> Antibodies in Camels	45
2.1.4.5.1. Seroprevalence of <i>T. gondii</i> Antibodies in Camels from the Sudan	45
2.1.4.6. Seroprevalence of <i>T. gondii</i> Antibodies in Cats	46
2.1.4.6.1. Seroprevalence of <i>T. gondii</i> Antibodies in Cats from the Sudan	48
2.1.4.7. Seroprevalence of <i>T. gondii</i> Antibodies in Dogs	48
2.1.4.8. Seroprevalence of <i>T. gondii</i> Antibodies in Wild Animals	49
2.1.4.9. Seroprevalence of <i>T. gondii</i> antibodies in Pigs	49
2.1.4.10. Seroprevalence of <i>T. gondii</i> Antibodies in Fowl	50
2.1.4.11. Seroprevalence of <i>T. gondii</i> Antibodies in Humans	50
2.1.4.11.1. Seroprevalence of <i>T. gondii</i> Antibodies in Humans in Africa:	54
2.1.4.11.2. Seroprevalence of <i>T. gondii</i> Antibodies in Humans in the Sudan	55
2.1.5. Control of Toxoplasmosis	55
2.1.5.1. Treatment of Toxoplasmosis	55
2.1.5.2. Prevention Measures	56
2.1.5.2.1. Vaccination	56
2.1.5.3. Control of Toxoplasmosis in the Sudan	57
2.2. <i>Neospora caninum</i> (<i>N. caninum</i>)	58
2.2.1. History of <i>N. caninum</i>	58
2.2.2. General Biology of <i>N. caninum</i>	58
2.2.2.1. Pathogenesis of <i>N. caninum</i> Infection	60
2.2.3. Epidemiology of <i>N. caninum</i> Infection	60

2.2.3.1. Transmission	60
2.2.3.1.1. Transmission of <i>N. caninum</i> in Dogs	61
2.2.3.2. Risk factors Associated with <i>N. caninum</i> Infection	62
2.2.4. Neosporosis	62
2.2.4.1. Cattle Neosporosis	62
2.2.4.1.1. Clinical signs of Neosporosis in Cattle	63
2.2.4.2. Neosporosis in dogs	64
2.2.4.3. Camel neosporosis	64
2.2.4.4. Neosporosis in Sheep and Goats	65
2.2.4.5. Equine Neosporosis	65
2.2.4.6. The Economic Losses due to Neosporosis	66
2.2.4.7. Diagnosis of <i>N. caninum</i> Infection	67
2.2.4.7.1. Serologic Prevalence of <i>N. caninum</i>	68
2.2.4.7.2. Seroprevalence of <i>N. caninum</i> Infection in Cattle	69
2.2.4.7.2.1. Seroprevalence of <i>N. caninum</i> infection in Cattle from the Sudan	69
2.2.4.7.3. Seroprevalence of <i>N. caninum</i> Infection in Other animals	70
2.2.4.7.3.1. Seroprevalence of <i>N. caninum</i> Infection in Sheep and Goats	70
2.2.4.7.3.2. Seroprevalence of <i>N. caninum</i> Infection in Camels	71
2.2.4.7.3.3. Seroprevalence of <i>N. caninum</i> Infection in Water buffaloes	71
2.2.4.8. Control of <i>N. caninum</i> Infection	71
2.2.4.8.1. Treatment of Neosporosis	71
2.2.4.8.2. Prevention Measures	72
2.2.4.8.3. Vaccination	72
2.3. Mix-infection of <i>N. caninum</i> with <i>T. gondii</i> and Other Abortifacient Pathogens	72
2.3.1. Mix-infection in Cattle and Water buffaloes	73
2.3.2. Mix-infection in Sheep and Goats	74
2.3.3. Mix-infection in Dogs and Cats	74
2.3.4. Mix-infection in Camel	74
2.4. <i>N. caninum</i> Infection in the Sudan	75
CHAPTER THREE: MATERIALS AND METHODS	
3.1. Study Design	77
3.2. The Study Area Description	77
3.2.1. Criteria for Selection of the Study Area	78
3.3. Study Population	79
3.3.1. Animals	79
3.3.1.1. Cattle	79
3.3.1.2. Sheep, Goats and Camels	80
3.3.1.3. Dogs and Cats	80
3.3.1.4. Inclusion and Exclusion Criteria of the investigated Animals	80
3.4. Sampling (Sample Design)	81
3.5. Collection of Epizootiological Data	82
3.6. Samples Collection	83

3.6.1. Serum Samples	83
3.6.2. Faecal Samples	84
3.7. Serological Tests	84
3.7.1. Detection of Antibodies against <i>Toxoplasma gondii</i>	84
3.7.1.1. Latex Agglutination Test (LAT)	84
3.7.1.1.a. Screening Test	85
3.7.1.1.b. The Level of Antibody Titration	85
3.7.1.2. Indirect ELISA	86
3.7.2. Detection of Antibodies Against <i>Neospora caninum</i>	87
3.8. Detection of Antibodies against <i>Brucella abortus</i>	88
3.8.1. Rose Bengal Plate Test (RBPT)	88
3.8.2. Competitive enzyme linked Immuno-sorbent Assay (cELISA)	88
3.9. Data Management and Statistical Analysis	89

CHAPTER FOUR: RESULTS	
4.1. Results of <i>T. gondii</i> infection	94
4.1.1. Sero-prevalence of <i>T. gondii</i> Infection Using LAT	94
4.1.1.1. Sero-prevalence of <i>T. gondii</i> Infection at herd level	94
4.1.1.2. Ser-prevalence of <i>T. gondii</i> infection at individual level	97
4.1.2. Detection of <i>T. gondii</i> infection Using ELISA	99
4.1.2.1. Seroprevalence of <i>T. gondii</i> at herd level Using ELISA	99
4.1.2.2. At individual level Ser-prevalence Using ELISA	101
4.1.3. Detection of Antibody against <i>T. gondii</i> in Dairy Cows Using LAT and ELISA	102
4.1.3.1. The Level of agreement between LAT and ELISA	102
4.1.3.2. The effect of the level of antibody titration on ELISA	103
4.1.4. Analysis of Risk Factors Associated with Seroprevalence of <i>T. gondii</i>	104
4.1.4.1. Univariate analysis of risk factors	104
4.1.4.2. Multivariate analysis of risk factors	104
4.2. Results of <i>N. caninum</i> infection Using cELISA	107
4.2.1. Ser-prevalence of <i>N. caninum</i> in dairy farms at herd level	107
4.2.2. Ser-prevalence of <i>N. caninum</i> in the dairy farms at individual level	110
4.2.3. Analysis of Risk Factors Associated with Seroprevalence of <i>N. caninum</i>	113
4.2.3.1. Univariate analysis of risk factors Associated with <i>N. caninum</i> infection	113
4.2.3.2. Multivariate analysis of risk factors Associated with <i>N. caninum</i> infection	114
4.3. Co-existence of <i>T. gondii</i> and <i>N. caninum</i>	116
4.4. Co-existence of <i>T. gondii</i> , <i>N. caninum</i> and <i>B. abortus</i>	119
4.5. Summary of the Questionnaire Results	122
4.5.1. Herders Awareness and Perception	123
CHAPTER FIVE: DISCUSSION	
5. Discussion	125
CHAPTER SIX: CONCLUSION&RECOMMENDATION	
6.1. Conclusions	137

6.2. Recommendations	139
REFERENCES	
	141
APPENDICES	
	183

LIST OF TABLES

Table	Page
1.1: Previous data on Serological surveys for <i>T. gondii</i> infection in animals in the Sudan	7
1.2: Previous Serological surveys for <i>N. caninum</i> infection in cattle from the Sudan	7
3.1: Live stock estimate in the Khartoum State	91
3.2: Some Geographical information about the study area	91
3.3: Distribution of dairy herds/animals sampled for detection of antibodies directed to <i>T. gondii</i> and or/and <i>N. caninum</i> in the seven localities of the Khartoum State	91
3.4: Number of animals sampled for detection of antibody against <i>T. gondii</i> or/and <i>N. caninum</i> in the three district of the State	91
3.5: Details of the sampled sites of dairy farms tested for detection of antibodies directed to <i>N. caninum</i> or/and <i>T. gondii</i> in the State	91
4.1.1: Sero-prevalence of <i>T. gondii</i> infection in Dairy herds from the Khartoum State	94
4.1.2: Frequency distribution of Sero-prevalence rate of <i>T. gondii</i> infection in the State	94
4.1.3: Sero-prevalence of <i>T. gondii</i> infection in Dairy herds from the three districts of the State	95
4.1.4: Sero-prevalence of <i>T. gondii</i> infection in dairy herds from the seven localities of the State	95
4.1.5: Frequency distribution of within herd prevalence rate of <i>T. gondii</i> infection in the three districts of the State	96
4.1.6: Frequency distribution of within herd prevalence rate of <i>T. gondii</i> infection in the seven localities of the State	96
4.1.7: Seroprevalence of <i>T. gondii</i> infection in dairy herds of different animals in the State	96
4.1.8: Frequency distribution of within herd prevalence rate of <i>T. gondii</i> infection in different dairy animals in the State	97
4.1.9: Sero-prevalence of <i>T. gondii</i> infection in dairy animals from the Khartoum State	97
4.1.10: Sero-prevalence of <i>T. gondii</i> infection in dairy animals from the three districts of the State	98
4.1.11: Sero-prevalence of <i>T. gondii</i> infection in dairy animals	98

from the seven localities of the State	
4.1.12. Sero-prevalence of <i>T. gondii</i> infection in different dairy animal species from the State	99
4.1.2.1: Sero-prevalence of <i>T. gondii</i> infection in Dairy herds using ELISA	99
4.1.2.2: Seroprevalence and Frequency Distribution of Prevalence rate of <i>T. gondii</i> infection within herds of Dairy Cattle in the three Districts of the State using ELISA	100
4.1.2.3: Seroprevalence and Frequency Distribution of Prevalence rate of <i>T. gondii</i> infection within herds of Dairy Cattle in the seven localities of the State using ELISA	101
4.1.2.4. Sero-prevalence of <i>T. gondii</i> in dairy cattle from the Khartoum State, using ELISA	101
4.1.2.5. Sero-prevalence of <i>T. gondii</i> infection in Dairy Cattle from the three districts of the Khartoum State using ELISA	101
4.1.2.6. Sero-prevalence of <i>T. gondii</i> infection in dairy cattle from the seven localities of the Khartoum State using ELISA	102
4.1.3.1. The overall prevalence rate of <i>T. gondii</i> in dairy cattle in the Khartoum State using LAT and ELISA tests	102
4.1.3.2: The level of agreement between ELISA and LAT in the detection of <i>T. gondii</i> infection in dairy cattle from the State	103
4.1.3.3: The level of agreement between ELISA and the level of antibody titration using LAT in the detection of <i>T. gondii</i> infection in dairy cattle from the State	104
4.1.4.1: Estimated Seroprevalence of <i>T. gondii</i> infection in Dairy animals from Khartoum State and Univariate analysis for the associated Risk factors	105
4.1.4.2: Results of univariate association of Risk factor with LAT toxoplasma seropositivity in dairy animals from Khartoum State	106
4.1.4.3: Results of Multivariate association of Risk factor with LAT toxoplasma seropositivity in dairy animals from the state	107
4.2.1: Sero-prevalence of <i>N. caninum</i> and percent inhibition in dairy herds in the Khartoum State	108
4.2.2: Frequency distribution of sero-prevalence rate of <i>N. caninum</i> in dairy herds from the State.	108
4.2.3: Sero-prevalence and frequency distribution of prevalence rate of <i>N. caninum</i> within herds of the three districts of the State	109
4.2.4: Seroprevalence and Frequency distribution of prevalence rate of <i>N. caninum</i> in herds of the seven localities of the State	109
4.2.5: Sero-prevalence and frequency distribution of prevalence rate of <i>N.</i>	110

<i>caninum</i> within herds of different dairy animals species from the State	
4.2.6: Sero-prevalence of <i>N. caninum</i> and percent inhibition in dairy animals from the Khartoum State	111
4.2.7: Frequency distribution of Percent Inhibition (pi) among seropositive dairy animals to <i>N. caninum</i>	111
4.2.8: Seroprevalence of <i>N. caninum</i> and percent inhibition in dairy animals from the three districts of the State	111
4.2.9: Seroprevalence of <i>N. caninum</i> and percent inhibition in dairy animals in the seven localities of the State	112
4.2.10: Seroprevalence of <i>N. caninum</i> and percent inhibition in dairy animals from the three districts of the State	113
4.2.3.1: Estimated Seroprevalence of <i>N. caninum</i> infection in Dairy animals from the State and Univariate analysis for the associated Risk factors	114
4.2.3.2: Results of univariate association of Risk factor with cELISA Neospora seropositivity in dairy animals from the state	115
4.2.3.3: Results of multivariate association of Risk factor with cELISA Neospora seropositivity in dairy animals from Khartoum state	115
4.3.1. Occurrence of <i>T. gondii</i> and <i>N. caninum</i> infection in Dairy Animals from the three Districts of the Khartoum State	116
4.3.2. Co-infection among <i>N. caninum</i> seropositive Dairy animals from the three districts of the Khartoum State	116
4.3.3. Occurrence of <i>T. gondii</i> and <i>N. caninum</i> in Dairy Animals from the seven localities of the Khartoum State	117
4.3.4. Co-infection among <i>N. caninum</i> seropositive dairy Animals in the different localities of the Khartoum State	117
4.3.5. Occurrence of <i>T. gondii</i> and <i>N. caninum</i> in different farm animal species from the Khartoum State	118
4.3.6. Co-infection among <i>N. caninum</i> seropositive dairy Animals from the Khartoum State	118
4.3.7: Results of univariate association of <i>T. gondii</i> infection as Risk factors with <i>N. caninum</i> seropositivity in dairy animals	119
4.3.8: Results of multivariate association of <i>T. gondii</i> infection as Risk factors with <i>N. caninum</i> seropositivity in dairy animals from the State	119
4.4.1: Over all Seroprevalence of three abortifacients in dairy farms from the Khartoum State	119
4.4.2: Seroprevalence of the three abortifacients in dairy herds from the Khartoum State	119
4.4.3: Frequency distributions of prevalence rates of the three abortifacients in dairy herds from the Khartoum State	120
4.4.4: Seroprevalence and Co-existence of three abortifacients in different dairy animals from the Khartoum State	120
4.4.5: Distribution of Mix infection among over all seropositive dairy animals from the Khartoum state	121

4.4.6: Mix-infection among Brucella positive dairy animals from the Khartoum State	121
4.4.7: Results of univariate association of protozoal abortifacients as Risk factors with <i>B. abortus</i> seropositivity in dairy animals from Khartoum State	122
4.4.8: Results of multivariate association of protozoal abortifacients as Risk factors with <i>B. abortus</i> seropositivity in dairy animals	122
4.5.1: Results of owner's interview on occurrence of abortion, repeat breeding and still-birth among the dairy herds in the State	123
4.5.2: Results of owner's awareness on causes of abortion and toxoplasmosis	124

LIST OF FIGURES

Figure	Page
3.1: Map of Sudan showing the area of the Study (The Khartoum State).	78
4.1.3.1: ROC Curves of LAT and ELISA for detection of <i>T. gondii</i> antibodies in Dairy cows	103
4.1.4: Distribution of seroprevalence of <i>T. gondii</i> in Dairy Animals in different Localities of the Khartoum State.	106
4.2: Distribution of seroprevalence of <i>N. caninum</i> in Dairy Animals in different Localities of the Khartoum State.	112

LIST OF PLATES

Plate	Page
3.1: Co-herded Dairy Farms (multi-species)	90
3.2: Profesional Camels dairy Farms in Eastern Nile and Bahri	90
3.3: Latex Agglutination Test for detection of Antibody against <i>T. gondii</i> (Qualitative and quantitative).	93
3.4: Indirect ELISA (DRG) and cELISA (VMRD) for detection of Antibody against <i>T. gondii</i> and <i>N. caninum</i>	93
4.1: Dogs were seen inside the farm, in the feed storage and around dairy farms eating dead and/or aborted calves	123