PARASITIC DISEASES OF GOATS

Editor:
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Parasitic Diseases of Goat

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CONTENTS

FOREWORD i

PREFACE ii

ACKNOWLEDGEMENTS iii

LIST OF CONTRIBUTORS iv

CHAPTER 1 INTRODUCTION 1

Binod Kumar, Biswa Ranjan Maharana and *Tanmoy Rana*

INTRODUCTION 1

PARASITES OF GOATS 7

LIFE-CYCLE OF PARASITES 10

TRANSMISSION AND DISSEMINATION OF PARASITES 11

HARMFUL EFFECTS OF PARASITES 16

COMMON CONTROL MEASURES AGAINST PARASITES 17

PARASITE AND PARASITIC DISEASE NAMING 19

SOME OF THE IMPORTANT TERMINOLOGY RELATED TO PARASITOLOGY 20

REFRENCES 24

CHAPTER 2 PARASITES OF GASTROINTESTINAL SYSTEM 26

Vivek Agrawal, Madhu Swami, Amit Kumar Jaiswal, Pradeep Kumar, Amit Singh and *Mukesh Shakya*

INTRODUCTION 27

OESOPHAGUS 27

Gongylonema pulchrum 27

RUMEN/RETICULUM 28

Gongylonema 29

Gongylonema verrucosum 29

Gongylonema mönnigi 29

Cymbiforma 29

Cymbiforma Indica 29

Paramphistomum 29

ABOMASUM 31

Haemonchus 31

Haemonchus Contortus 31

Mecistocirrus 35

Mecistocirrus digitatus 35

Ostertagia 36

Ostertagia Ostertagi 36

Ostertagia Circumcincta 37

Ostertagia Trifurcata 37

Marshallagia 38

Marshallagia Marshalli 38

Trichostrongylus 39

Trichostrongylus Axei 39

SMALL INTESTINE 39

Trichostrongylus 39

Trichostrongylus Colubriformis 39

Trichostrongylus Falculatus 40

Trichostrongylus Vitrinus 40

Trichostrongylus Capricola 41

Trichostrongylus Probolurus 41
Trichostrongylus Rugatus 41
Nematodirus 44
Nematodirus Filicollis 44
Bunostomum 46
Bunostomum Trigonocephalum 46
Gaigeria 47
Gaigeria Pachyscelis 47
Skrjabinema 48
Skrjabinema Ovis 48
Capillaria 48
Trichuris 49
Trichuris Ovis 49
Trichuris Discolour 49
Trichuris Globulosa 49
Chabertia 49
Chabertia Ovina 49
Avitellina 52
Avitellina centripunctata 52
Thysaniezia 52
Thysaniezia Ovilla 52
Eimeria 52
Eimeria Christenseni 52
Eimeria Ninakohlyakimovae 54
Eimeria Hirci 54
Eimeria Alijevi 55
Eimeria Arloingi 56
Cryptosporidium 57
Cryptosporidium parvum 57
Giardia 57
Giardia intestinalis 57
Entamoeba 57
Entamoeba ovis 57
LARGE INTESTINE 58
Oesophagostomum 58
Oesophagostomum Columbianum 58
Oesophagostomum Venulosum 59
CONCLUDING REMARKS 60
CONSENT FOR PUBLICATION 60
ACKNOWLEDGEMENTS 60
REFERENCES 60

CHAPTER 3 PARASITES OF UROGENITAL TRACT OF GOAT 62
G. Jyothimol
INTRODUCTION 62
General Information about Toxoplasma Gondii 63
Entero-Epithelial Cycle 64
Extra Intestinal Cycle 65
Genetic Diversity of T. gondii Population 66
Epidemiology of Toxoplasma Infection 66
Prevalence of Toxoplasmosis 67

Pathogenesis of Toxoplasmosis 68
Symptomatic Conditions are Classified as Acute, Subacute and Chronic 68
Clinical Infections in Sheep 69
Clinical Infection in Goat 69
Infection in Adult Goats 69
Neonatal Toxoplasmosis 69
Diagnosis of Toxoplasmosis 71
Treatment /Prophylaxis of Abortion 71
Immunity to T. gondii Infection 72
T. gondii and Public Health Significance 73
CONCLUDING REMARKS 73
ACKNOWLEDGEMENTS 73
REFERENCES 73

CHAPTER 4 PARASITES IN THE CARDIOVASCULAR SYSTEM 76
Pradeep Kumar, Amit Kumar Jaiswal, Alok Kumar Singh, Vivek Agarwal and *Gaurav Kumar Verma*
INTRODUCTION 76
Importance of Cardiovascular System of Goat 77
Brief Description of Cardiovascular System of Goats 77
Harm by Parasites in Cardiovascular System 79
Parasites Involve in Cardiovascular System of Goats 80
Description of Parasites of Cardiovascular System 81
Elaeophora Schneideri 81
Family- Schistosomatidae 83
Schistosoma Bovis 85
Schistosoma Japonicum 85
Schistosoma Mattheei 86
Schistosoma Indicum 86
Schistosoma Nasalis 86
Orientobilharzia Turkstanicum 87
Trypanosoma 88
Trypanosoma Brucei 90
Trypanosoma Congolense 90
Trypanosoma Vivax 91
Trypanosoma Simiae 91
Trypanosoma Melophagium 91
Treatment and Control 91
Babesia 92
Babesia Motasi 93
Babesia Ovis 94
Theileria 95
Theileria Hirci 96
Theileria Ovis 97
Rickettsiales 97
Anaplasma Ovis 98
Eperythrozoon Ovis 101
Rickettsia Conorii 102
Anaplasma Marginale 103
Anaplasma Centrale 103
Ehrlichia Ruminantium 104

CONCLUDING REMARKS 104
REFERENCES 105

CHAPTER 5 PARASITES IN THE INTEGUMENTARY SYSTEM OF GOATS 108
Banothu Dasmabai and *Lunavat Gopala*
INTRODUCTION 108
Lice (Order: Phthiraptera) 109
Transmission 109
Control 110
Mites 111
Fleas 113
Ticks 114
Flies 116
Control of Flies 116
Entomopathogenic Fungus 116
Hyphomycetes 116
Nematodes 117
Predators 118
Parasitoids 118
Transgenic Pesticides Genetically Modified Organisms 118
Safety 119
Transgenic Insects/ Genetic Control for Insect Pests 119
Types of Genetic Pest Management 119
CONCLUSION 120
REFERENCES 120

CHAPTER 6 PARASITIC INFECTION OF THE NERVOUS SYSTEM OF GOATS 121
Fathy Ahmad Osman
INTRODUCTION 121
Cestode Causing Nervous Manifestations in Goats ("gid", "stagger", "sturdy") 123
Definition 123
Definitive Host 123
Pathogenesis 123
Geographical Distribution 123
Life Cycle 124
Clinical Signs 124
Diagnosis 125
Differential Diagnosis 126
Treatment 126
Prevention and Control 126
Echinococcosis (Hydatid disease) Description 127
Etiological Agent 127
Definitive Hosts 127
Intermediate Host 127
Geographical Distribution 127
Life Cycle 127
Diagnosis 128
Clinical Signs and Case History 128
Macroscopically Examination 129
Parasitological Examination 129
Ultrasonography 129
Laboratory Examination 129

Polymerase Chain Reaction (PCR) 130
Differential Diagnosis 130
Prevention 130
Nematode Causing Nervous Manifestations in Goats 130
Meningeal Worm in Goats 130
Description 130
Definitive Host (Natural Host) 131
Intermediate Host 131
Clinical Signs, Pathogenesis 132
Diagnosis 133
Laboratory Examination 133
Necropsy Examination 133
Differential Diagnosis 134
Treatment 134
Prognosis 135
Prevention of Meningeal Worm 135
Protozoa Parasites Causing Nervous Manifestations in Goats 135
Toxoplasmosis 135
Definitive Host 135
Intermediated Host 136
Etiological Cause 136
Transmission 136
Life Cycle 136
Clinical Signs 137
Diagnosis 138
Post-mortem Examination 138
Histological Examination 139
Molecular Diagnosis 139
Treatment 139
Neosprosis (Neospora caninum) 140
Causative agent 140
Geographical Distribution 140
Life Cycle and Transmission 140
Clinical Signs and Lesions 141
Macroscopic Lesions of Aborted Fetus's 141
Diagnosis 142
Diagnosis Technique 142
Microscopic Examination 143
Molecular Diagnosis 143
Serology Diagnosis 144
Sarcocystiosis (Sarcosporidiosis) 144
Causative Agents 145
Distribution 145
Transmission and Development 145
The Life Cycle of Sarcocystis 145
Clinical Sign 145
Diagnosis 146
Macroscopic Analysis 146
Microscopic Examination of Fresh Tissues 147
Histologic Examination 147
Electron Microscopy 147

Molecular Diagnosis 148
Treatment and Control 148
REFERENCES 148

CHAPTER 7 PARASITES IN THE EYES AND EARS 152
Pradeep Kumar, Amit Kumar Jaiswal, Alok Kumar Singh, Abhinov Verma, Vivek Agarwal, Alok Kumar Chaudhary, Gaurav Kumar Verma and *Renu Singh*
INTRODUCTION 153
Anatomy of the Eye 153
Parasites of Eye 157
Setaria Digitata 157
Thelazia Rhodesii 160
Coenurus Gaigeri 162
Genus: Otobius 166
Otobius Megnini 166
Mite 170
Sarcoptes scabiei var. caprae 175
Lices 177
Fleas 180
CONCLUSION 181
REFERENCES 181

CHAPTER 8 PARASITES OF THE RESPIRATORY SYSTEM OF GOATS 184
Jitendra Tiwari
INTRODUCTION 184
PARASITES AFFECTING THE NASAL PASSAGE 185
Oestrus Ovis Larvae 185
PARASITES AFFECTING THE LUNG PARENCHYMA 187
Cystic Pulmonary Hydatidosis 187
Muellerius Capillaris 188
PARASITES AFFECTING THE TRACHEA AND BRONCHI 190
Dictyocaulus Filaria 190
Common Name 190
Protostrongylus Rufescens 194
Cystocaulus Ocreatus 197
Neostrongylus Linearis 200
Mammomonogamus Laryngeus 201
REFERENCES 202

CHAPTER 9 PARASITES OF LIVER AND PANCREAS 203
G. Jyothimol and *Manaswini Dehuri*
INTRODUCTION 203
PARASITES OF LIVER 204
PARASITES OF PANCREAS 204
Fasciolosis 204
History 204
Introduction 204
Status of Fasciolosis 205
Economic Importance 205
Fasciola Hepatica 206
Pathogenesis of Fasciolosis 211
Acute Fasciolosis 212

Chemical Pathology 214
Clinical Signs 215
Diagnosis 215
Treatment 217
Control 217
Fasciola Gigantica 221
Fascioloides Magna 223
Dicrocoelium Dendriticum 225
Eurytrema Pancreaticum 226
Stilesia Hepatica 228
Cysticercus tenuicollis (metacestode of Taenia hydatigena) 229
Hydatid cysts (metacestode of Echinococcus granulosus) 230
CONCLUDING REMARKS 232
REFERENCES 233

CHAPTER 10 PARASITES AFFECTING THE MUSCULOSKELETAL SYSTEM OF GOATS 240
H. Dhanalakshmi
INTRODUCTION 240
Life Cycle 242
Diagnosis 243
Treatment 243
Vaccine 243
Control 243
Epidemiology 243
Sarcocystosis 244
Life Cycle 244
Definitive hosts 244
Sarcocystis Capracanis 245
S.hircicanis 245
Prevalence 245
Pathogenecity 246
Clinical Signs 247
Diagnosis 247
Epidemiology of Sarcocystis 248
Control 248
Genus: Besnoitia 249
Life Cycle 249
Histology 249
Clinical Signs 249
Epidemiology 249
Transmission 250
Pathogenesis, Lesions and Clinical Signs 250
Clinical Signs 251
Diagnosis 251
Control 251
Economic Impact 252
Hammondia 252
Hammondia Hammondi 252
Pathogenecity 252
Hammondia Heydorni 253
Comparison of Hammondia Species 253

Oestrus Ovis 253
Life Cycle 253
Clinical Signs 254
Pathogenesis 255
Cellular Immune Response 256
Diagnosis 256
Treatment 256
Epidemiology 256
Wohlfahrtia Magnifica 257
Clinical Signs 257
Control 257
Taenia Multiceps 257
Taenia Gaigeri 258
Location of Coenurus gaigeri 258
Treatment and Control 260
Taenia Ovis 260
Life Cycle 260
Control 261
Onchocerca 262
Trichinellosis 262
Trichinella spiralis 262
Diagnosis 263
REFERENCES 263

CHAPTER 11 DIAGNOSTIC EVALUATION 265
Amit Kumar Jaiswal, Pradeep Kumar, Vivek Agrawal, Amit Singh, Atul Prakash and *Shanker Kumar Singh*
INTRODUCTION 266
CONVENTIONAL METHODS 267
Diagnosis of Parasites Located in Digestive (GI) Tract 267
Collection of Faeces 267
Transportation of the Sample 267
Gross Examination of Faeces 267
Microscopic Examination 268
QUALITATIVE EXAMINATION 268
Direct Smear Examination 268
Concentration Methods 269
Procedure for Examination of Faecal Samples 269
Procedure 270
QUANTITATIVE EXAMINATION 270
Procedure 271
Procedure 271
FAECAL CULTURE 271
EXAMINATION OF BLOOD 273
Methods for Blood Examination 273
Direct Fresh Mount of Blood 273
Thin Blood Smear Method 274
Thick Blood Smear Method 275
EXAMINATION OF RESPIRATORY DISCHARGES 275
EXAMINATION OF SKIN FOR PARASITES 275
SEROLOGY-BASED TESTS 276

Falcon Assay Screening Test ELISA (FAST-ELISA) 276
Dot-ELISA 277
Rapid Antigen Detection System (RDTS) 277
Luciferase Immunoprecipitation System (LIPS) 278
MOLECULAR BASED TECHNIQUES 278
Polymerase Chain Reaction (PCR) 278
Real-Time Polymerase Chain Reaction (RT-PCR) 279
Loop-Mediated Isothermal Amplification (LAMP) 280
Luminex 280
Random Amplified Polymorphic DNA (RAPD) 281
Amplified Fragment Length Polymorphism (AFLP) 281
Restriction Fragment Length Polymorphism (RFLP) 281
Microsatellites 282
PROTEOMIC TECHNOLOGY 282
CONCLUDING REMARKS 284
ACKNOWLEDGEMENTS 284
REFERENCES 284

CHAPTER 12 PARASITIC DISEASES IN GOATS: THERAPEUTICS AND CONTROL MEASURES 289
Snehil Gupta, Diksha Sharma, Surbhi Gupta and *Rajender Kumar*
INTRODUCTION 289
Endo-parasite Control 290
Chemical Control (Anthelmintics) 294
Benzimidazole and Probenzimidazole (Albendazole, Thiabendazole, Parbendazole, Netobimin and Oxfendazole) 294
Macrocyclic Lactones (Ivermectin, Doramectin, Abamectin and Moxidectin) 295
Amino-Acetonitrile Derivatives (Monepantel, Zolvix®, Elanco Animal Health) 296
Salicylanilides and Substituted Phenols (Closantel, Niclosamide, Oxyclozanide, Rafoxanide, Disophenol, Nitroxynil) 296
Imidazothiazoles (Levamisole, Tetramisole) 297
Tetrahydropyrimidines (Pyrantel, Morantel) 297
Spiroindoles (Derquantel) 298
Praziquantel 298
Chorsulon 298
Pasture Management 301
Bioactive Forages 301
Copper Oxide Wire Particles (COWP) 301
Biological Control 302
Control of Snail as Intermediate Host 302
Anthelmintic Intoxication in Goats 303
Control of Ecto-parasitic Diseases 304
Chemical Control (Insecticide/Acaricides) 304
Organochlorines (DDT, HCH, Dieldrin, Aldrin, Toxaphene 305
Organophosphates (Coumaphos, Diazinon, Dichlorvos and Malathion) 305
Carbamates (Carbaryl and Propoxur) 306
Trizepentadienes Formamidines (Amitraz) 306
Synthetic Pyrethroids (Cypermethrin, Deltamethrin, Fenvalerate, Flumethrin and Permethrin) 306
Macrocyclic Lactones/ Macrolide Antibiotics (Ivermectin, Doramectin, Moxidectin) 306
Neonicotinoids (Imidacloprid) 307

Phenyl Pyrazoles (Fipronil) 307
Salicylanilide Ectoparasiticides (Closantel) 307
Synergists 308
Benzyl Benzoate 309
Semiochemicals Mediated Control 310
Allomones 310
Kairomones 310
Pheromones 310
Heterotelergones 311
Repellents 311
Insect Growth Regulators/ Insect Development Inhibitors 312
Herbal or Botanical Ectoparasiticides 312
Non Chemical Control 313
Biological Control 313
Managemental Control 314
Immunological Control 316
Genetic Control 316
Integrated Parasite Management 316
Therapeutic and Control of Protozoan Parasites of Goats 317
Goat Babesiosis 317
Goat theileriosis 317
Goat Trypanosomosis 317
Goat Sarcocystosis 318
Goat Coccidiosis 318
CONCLUSION 319
REFERENCES 320

SUBJECT INDEX 324

FOREWORD

Parasitic infections can represent a serious obstacle to goat farming, reducing productive performance or even causing deaths. Therefore, it is essential to diagnose parasitic diseases correctly, apply the right treatment, and adopt effective prophylactic measures to raise goats efficiently. Unfortunately, it is common to adopt appropriate measures for other animals, but those are inadequate for goats. These inadequate procedures are the result of a gap in the literature regarding parasitic diseases of goats. The book "Parasitic Diseases of Goats" should contribute to filling that gap. In this book, veterinarians will find information specific to the species, which will assist them in making informed decisions. Veterinary professionals and goat producers should benefit from this book's description of parasitic diseases' etiopathogenesis, clinical effects, diagnosis, treatment, and prevention. In light of all the knowledge presented in this book, I congratulate its editor, Tanmoy Rana. I hope that everyone who reads it finds it both interesting and informative.

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PREFACE

Goats play a significant role in the economy of small and marginal families. They also play a key role in the upliftment of the socio-economic status of marginal farmers. Generally, goats are resistant to various diseases. However, they suffer mostly from parasitic diseases. They are selective feeders and require a lot of managemental practices that safeguard their health. This book generally focuses on system-wise parasitic diseases, clinical signs, advanced diagnosis, and management of parasitic diseases. The book constituents of a considerably larger amount of color photographs, illustrations, and diagrams to attract the reader. The handbook is intended for students, academicians, progressive farmers, veterinary practitioners, and extension personnel. This handbook will provide useful information for a better understanding of the parasitism of goats.

The book "Parasitic Diseases of Goats" is divided into 12 chapters emphasizing the clinical parasitic evaluation, diagnosis, and management of goats. It describes parasites of the digestive system, respiratory system, liver, pancreas, circulatory system, nervous system, reproductive/urogenital system, locomotory system, and the integument of goats. Additionally, it explores various aspects of parasitological interventions and provides recent information to veterinary professionals and farmers regarding their parasitological questions. I hope that the readers will enjoy the amazing world of parasites of goats. The control of caprine parasite infections through various endoparasite and ectoparasite management strategies has become routine for veterinary professionals, farm managers, and progressive farmers. The therapeutics and preventive management are based on clinical diagnosis of the parasites based on the detection of eggs, antigens from the parasite, seroconversion by the host, and molecular indices of the parasites. The application of drugs is based on their chemical form rather than proprietary. I am also thankful to the authors involved in parasitological research for their consultation. It is the responsibility of the veterinarian to recommend the drugs correctly based on local laws and legislation governing drugs in the practicing field. Neither any publisher nor the authors have any liability for any damage/ injury to persons or property with the application of all information and material(s) constraints for the diseases in this book. The use of any trade names or commercial products in this book is purely for the purpose of distinct information and also does not evaluate any finalization and/or recommendation by the publisher or authors. Scientists, researchers, industry veterinarians, government veterinarians, laboratory diagnosticians, veterinary technicians, and veterinary practitioners throughout the globe can consult this book to acquire knowledge about the parasitic diseases of goats.

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CHAPTER 1

Introduction

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Abstract: Goats are livestock, which is very popular among the poor people of developing countries who cannot afford to raise large ruminants. However, small ruminant producers face significant economic threats due to parasitism. Both ecto- and endo-parasites cause significant damage to the animals that either reduces the performance or may cause death of animals. These parasites are either single-cell, protozoa or multicellular, helminths and arthropods. They enter into the host by various means, such as foods, water, penetration of the skin, from mother to foetus *via* placenta and/or milk, *etc*. A number of parasites affect the goats, leading to different kinds of diseases. Some are very serious in nature, while others cause mild to moderate kinds of diseases. Furthermore, the severity of the disease depends upon different factors associated with the animals, like age, sex, and breed, parasites like species/strain, quantum of infection, virulence, and environment factors like temperature, humidity, soil type, food, management, *etc*. Management of parasites is somewhat challenging in the extensive system, while it can be well managed in the intensive system of animal rearing by following the good practices of management.

Keywords: Arthropod, Goat, Helminth, Host, Parasite, Protozoa, Parasitism.

INTRODUCTION

Goats were domesticated along with sheep in central Asia over ten thousand years ago and considered livestock to be domesticated first. Both are termed as small domestic ruminants and are currently found throughout the world. *Capra aegagrus hircus*, the domestic goat, is kept mainly for meat, milk, hides, and hair. In contrast to cattle, goats are primarily browsing animals [1]. They can adapt to different environments due to their diverse food habits on a varied plant diet. The goat husbandry practices are mainly done by poor people, and goats are known as

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'poor men's cows'. Though majorities are raised in smallholder and mixed farming systems, they are an important component of pastoralist herds too. Besides, the high-value animals are also raised for specialized dairy production [2]. However, small ruminant producers are facing significant economic threats due to parasitism. Both ecto- and endo-parasites cause significant damage to the animals that either reduce their performance or may cause death of animals. Animal health is an important factor in maintaining its natural productivity. So, first we should know that, what is parasite? Parasite is an organism the live on or within other living organism of different species (host) for their survival. Parasites derive benefit as food or shelter or both for itself at the expense of the host and causing harm to them. Parasites are always smaller partner to their host [3]. The word parasite is derived from the Greek words, "para" means beside and "sitos" means food. In this definition bacterium, viruses, fungi, *etc*. may also be considered as parasites. But, looking to the vastness of the subject only helminthes, arthropods and protozoans are studied under parasitology. Then what is parasitology? Parasitology is a branch of biology which deals with the study of parasitism, *i.e*. a phenomenon of dependence of one living organism on the other. *e.g*. Ascaris (parasite) in men (host), biting files, liver fluke, coccidia Parasitism is one kind of animals association like other *viz*. commensalism, mutualism, predation, phoresis. But, in parasitism live in close association where parasite, either harms its host or lives at the expense of the host.

https://editorial.elsevier.com/app/loginhttps://editorial.elsevier.com/app/loginpart ner usually smaller, lives on or within the other, in order to obtain nourishment and habitat. However, in other association like in Commensalism: One partner benefits from the association, but the host is neither harmed nor benefited (Fig. **1**). *e.g. Entamoeba gingivalis* in human mouth.

Fig. (1). Topic covered under study of parasitology.

Commensalisms may be facultative, in the sense that the commensals may not be required to participate in an association to survive. Stalked ciliates (Genus: Vorticella) are frequently found on small crustaceans and can survive equally well on sticks in the same pond. However, related forms such as Epistylis spp. are evidently obligate commensals since they are not found except on other organisms, especially crustaceans [4]. Similarly, Mutualism describes an obligatory relationship in which both partners benefit from the association. *E.g.*, termites and their intestinal protistan fauna. Predation and parasitism are conceptually similar in that both the parasite and the predator live at the expense of the host or prey. The Parasite, however, normally does not kill its host, is small relative to the size of the host, has only one host (or one host at each stage in its life cycle), and is symbiotic. The predator kills its prey, is large relative to the prey, has numerous prey, and is not symbiotic. Lastly, Phoresis, which means travelling together, is a temporary association between two individuals or living beings in which there is no metabolic dependence. Example: Bacteria and amoebae on the legs of a fly or fungal spores on the legs of a beetle (Fig. **2**).

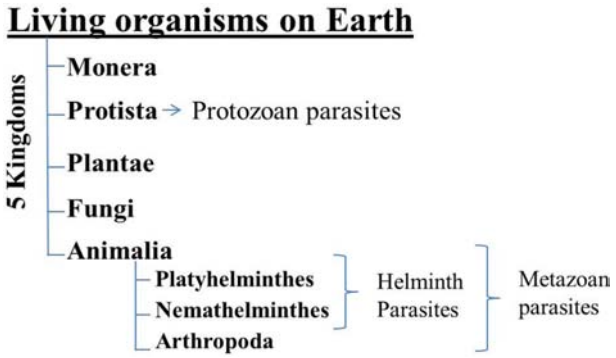

Fig. (2). Broad categorization of parasites.

Now we look into the types of parasites. According to the duration of the parasite on/in the host they are:

Temporary parasites: The parasites which lead free life during a part of life cycle or in other words, are those which visit the host as and when but do not remain with it all the time, *e.g*. *Gasterophilus*, fleas, flies, *etc*.

Permanent parasites: These are those which live as parasites, for whole life or in other words, are those parasites which remain with the host all the time and do not leave it at any time, *e.g.*, lice, helminths, *etc*.

Periodic or sporadic or intermittent parasites: They are those parasites which make a short visit to their hosts to obtain nourishment or food or other benefits, *e.g.*, mosquitoes, biting flies, soft ticks.

CHAPTER 2

Parasites of Gastrointestinal System

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Abstract: Goats, being hardy and prolific in their growth, play a crucial role in cultural and socioeconomic life of rural poor under privileged people by providing meat, milk, wool and hide to them. Gastrointestinal parasitic infections are worldwide problem in ruminants. They results considerable loss in them causing mortality and poor production. Various gastrointestinal parasites like trematodes, cestodes, nematodes and protozoa are prevalent in different climates and geographical regions depending on rearing systems, intermediate host's availability and management practices. Epidemiology of gastrointestinal parasites, though variable at times, is determined by various factors like treatment, climate and poverty (socio-economic and traditional practices). The diseases like Fasciolosis, Dicrocoelosis, Amphistomosis in trematodes, Monieziosis, Avitellinosis in cestodes, Haemonchosis, Trichostronglylosis, Oesophagostomosis, Trichuriosis, Strongyloidosis in nematodes and coccidiosis in protozoa were still serious challenges in the region threatening the small ruminant production.

Keywords: Avitellina, Bunostomum, Chabertia, Cryptosporidium, Clinical Symptoms, Diagnosis, Eimeria, Entamoeba, Gaigeria, Giardia, Goat, Gastrointestinal parasites, Haemonchus Gongylonema, Life cycle, Moniezia, Nematodirus, Ostertagia, Oesophagostomum, Paramphistomum, Pathogenesis, Trichostrongylus, Trichuris.

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INTRODUCTION

Goats play an important role in providing food security to large population of small and marginal farmers and poor landless peoples. Through production of meat, milk, skin and wool they contribute significantly to their subsistence, employment generation and poverty alleviation [1]. Production of goats, however, suffers severely from various infectious diseases of bacterial, viral and parasitic nature along with other management problems. Gastrointestinal parasitic infections (Trematodes, Cestodes Nematodes and protozoa) in small ruminants, both in intensive and extensive management, are considered serious constraints in their production as they lead to serious economic losses through lowering production of their produces along with morbidity and mortality [2]. Further, substantial economic losses are encountered by the farmers in goat production in the form of expenditure incurred to control the gastrointestinal parasitic infections. The names of various gastrointestinal parasites, as well as their distinctive morphological characteristics, lifecycles, pathogenesis, clinical symptoms, and diagnoses, are discussed in the chapter.

OESOPHAGUS

Gongylonema pulchrum

Gongylonema pulchrum is found in sheep, goats, cattle, pigs, zebu, and buffalo, as well as horses, camels, donkeys, and feral hogs on a less frequent basis. It is also found in humans, most notably in the oral epithelium and the subcutaneous layer. It is widespread throughout the world. The worm resides in the oesophagus, where it is ingrained in the mucosa or submucosa in a zigzag pattern. It may also be found in the rumen of ruminant animals. Males can reach a maximum length of 62 mm, while females can reach a maximum length of 145 mm [1]. Several rounded or oval, and sometimes irregularly shaped, thickenings can be seen on the anterior end of the cuticle. The alae in the cervical region are fully formed. There are small lips and a brief pharynx with simple walls. The male's tail is somewhat asymmetrical and has a number of papillae that are also set up in an asymmetrical way. Left spicule length is between 4 and 23 mm. Long and stout, the right one measures 0.084-0.18 mm. There is a gubernaculum present. The vulva opens posteriorly, and the dimensions of the eggs are 50-70 by 25-37 μm.

In the life-cycle of *Gongylonema pulchrum* more than 70 species of coprophagous beetles have been involved [2] and their larvae develop into the infective stage in about 30 days after hatching from eggs passed in the faeces of the host. *Blatella germanica*, a species of small cockroach, is susceptible to infection in experiments. When the intermediate host eats the infected beetles, it becomes infected as well. Cockroaches that fall into water will spontaneously produce

larvae, but it is unlikely that these larvae would be a significant source of infection. The route of migration is unknown for most animals. Larvae, he speculated, would first be excysted in the stomach before moving anteriorly to the buccal cavity and, from there, to the oesophageal wall.

RUMEN/RETICULUM

There are various types of amphistomes in goats that result in bottle-jaw (Fig. **1**). Although finding an amphistomatic egg (Fig. **2**) in faeces is too late because parasites have already caused the majority of the damage, immature amphistomiasis is more significant clinically.

Fig. (1). Bottle jaw in an amphistome-infected goat.

Fig. (2). Amphistome egg.

CHAPTER 3

Parasites of Urogenital Tract of Goat

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Abstract: Goats are an important part of the agrarian economy in different parts of the world. They are known as poor man's cows. Some of the parasitic infections can lead to a reduction in performance and reproductive failures in goats. *Toxoplasma gondii* is one among them, and only one reported parasite affecting the urogenital tract of goats. Goats usually harbor the intermediate stages of this organism in different body tissues. It causes abortion in goats if pregnant goats are infected during any stage of pregnancy. This lead to great economic loss to the farmer. However, abortions in goats may not always attributed to Toxoplasma infections alone. In most cases, it may be due to co-infections with other abortifacient parasites like *Neospora caninum*. The problem with this infection lies mainly in the lack of facilities for early diagnosis or treatment of this condition. Even though many serologic tools like IFA, ELISA and MAT can be used for its diagnosis, a confirmative diagnosis is not possible. Biotechnological tools like PCR and Genotyping have been reported to produce better results. In addition to the problems caused by Toxoplasma infections in livestock, this parasite possesses a significant public health status as it is a highly potent zoonotic agent. Worldwide, one-third of the human population is chronically infected with this parasite. This chapter dealt in detail with all aspects of this parasitic infection.

Keywords: Abortion, Goat, PCR, Public Health, Reproductive failures, Serologic survey, *Toxoplasma gondii*, Urogenital parasite, Zoonotic infection.

INTRODUCTION

Goats are raised mainly for meat, fibre and milk. They are important in the economy of many of the Asian and African countries. Among the Asian countries, India and China hold the largest goat population [1].The most common causes of parasites in goats are poor nutrition, imbalanced diet, poor management, dirty and unhygienic environment, overcrowding and low immunity to parasites. Parasites of goats fall into two main categories, *viz*., ectoparasites (flies, fleas, lice, mites, and ticks) and endoparasites (nematodes, cestodes, trematodes). Most of the

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endoparasites infect the gastro intestinal system of the animals and cause symptoms like anemia, emaciation and reduction in production performance.

Reports on the occurrence of parasites in the urogenital system of goats are scarce. The only parasite reported to infect the genital system of goats is *Toxoplasma gondii*, whose definitive host is felines while the intermediate stages can be found in any domestic animals. *T. gondii* infections are common in humans and animals worldwide.

Toxoplasma-induced abortions are more common in sheep and goats than in cattle. Goats are considered poor man's cows and hence, toxoplasmosis in goats is a significant public health and economic concern [2]. This chapter discusses in detail about Toxoplasma infections in goats.

General Information about *Toxoplasma Gondii*

The protozoan *Toxoplasma gondii* infects all warm-blooded animals, including humans, livestock, and marine mammals [3]. Approximately one-third of the human population around the globe carries chronic infection with *T. gondii*. Most infections appear to be asymptomatic in immunocompetent persons. However, the parasite can cause serious disease in humans, especially neonates and immunocompromised people. In most animal hosts, which act as intermediate hosts of infection, it is exhibited in the subclinical form. However, toxoplasmosis can be fatal in many hosts [4].

Final hosts: Cat, other felids.
Intermediate hosts: Any mammal, including humans, or birds. It is observed that the final host, the cat, can also harbor extra-intestinal stages and may act as an intermediate host.
Predilection site: (Table **1**). Muscle, Lung, Lier, Reproductive system, CNS, Placenta Life cycle of *T. gondii* (Fig. **1**).

Table 1. Taxonomic Classification of Toxoplasma *Gondii*.

Division: Eukarya	Kingdom: Protista
Phylum: Apicomplexa	Order: Eucoccidiorida
Order: Eucoccidiorida	Order: Eucoccidiorida
Order: Eucoccidiorida	Species: gondii

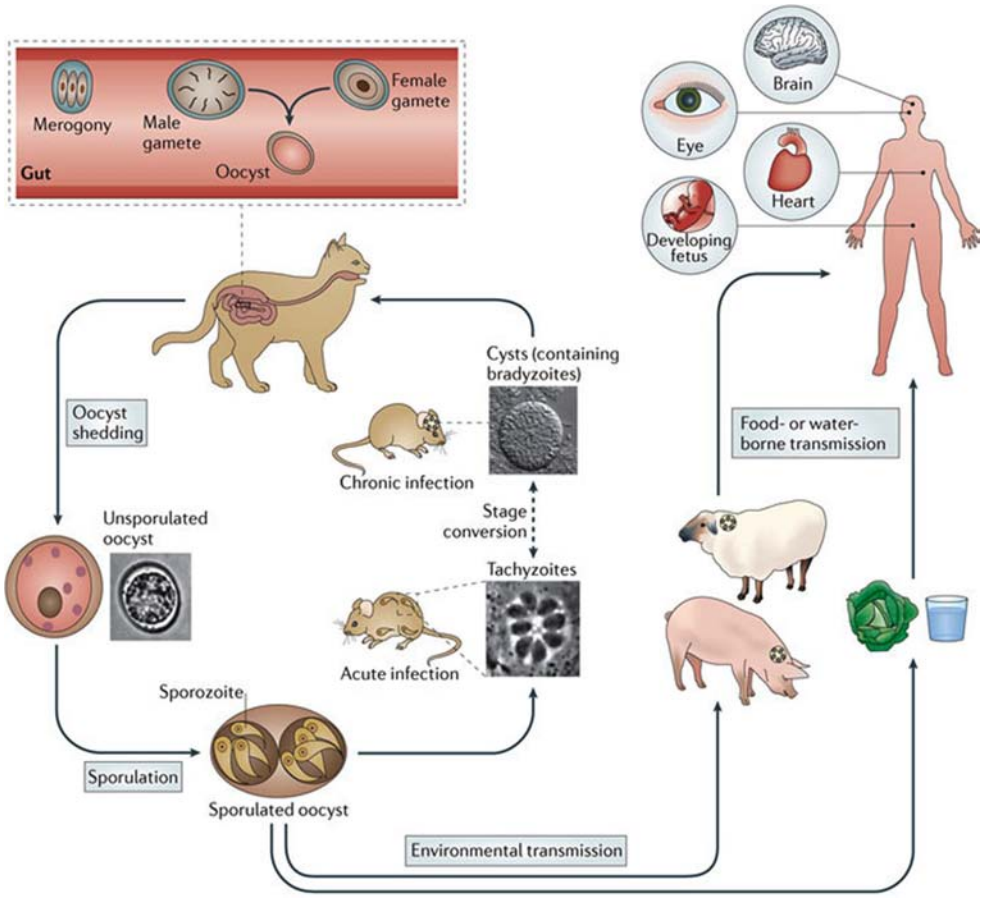

Fig. (1). Life cycle of *Toxoplasma gondii*.

The developmental cycle of *T. gondii* consists of two different cycles *viz*., entero epithelial cycle and extra-intestinal cycle.

Entero-Epithelial Cycle

It typically occurs in the intestinal tracts of cats and is very similar to that of other coccidian parasites, resulting in the formation of oocyst production. Felines get infection by ingestion of oocyst through contaminated feed and water or by ingestion of muscles of infected intermediate host harboring tachyzoites or bradyzoites of *T. gondii*. In the intestine of feline host, 5 different multiplicative stages which are designated as Type A, B, C, D, E can occur. Type A and B divides by endodyogeny and endopolygeny (internal budding to produce daughter forms) whereas, Type C, D and E divides by schizogony. Gamont formation occur

CHAPTER 4

Parasites in the Cardiovascular System

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Abstract: Goats play an important role in providing supplementary income in a landless farming system. Nowadays, goat farming has converted into a profitable industry. Goats suffer from various diseases, especially parasitic diseases, that adversely impact this industry. The cardiovascular system is a very important system for communication between different parts of the body in all animals. Several parasites, which are found in the cardiovascular system, cause morbidity and mortality in the goat population. These parasites may cause myocarditis, pericarditis and cardiomyopathy, which are the major causes of heart failure in goats. Some other protozoan and rickettsial parasites found in blood produce severe harm to goats. The present chapter elaborates on the various parasites of the goat's cardiovascular system. This chapter helps to understand the morphological identification, life cycle, pathogenesis, clinical signs, diagnostic methods, treatment and control aspects of parasites in the cardiovascular system of goats.

Keywords: Cardiovascular system, Cardiomyopathy, Goats, Parasites.

INTRODUCTION

Goats (*Capra hircus*) are the earliest domesticated animals and have been associated with humans for at least 10,000 years. The importance of goats has increased as they play an important role in providing supplementary income in terms of meat, milk, fertilizer, draft power as well as fibers for clothing. It is known as a "poor man's cow" due to its small body size, docile nature and very

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less housing requirements are and now this is also called ATM for poor peoples in villages [1]. According to FAO, around 1,153 breeds of goats are found on our planet, which resides on every continent except Antarctica and in quite a harsh range of environments, from humid and tropical rain forests to dry hot desert regions and extreme cold, hypoxic high-altitude weather. Due to these important characters it is said about the goat that it is very strong ruminant which can exist in cruel environments in which other livestock species would perish. According to environment the morphology of goats are different from one another by their size, shape and production types [2]. The world constitutes approximately one billion goats. Goat meat (Chevon) is considered as the most preferred meat and widely consumed due to its nutritious value. The importance of goat's milk could not be ignored due to its medicinal value, easy digestibility and it's all round health promoting traits.

Importance of Cardiovascular System of Goat

The cardiovascular system is the very important system for communication between different parts of the body in all animals. It pumps and circulates the whole blood to every part of the body. Blood is also very necessary for transporting ravage products, food, oxygen, carbon dioxide as well as secretions like hormones. It also has other functions like thermoregulation of body [1]. The cardiovascular system is a dual track system, one supplies the lungs, and the other supply the rest of whole body. Both passage start and end in the heart, which is the organ in charge of keeping the blood in regular movement. The pattern of blood vessels become same in the both circuits and it was started from heart, arteries, arterioles, capillary net, small veins, veins and heart again. Arterioles and small veins may be found between two capillary nets. This is a called portal system, and named according to organ include like the hepatic portal system that includes the intestine and liver. Whole organ called the heart and it pumps the blood through the circulatory system, is made up of cardiac muscles which are found only in this organ and have four chambers [2]. The wall of the heart is made up of the three different layers namely epicardium, myocardium, and endocardium. Epicardium surrounds the heart, myocardium occurs in all four chambers and become thicker in the ventricles and thinner in the atria while the endocardium consists of a single layer of endothelial cells which remains in lining of the heart chambers (Fig. **1**).

Brief Description of Cardiovascular System of Goats

The cardiovascular system includes heart and the network of blood vessels that circulate blood around the body. It is also called blood vascular system and it consists arteries, capillary beds and veins. Arteries carry oxygenated blood away

from the heart to the tissues; capillary beds, permit necessary interchange between the blood and the tissues and are microscopic tubes in the tissues; veins, carry the blood back to the heart. Blood vessels are divided into the systemic arteries and pulmonary arteries [3]. Around heart a fibro-serous sac is present which is called pericardium which is made up of two types of layers *viz*. fibrous layer and serous layer. The serous layer divides in to parietal and visceral part. Visceral part of serous pericardium is termed as epicardium. The heart consist mainly four valves *viz*. mitral, tricuspid, pulmonary and aortic valves, which regulate blood flowing in the right direction. Each valve has own flaps that open and close once per heartbeat. The atrio-ventricular and semilunar valves keep blood flowing in one direction through the heart, and valves in large veins keeps blood flowing back toward the heart [4].

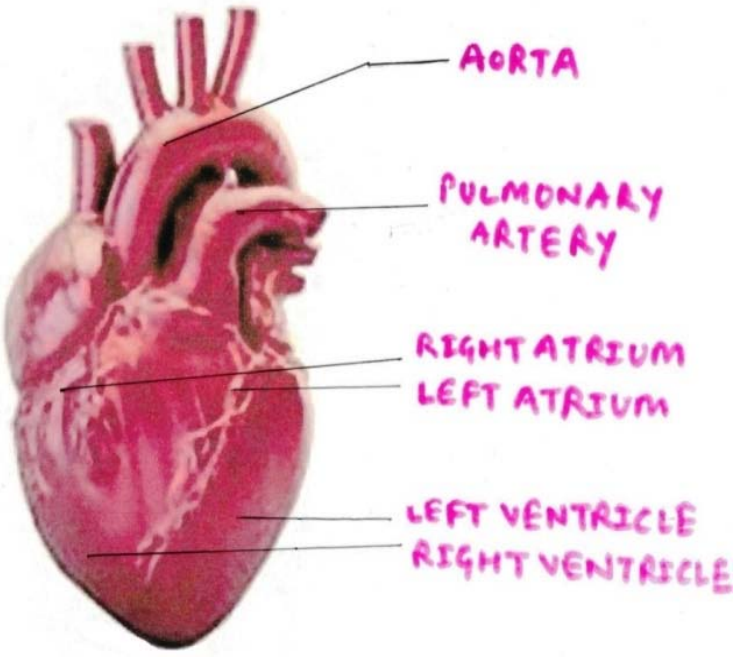

Fig. (1). cardiovascular system of goat.

All small ruminant including goat have a very similar conduction system in which main components are sino-atrial node (SA node), atrio-ventricular node (AV node), bundle of His, right and left main bundle branches and Purkinje fibers. In all mammalian heart the SA node is normal pacemaker and located in the high on the right atrial wall near the junction of the superior vena cava and the right atrium. Generally conduction spread through the atria to the AV node and then to the bundle of His. The AV nodes located at the base of the atrial septum, anterior

CHAPTER 5

Parasites in the Integumentary System of Goats

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Abstract: The ectoparasites that affect the skin, such as ticks, mites, fleas, and lice, are integumentary parasites. Diseases spread by various ectoparasites are distinguished by their distinctive morphology, while symptoms are caused by interactions between the parasite and the host. Parasites from outside the body eat bodily surface tissues like skin, blood, and hair. Ectoparasite wounds, as well as skin irritation, cause animal discomfort and irritability and function as an attractant for myiasis by blood-sucking flies. As they impair animal health, growth, and productivity, these ectoparasites have a substantial economic impact on goat farmers. In general, it is impossible to effectively handle infected livestock. Since there is a strong correlation between the climate, management techniques, and the prevalence of ectoparasitism in animals, it is imperative that biological control agents rather than chemical treatments should be used to control flies.

Keywords: Biological control, Ectoparasites, Integumentary parasites, Mites, Ticks.

INTRODUCTION

According to the World Food and Agriculture Organisation of the United Nations (2012), the goat is referred to as a “Poor man's cow” and is a small ruminant that is mostly raised by poor and marginalised farmers in Asian and African nations. Goats are the second most reared livestock in India, and India ranks second in the world in terms of goat population (135.17 million), behind China. The integumentary system is the largest organ in the body and acts as a physical barrier between the internal and exterior environments. It is made up of the epidermis, dermis, and hypodermis, as well as related glands, hair, and nails. The integumentary system of domestic animals is where the majority of arthropods reside.

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The output of goats is restricted in numerous ways by these arthropod pests. Parasites from outside the body survive on blood, hair, and skin. These parasites cause sores and skin inflammation, which makes the animal uncomfortable and irritated. In addition to preventing cows from gaining weight and producing much milk, parasites can spread diseases from ill to healthy animals. By impairing health, development rate, and production efficiency, these ectoparasites can have a major impact on the economics of the goat population.

Lice (Order: Phthiraptera)

The goats are frequently infested with *Bovicola caprae, Bovicola limbata, Linognathus stenopsis, Linognathus pedalis*, and *Linognathus africanus*. These permanent goat ectoparasites lack wings and are flattened. Comparing the growth of lice to that of other external parasites, a little difference has been observed. They have incomplete maturation, during which the juveniles are referred to as nymphs and resemble adults. A significant infestation of lice is known as pediculosis and is characterised by continual irritability, itching, scratching, and biting of the hair or fleece. Lice can infest a variety of domesticated animals, including cattle, pigs, sheep, and goats. This infestation results in chronic dermatitis. Only goats and sheep are targeted by goat lice, which are host-specific. The itchiness that lice produce has the biggest effects on their hosts. Due to the longer hair on the host's coat, closer proximity to the animals, and general lack of vitality, they are most prevalent in the winter. The hosts get agitated, do not eat or sleep well, and may hurt or harm their feathers, hair, or wool by biting and clawing the lice-infested areas of their bodies [1].

Anoplura, or sucking lice, and Mallophaga, or chewing or biting lice, are the two primary categories of lice. Biting lice have chewable mouthparts and consume hair, skin exudates, and scabs as food. Lice that suck puncture the skin of the host surface and bleed. Animals with louse infestations can be identified with matted, drab coats with frequent scratching as well as grooming behaviour. When animals rub and scratch because of the irritation from louse feeding, the result is raw skin or hair loss. Anxiety and poor nutrition can both lead to weight loss. Up to 25% less milk is produced than normal. Additionally, the host exhibits a lot of lethargy, and in severe cases, blood loss from louse sucking can cause anaemia [2].

Transmission

By direct physical contact, lice are typically spread from one animal to another or from one flock to another. Lice can travel from one place to another place by adhering to flies (Phoresy). The majority of herd-to-herd transmission occurs when infected animals are moved between herds. Since lice cannot survive long without their host, infected animals are typically used to transfer lice to herds.

Control

Production techniques and chemical treatment are both effective methods for controlling goat lice. Offering a high-energy meal can help control the louse population. Pour-on Pyrethroid cypermethrin, spot-on deltamethrin, and the insect growth inhibitor triflumuron have all been proven to be efficient when applied topically. The majority of animal louse populations fluctuate seasonally depending on the host's health. Typically, louse populations on animals are higher in the winter and are at their busiest in late winter and early spring. Larger populations of louse are typically supported by stressed animals than would be the case under normal circumstances. Late October is typically the ideal time to use insecticides [3]. Every time an animal scratches and rubs excessively, a louse infestation needs to be controlled. Since insecticides do not destroy louse eggs, controlling louse populations can be challenging with a single treatment. Two weeks following the first treatment, a second application is required to allow the eggs to hatch. A good management practise is to treat goats immediately after shearing, which ensures a greater proportion of lice come into contact with insecticide and reduces the volume of chemical necessary to achieve this. Shearing can be used to achieve a good degree of louse control because solar radiation and dehydration reduce the hatch rate of louse eggs (Fig. **1**).

Fig. (1). Goat sucking louse Linognathus stenopsis.

CHAPTER 6

Parasitic infection of the nervous system of goats

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Abstract: The nervous system may be the primary or secondary site of parasitic infection; parasitic diseases may occur as opportunistic infections or arise in immune-competent hosts. Parasitic infections cause a major economic impact on the farm goats industry, especially the infected central nervous system, as they cause a group of neurological diseases and constitute the biggest single and only challenge for veterinarians. The neurological health problems caused by these parasites affect goats as an outbreak in an endemic area or as sporadic cases in no endemic areas because of a decrease in good management, and immunosuppression caused by different stress as (transportation, grassing, pregnancy, and other risk factors). Parasites are a diverse group of organisms that can be broadly classified into single-celled organisms (*i.e*. protozoa) or multicellular helminthes (*i.e*. metazoan). Parasites can cause disease by physical disruption of tissue as they migrate, inflammatory response, provoking an intense, and often eosinophilia, some helminthic larvae can be very large, causing disease because of their expanding mass. A relatively large number of parasites are zoonotic and transmitted to humans, sometimes migrating through or lodging in tissues, including the CNS. Some parasites regularly cause symptomatic disease, while others cause asymptomatic diseases. Most goats through the word carry worms. However, the extent of their effect on goats in terms of deaths, loss of productivity, and the cost of control depends on the severity of the infestation and the species of the parasite, where goats are less able to develop natural immunity compared with other livestock species. Most common parasites have two stages of development: the larval stage, which may develop on pasture or tissue of goats as intermediate host, and the adult parasitic stage, which occurs in the intestine of goats or another definitive host.

Keywords: Clinical manifestation, Goats, Nervous system, Parasites.

INTRODUCTION

The nervous system may be the primary or secondary site of parasitic infection; parasitic diseases may occur as opportunistic infections or arise in immune-competent hosts. Parasitic infections cause a major economic impact on the farm goats' industry, especially the infected central nervous system, as they cause a

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group of neurological diseases and constitute the biggest single and only challenge for veterinarians, in addition to lack of vaccination in developing preventive and curative programs for this type of parasite. The neurological health problems caused by these parasites affect goats as an outbreak in an endemic area or as sporadic cases in no endemic areas because of a decrease in good management, and immunosuppression caused by different stress as (transportation, grassing, pregnancy, and other risk factors such).

Parasites are a diverse group of organisms that can be broadly classified into single-celled organisms (*i.e*. protozoa) or multicellular helminths (*i.e*. metazoa). Parasites can cause disease by physical disruption of tissue as they migrate, inflammatory response, provoking an intense, and often eosinophilia, Some helminthic larvae can be very large, causing disease because of their expanding mass [1].

A relatively large number of parasites are zoonotic and transmitted to humans, sometimes migrating through or lodging in tissues, including the CNS. Some parasites regularly cause symptomatic disease, while others cause asymptomatic diseases. Concomitant infections are possible in areas endemic to several parasites. Most goats through the word carry worms. However, the extent of their effect on goats in terms of deaths, loss of productivity, and the cost of control depends on the severity of the infestation and the species of the parasite, where goats are less able to develop natural immunity compared with other livestock species, where high stocking rates on pasture rapidly magnify the problem of parasitic infection in goats, most species of animals become more resistant to worms as they grow older, but age resistance is less effective in goats, worm drenches are less effective in goats, compared with sheep, so must be administered more frequently, warm wet weather enables a rapid build-up of free-living stages of parasites on pasture and Reduced natural immunity occurs in female goats during lactation, making them more susceptible to worms [2].

Most common parasites have two stages of development: the larval stage, which may develop on pasture or tissue of goats as intermediated host, and the adult parasitic stage, which occurs in the intestine of goats or another definitive host. Adult stages in the goat's intestine or other definitive host lay eggs that are passed out in feces. The eggs hatch and develop into larvae on pasture. The larvae are then consumed off pasture by the goat, and develop into adults in the intestine where they start laying more eggs. Understanding these stages helps in the management of parasitic problems.

Parasites commonly found in goats can be divided into two general categories: external (skin) and internal (organ) parasites. One of these parasites that affect goats is central nervous system parasites which are the topic of study.

Cestode Causing Nervous Manifestations in Goats ("gid", "stagger", "sturdy")

Definition

Cestode causing nervous manifestations in goats Coenurosis (“gid”, “stagger”, “sturdy”).

The larval stage of *Taenia Multicieps* parasite (*Coenurus cerebralis*), often known as sturdy, stagger, or gid, is a cestode that typically affects the central nervous system (CNS) of livestock, particularly the brain and spinal cord.

Definitive Host

Domestic and wild carnivores, such as dogs, jackals, foxes, and coyotes act as definitive hosts, where harboring adult worms in their small intestines and measuring about 40-100 cm in length. Intermediated host.

Domestic animals (including goats) and human beings, where larvae stage (large fluid-containing cyst; measuring 5-6 cm in diameter, the cyst contains several hundred protoscolices and collected in clusters on the cyst wall), develop in the brain.

Pathogenesis

Larval-stage cysts development causes intracranial pressure which is the cause of the neurological symptoms in intermediated hosts and the severity of the disease depends on the location and size of the cyst. Acute coenurosis occurs generally 10– 33 days after infection during the migration of oncospheres in the CNS; its symptoms are caused mostly by an acute inflammatory response related to a toxic and allergic reaction rather than by the mechanical action of the oncospheres, and are proportional to the number of migrating oncospheres [3].

Geographical Distribution

The parasite is typically prevalent worldwide, especially in rural areas, where the dog-goat route appears to be the most important transmission pathway [4], in Africa *Conuores cerebralis* was reported from Kenya, Ethiopia, Sudan, Angola, Tchad, Zaire, Congo, Senegal, northern and southern Africa.

CHAPTER 7

Parasites in the Eyes and Ears

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Abstract: The goat (*Capra hircus*) is the most important domesticated animal due to its importance in various parts of the world since it produces wool, meat, milk, fertilizer, draught power, and leather. There are numerous ways through which parasitic illnesses restrict goat industry production. Parasites outside the body survive on blood, skin, and hair. These parasites cause sores and skin inflammation, which makes the animal uncomfortable and irritated. Diseases can be spread by parasites from ill to healthy animals. These can reduce milk production and weight gain. Livestock that is infested cannot typically be managed well. The eyes and ears are the main organs of any animal, which serve as windows to the outside world and help to find food and shelter and defend them. The eyes and ears of goats are frequently affected by parasitic infections, which are characterized by blindness, severe lacrimation, conjunctivitis, corneal opacity, keratitis, abscesses in the eyelid, photophobia, and deafness. Amongst several species of external parasites that infect the goat include ticks, mites, fleas, flies, and lice. Out of these, ticks are ranked the uppermost in terms of causing infections. There are several genera of ticks that are present on the ear surface, ear canal, and body surface of goats, which are responsible for the transmis-

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sion of various tickborne diseases, tick worry, metabolic debilitation, tick-toxicosis, and also anemia. Ticks are also considered the second vector in the world after mosquitoes in the transmission of different diseases.

Keywords: Ear, Eye, Eyeworm, Goat, Spinose ear tick.

INTRODUCTION

The goat (*Capra hircus*) is the first species of domesticated animal, and it is one of the most useful domestic animals in various parts of the world since it produces wool, meat, milk, fertilizer, draught power, and leather. Due to its small size, docile disposition, and low housing needs compared to cows, it is incredibly inexpensive to rear [1]. It serves as an ATM for the underprivileged in remote areas. Around 1,153 different kinds of goats, which live on all continents but Antarctica and are able to bear children for the first time at the age of 14 months, are said to exist on Earth. It can produce milk for up to 2 years if managed properly throughout rearing. The goat is a powerful ruminant that can survive in harsh situations where other livestock animals would perish due to its significant characteristics. Goats differ from one another in size, form, and kind of production depending on their location. In India and other countries as well, goat meat, or chevon, is the most popular meat. Due to its therapeutic benefits, ease of digestion, and general health-promoting qualities, goat milk is widely used. Moreover, it serves as the most dependable source of income for small, landless labour and poor farmers in rural areas [2].

Anatomy of the Eye

Any animal's eyes, which serve as its main organ of vision and serve as windows to the outside world, are incredibly complex and have a variety of functions. Animals need vision to find food, defend themselves, find shelter, and do other things. The eye is the primary visual organ. It is situated inside the orbit of the eye and is made up of the eyeball, the optic nerve, and auxiliary structures. Eyelids, the conjunctiva and lacrimal system, the orbital fascia, and muscles make up the accessory structures [3]. The sclera (outermost layer), uveal tissue (middle layer), and retina make up the eye's exterior structure (innermost layer). The orbit contains each eyeball, which occupies around one-fifth of the orbital volume.

The extra-ocular muscles, fascia, fat, blood vessels, nerves, and the lacrimal gland occupy the remaining area. From an embryological perspective, the eye is an outgrowth of the central nervous system. The eye and the brain have a lot of similar structural and physiological characteristics. Both are shielded by bone walls, have sturdy fibrous coverings, and have two blood vessels supplying the

retina's vital nerve layer [4]. Internal cavities of the eye and brain are flooded with fluids of comparable composition and pressure (Fig. **1**).

Fig. (1). Eye of goat.

The eye has three fluid-containing compartments, three layers or coats, and contain three fluids.

- The three coats of the eye include: (a) Cornea, sclera, and lamina cribrosa, which make up the outer fibrous layer. (b) The iris, ciliary body, which is made up of the pars plicata and pars plana, and choroids are located in the middle vascular layer, or "uveal tract." (c) The retina's pigment epithelium, photoreceptors, and neurons are located in the inner nerve layer.
- The three fluid-containing compartments of the eye are as follows: (a) The area between the cornea and the iris diaphragm is known as the anterior chamber. (b) Posterior chamber: the triangle-shaped region between the ciliary body, lens, and zonule in the back and the iris in the front. (c) The vitreous chamber, or zonule and lens, is located there.
- There are intraocular fluids in the eye: (a) Aqueous humor, a watery, optically clear solution of water and electrolytes similar to tissue fluids, except that aqueous humor has a low protein content normally. (b) Vitreous humour, a transparent gel consisting of a three-dimensional network of collagen fibres with interspaces filled with polymerised hyaluronic acid molecules and water [5]. (c) Blood: in addition to its usual functions, blood contributes to the maintenance of intraocular pressure.

The goat's eye anatomy starts with the eyeball, or bulbus oculi, the optic nerve, and a few ancillary structures like the muscles, eyelids, and lacrimal apparatus. The eyeballs are housed inside the skeletal orbits that make up each eye. There is a layer of fat covering these orbits. Lacrimal, malar, frontal, and sphenoid bones, among others, help to construct the orbits. The frontal, lacrimal, and malar bones combine to produce the eye orbit's outer border. When we close our eyes, the

CHAPTER 8

Parasites of the Respiratory System of Goats

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Abstract: Goats are susceptible to a variety of respiratory illnesses. Lungworms primarily affect young goats with severe parasitic bronchitis. Coughing, dyspnoea, nasal discharge, weight loss, lethargy, and occasionally fever are some of the symptoms that may be present in animals infected with lungworms. This chapter will deal with parasitic cestodes, nematodes, and arthropods affecting the goats' respiratory systems. Here, parasites have been described according to the region of the respiratory system they affect. Parasitic nematodes such as Dictyocaulus and Protostrongylus commonly infect the trachea and bronchi, Muellerius spp. and metacestode stages of Echinococcus granulosus infest the lung parenchyma, while larvae of the dipteran fly *Oestrus ovis* infest the nasal passages. The symptoms of pulmonary parasitic diseases can be made worse by secondary bacterial or viral infections, which can lead to bronchitis, bronchiolitis, or pneumonia.

Keywords: False gid, Lungworm, Pulmonary hydatidosis, Verminous pneumonia.

INTRODUCTION

Domestic goats often get respiratory illnesses affecting single animals or groups in a herd. Diseases of the upper respiratory tract, like sinusitis brought on by parasite larvae, nasal foreign bodies, and enzootic nasal tumours, and conditions of the lower respiratory tract, like pneumonia of infectious origin, are particularly dangerous. Goats are particularly susceptible to lungworms between the ages of 2 to 18 months when they develop severe parasitic bronchitis (called "verminous pneumonia"). Coughing, dyspnea, nasal discharge, weight loss, sluggishness, and rarely fever are some of the symptoms that may be seen in infected animals with lungworms [1].

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Many studies have shown that lungworms have several clinical and pathological effects on the respiratory system of goats. Parasitic helminths of the protostrongylid nematode family, specifically the families Protostrongylidae and Dictyocaulidae, which cause damage to various parts of the pulmonary parenchyma in ruminants, are known as lungworms. These nematodes are widely regarded as a major parasite of domestic goats as well as other related wild ruminants. Secondary bacterial and viral infections can occur in animals with protostrongylid nematode infections due to resulting bronchitis, bronchiolitis, and pneumonia. Clinically, these nematodes cause an increase in respiratory rate due to the impairment of gas exchange in the lungs caused by parasitic bronchopneumonia. Bronchopulmonary lesions caused by lungworms, however, are a challenge for livestock farmers everywhere, especially those who raise small ruminants. Parasites that affect the respiratory system of goats can be put into different groups based on what part of the system is infected. The larvae of dipteran fly *Oestrus ovis* infest the nasal passages of the animal, the lung parenchyma is affected by the Muellerius spp. and metacestodal stages of cestode parasite Echinococcus granulosus. The air passages of the lung as the trachea and bronchi get infected with most lung worm species such as Dictyocaulus, Protostrongylus *etc* [2].

PARASITES AFFECTING THE NASAL PASSAGE

Oestrus Ovis Larvae

Adult female flies (*Oestrus ovis*) commonly swarm around the heads of animals, earning them the common name of nasal bot flies. Females are viviparous, meaning they deposit previously hatched larvae directly into the nostrils of host animals. Those larvae are obligate parasites of the sinuses and nasal passages. The first-stage larvae, which have just been deposited, actively move to the nasal passages and attach to the mucous membranes. They develop and go through two more moults before entering the third and final stage of the larval life cycle. The larvae irritate and mechanically harm the host's nasal sinuses as they migrate and develop. Nasal sinus damage can cause acute clinical problems like difficulty breathing, excessive nasal discharge, and restlessness, severely compromising the health of the animal. Larval secretions and excretions can also trigger a local and systemic immune response, making the problem even worse. Mild infestations are usually asymptomatic but can cause signs of generalised diseases, such as emaciation, which can negatively impact animal production and result in economic losses. As a rule, an infestation lasts between 25 and 30 days, though it can last as long as 10 months in warmer climates. The third-stage larvae develop into adult flies after being expelled from the host *via* sneezing. Third-stage larvae

sometimes die because they are unable to escape the nasal sinuses. An animal's life could be in danger if this causes septic sinusitis.

Adult flies are the cause of flock disturbances, and the larval stages of the parasite are significantly linked to significant losses in animal production [3].

Animals become restless and may shake their heads or press their nostrils into each other's fleeces or the ground when the adult nasal fly, *Oestrus ovis*, is out and about trying to deposit larvae. This prevents them from eating, which can lead to poor weight gain (Fig. **1**). It can also lead to self-inflicted wounds. Larvae in the nasal cavities and sinuses lead to a buildup of thick mucus that blocks the nostrils and forces the animal to breathe through the mouth. Migrating larvae can also erode their way through the skull, dorsal turbinates, and frontal sinuses to reach the brain. This produces neurological symptoms of false gid, such as a high-stepping gait and unsteadiness (Fig. **2**). Protection of grazing animals from adult flies is difficult; however, parasitic larvae can be eliminated after an attack through systemic insecticides before they reach a damaging maturity stage [4].

Fig. (1). *Oestrus ovis* mature larva with weak spines in distinct regions.

CHAPTER 9

Parasites of Liver and Pancreas

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Abstract: Goats are important in the economy of a country like India. In India, a vast majority of small-scale farmers depend on sheep and goat rearing as their livelihood. They can be completely utilized in different forms, such as milk, meat, skin, and manure. Researchers suggest that the goat sector contributes 8.4% to India's livestock GDP. A multitude of different species of parasites make goats their hosts, some of which can cause significant diseases. A systematic way to identify them is by examining the organs in which they inhabit. Parasites infecting the liver and pancreas of goats include *Fasciola hepatica*, *F. gigantica, Fascioloides magna, Dicrocoelium dendriticum, Ehinococcus granulosus* (intermediate stage hydatid cyst occurs in the liver*), Stilesia hepatica*, *Taenia hydatigena, Eurytrema pancreaticum, etc*. Most of them cause severe damage to liver parenchyma, which, in turn, results in the loss of production and in some cases, fatality of farm animals. They can also cause internal bleeding and anemia. These parasites require an intermediate host (mostly snails of the genus *Lymnea, Planorbis, etc*) to complete their life cycle. This chapter describes in detail various parasites affecting the liver and pancreas of goats, their predilection site, pathogenesis, clinical signs, treatment, and control. Control of intermediate hosts, especially snails, is an important part of the control of the majority of these parasites. Hence, due importance is given to the various snail control methods in this chapter. Recent trends in this aspect are discussed in detail, which will be helpful for the scientific community.

Keywords: Clinical signs, Control, Epidemiology, Economic impact, Goat, Internal parasites, Immunodiagnosis, Liver, Molecular methods, Pathogenesis, Pancreas, Snails, Snail control, Treatment.

INTRODUCTION

In India, the majority of the small and marginal farmers derive their livelihood from goats. The goat sector contributes 8.4% to India's livestock GDP through its milk, meat, skin, and manure. Hence, they are known as poor man's cows. There

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are many parasites infecting the liver and pancreas of goats, which are listed below. This chapter discusses in detail the parasites of the liver and pancreas of goats.

PARASITES OF LIVER

- *Fasciola hepatica*.
- *Fasciola gigantica*.
- *Fascioloides magna*.
- *Dicrocoelium dendriticum*.
- *Ehinococcus granulosus*.
- *Stilesia hepatica*.
- *Taenia hydatigena*.

PARASITES OF PANCREAS

Eurytrema pancreaticum.

Fasciolosis

History

In the historic periods, Fasciolosis was considered a water-borne disease as many of the prehistoric human fecal sample studies revealed Fasciola eggs in human feces [18, 27]. In the year 1379, Jean de Brie, a cattle breeder in France, gave a detailed note on *Fasciola hepatica*-induced liver damage in sheep. *F. hepatica* was first described in rabbits by Francesco Redi in 1684. Again, in 1881, F.R. Leuckart documented the life cycle of *F. hepatica* as a series of articles. In the same year, Algemon P.W.T. also described the life cycle of *F. hepatica*. In 1882, he found that Lymnid snails act as intermediate hosts for Fasciola. The life cycle descriptions of Algemon and Leuckart had many lacunae. Organophosphorous Compounds. Later, in 1892, Adolf Lutz said that animals get infected by *F. hepatica* by ingestion of encysted larval stages on leaf blades [1]. He also observed that immature liver flukes penetrate the liver after migration through the intestinal wall into the abdominal cavity.

Introduction

Fasciolosis was caused by *Fasciola hepatica* and *Fasciola gigantica* [2, 3]. These parasites belong to the subfamily Fasciolinae, which includes two main genera: Fasciola and Fascioloides. Under the genus Fasciola, there are four species of parasites [4]. The most important one is *F. hepatica* which occurs in the liver of ruminants, horses, camels, pigs, and many wild animals. *F. gigantica*, also called Tropical liver fluke, infects the liver of domestic ruminants, pigs, camels, horses,

donkeys, and wild animals. Other important species *F. nyanzae* and *F. jacksoni* established in the livers of Hippopotamus and Asian elephants, respectively. *Fascioloides magna* is an important member of the genus Fascioloides. They are also known as Large American liver flukes. Snails of the family Planorbidae and Lymnaeidae are intermediate hosts for Fasciola. These snails are naturally found in water sources like ponds, lakes, canals, and paddy fields. Among different types of ruminants, buffaloes are more prone to Fasciolosis due to their wallowing behavior during summer. Other animals usually get infected by grazing near water-submerged areas or by drinking water from water bodies infested with carrier snails. Fasciolosis is reported all around the globe. Nowadays, Fasciolosis is reported as an emerging as well as reemerging zoonosis [5]. According to the World Health Organization [6], an estimated 2.4 million people around the globe were infected with Fasciola. It also stated that another 180 million are included in high-risk groups.

Status of Fasciolosis

Fasciolosis is a helminthic zoonotic disease of importance worldwide. A wide range of mammals can be infected by Liver flukes. Humans are regarded as accidental hosts [7]. Fasciolosis became an upcoming threat in India. This is because the survivability of snail intermediate hosts was increased significantly due to natural and human-induced changes in the external environment. In humid regions of underdeveloped countries, fasciolosis is the most predominant infection in large ruminants [8]. In India, this condition is mainly produced by *F. gigantica* and also by *F. hepatica.* Propagation of snails was favored by the construction of Dams and new irrigation systems. Monsoon rains also have an important effect on the occurrence of fasciolosis in India. In India, the National Dairy Development Board (NDDB) carried out a survey of dairy animals across the country. It revealed two dangerous periods in the year related to the dissemination of fasciolosis in India, which are July–September and February– March [9]. Endemic fasciolosis is mostly reported in cattle and buffaloes [10]. In recent years, fasciolosis has been reported from horses, pigs, and wild animals like hares [11], and humans from different parts of the world [12]. This re-emergence can be attributed to various factors like changes in climatic conditions, resistance to anthelmintic drugs, *etc.*

Economic Importance

The economic importance of fasciolosis is directly linked to the reduction in the production performances of ruminant animals. Fasciolosis-induced financial problems in cattle can be attributed to the death of farm animals, infertility problems, abortions, reduction in growth performances, decrease in milk

CHAPTER 10

Parasites Affecting the Musculoskeletal System of Goats

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Abstract: This chapter discusses some of the important parasites affecting or found in the musculoskeletal system of goats. Among them, many are zoonotic in nature. Toxoplasmosis is a worldwide occurring zoonotic disease belonging to the phylum Apicomplexa. Toxoplasma stages are found in different parts of goats, including the musculoskeletal system. Transmission of toxoplasma from goat meat to humans in India is of low importance as the meat is properly cooked before consumption. However, it can spread to cats if they are fed with improperly cooked infected meat. Also, carcasses infected with toxoplasmosis will lose their infectivity very shortly after the death of the animal. Similarly, sarcocystosis is a silent zoonotic parasitic disease caused by obligatory intracellular protozoa of the genus Sarcocystis. The main factor that helps in the control of sarcocystosis in goats is to avoid dogs and cats in the animal sheds. *Besnoitia caprae* is found in goats. To date, *Besnoitia caprae* has not been assigned with any definitive host and or intermediate hosts. This parasite has a close resemblance with other species of Besnoitia. Hammondia causes a transient myositis that may be present in the skeletal muscles of infected goats. In areas of high endemicity of *Oestrus ovis*, humans are at high risk of zoonosis and the parasite may cause ophthalmic infections. *Wohlfahrtia magnifica* causes traumatic myiasis in the flesh of goats. Coenurus is treated mainly by the treatment of infected dogs and proper disposal of intermediate host carcasses. In many countries, trichinellosis is an emerging disease in goats.

Keywords: *Besnoitia caprae*, *Cysticercus ovis*, *Coenurus gaigeri*, *Hammondia hammondi*, *Multiceps multiceps*, *Oestrus ovis*, *Sarcocystis caprae*, *Toxoplasma gondii*, *Taenia ovis*, *Trichinella Wohlfahrtia magnifica*.

INTRODUCTION

Toxoplasmosis is a worldwide occurring zoonotic disease belonging to the phylum Apicomplexa. Infection with *Toxoplasma gondii* is one of the most common parasitic infections of food animals. *Toxoplasma gondii* was discovered

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Tanmoy Rana (Ed.)

by Nicole and Manceaux in Tunisia in the year 1908, 1909 in a rodent *Ctenodactylus gundii*.

The name Toxoplasma (toxon means bow and plasma means form) relates to the crescent shape of the tachyzoite stage [1]. There are three infectious stages of the parasite: Tachyzoites (in groups), bradyzoites (in tissue cysts) and sporozoites (in oocysts). The term tachyzoite comes from the Greek word "tachos," which means speed. This term was used for the fast-multiplying stages of the parasite. They are found in the cells of food animals and non-intestinal epithelial cells of cats. When the tachyzoites are found in small or large aggregates, they are called clones, terminal colonies or groups [2].

The tachyzoites have a crescent shape with a pointed anterior end and round posterior end (Fig **1**). They move by gliding, flexing, undulating, and rotating. Upon entering the host cell, the tachyzoite actively penetrates by plasmalemma or phagocytosis and multiplies asexually by repeated endodyogeny. Once the multiplication is complete, the host cell bursts and releases the multiplying forms.

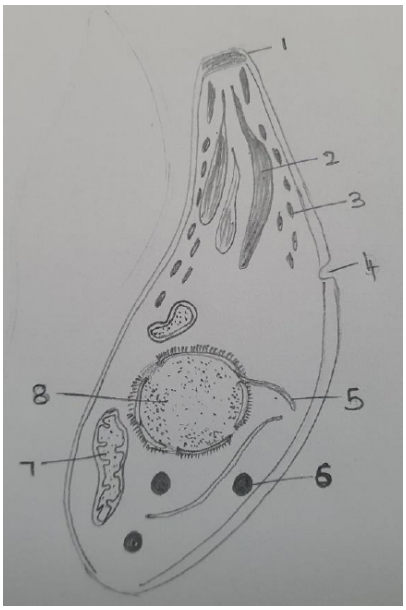

Fig. (1). Toxoplasma tachyzoite.

Bradyzoites or cystozoites: The word brady means slow in Greek. They are the slow multiplying forms, found in the cysts in the tissues. These cysts will not cause any inflammatory reactions in the host [3].

Life Cycle

Cats act as the definitive hosts, and the infected cats shed *Toxoplasma gondii* oocysts in their feces. The oocyst is small and contains a single sporont and is noninfective when passed in the feces. The sporulation (multiplication of sporont) is completed in 1-5 days and results in formation of two sporocysts, each of which contains four sporozoites. Fully sporulated oocysts are infective on ingestion to essentially all warm-blooded animals including cats. All warm blooded animals act as intermediate hosts. Through contaminated food and water the warm blooded animals get the infection.

On ingestion, outer wall of the sporulated oocysts will dissolve in the intestine and release the sporozoites. These sporozoites will enter into the cells of the intestine and associated lymph nodes and multiply to form rapidly multiplying stages, tachyzoites, which spread to all other tissues of the body, where they invade cells and continue to multiply. Eventually, tissue cysts containing slowly dividing forms, bradyzoites are formed in the brain, striated muscles and liver and remain viable for the life of the host [4].

Bradyzoites are infective on ingestion to essentially all warm-blooded animals and behave in the manner similar to that just described for sporozoites. Thus, paratenic hosts become infected with *T.gondii* by ingesting sporulated oocysts from cat feces or bradyzoites in the tissues of other paratenic hosts.

When the members of the cat family ingests tissue cysts of *T.gondii*, the bradyzoites penetrate the epithelial cells of the small intestine, undergo a series of asexual cycles and finally undergo the sexual cycle, which culminates in the shedding of oocysts. In the intermediate host, multiplication occurs in different organs/systems and form tissue cysts.

The tachyzoite stage is responsible for tissue damage in toxoplasmosis. The clinical signs in goats mainly depend on affected tissues, number of tachyzoites released and ability of the host immune response to combat the parasitic stage. If the animals are immunocompetent, then the parasite causes only subclinical illness [5].

Toxoplasma stages are found in different parts of goats including musculoskeletal system. Transmission of toxoplasma from goat meat to humans in India is of low importance as the meat is properly cooked before consumption. But it can spread to cats if they are fed with improperly cooked infected meat. Also carcasses infected with toxoplasmosis will lose their infectivity very shortly after the death of the animal.

CHAPTER 11

Diagnostic Evaluation

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Abstract: Parasitic infections in goats adversely affect health and productivity and are a major concern worldwide, leading to severe economic losses to the goat industry. The use of anti-parasitic drugs has been proven to be effective in the prevention and control of parasitic load in small ruminants. However, accurate diagnosis of parasitic infection is of utmost importance, which helps in the selection of the most suitable therapeutic agents and reduces the indiscriminate use of anti-parasitic drugs. The conventional diagnostic methods, such as microscopic examination of excretions, secretions, and blood smear for parasites, even nowadays are considered to be "gold standard" techniques in diagnosis, whereas the advancement in clinical diagnostic methods with rapid screening procedures and introduction of molecular biology tools without sacrificing sensitivity, value-added tests, and point-of-care tests overcome the issues related with these conventional methods. Recent diagnostic evaluation of parasitic diseases is performed by serology-based tests, parasite DNA-based molecular methods and proteomic technology. Serology-based tests/ assays are helpful for screening of large number of goats at a time, whereas the parasite DNA-based molecular methods are found helpful for the diagnosis of parasite with very high sensitivity and specificity. Recently, the use of proteomic technology with host or parasite protein as a biomarker opens a new horizon for parasite disease diagnosis. The current chapter discusses the detailed conventional methods and alternative approaches for the diagnosis of parasite disease.

Keywords: Dot-ELISA, ELISA, FAST-ELISA, ICAT, iTRAQ, Molecular diagnostic tests, MALDI-TOF MS, Microscopic examination, Parasitic disease diagnosis, Proteomic technology, Serology-based tests, SALDI-TOF MS.

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INTRODUCTION

The role of goats (*Capra hircus*) cannot be ignored in the establishment of the livestock sector. The global population of goats is approximately 450 million and contributes 27.80 percent of the total livestock population. Goat is one of the oldest domesticated species and is generally described as a "poor man's cow," but this seems to be an understatement due to its increased importance [1, 2]. Goat serves as one of the important means of livelihood and nutritional security for small and marginal farmers and landless rural households. They play an important role in capital storage, income and employment generation and household nutrition. In comparison to cows, goats are hardy, multi-utility, easy to maintain and prolific ruminants that can efficiently convert low-value vegetation, tree leaves and crop residues into high-value meat (chevon), milk, hide, manure and fibre, including pashmina. With these benefits of goats, their demand is increasing day by day, and in an estimate, to meet this rising demand, there is a requirement to double their population by 2030.

Goats are an integral part of the livestock production systems in crop-livestock mixed agriculture in the developing nations but the benefits obtained from goats today do not match with their actual potential. Diseases contribute to the constraints of goat production, particularly due to parasitic diseases. Although it is difficult to estimate the current economic impact of internal parasites on small ruminants but assumed that 15% of adult mortality in goats, arise from only roundworm-related diseases [3,4].

Clinical symptoms, clinical history, travel history, and the geographic location of the animal are the primary modes to suspect the parasitic disease. Now days, the tests currently used to diagnose many parasitic diseases have changed little since the development of the microscope in the 15th century by Antonie van Leeuwenhoek. Additionally, most of the existing tests cannot distinguish between past, latent, acute, and reactivated infections and are not useful for following response to therapy or for prognosis [5].

However, recent advancements in diagnostic techniques have created bright opportunities for a significant improvement in parasite disease diagnosis. First off, some more recent, extremely sensitive and specific serology-based tests have been developed, including the Falcon assay screening test ELISA (FAST-ELISA), Dot-ELISA, rapid antigen detection system (RDTS), and luciferase immuno-precipitation system (LIPS). Second, molecular based techniques have demonstrated a great potential for application in parasite identification with improved specificity and sensitivity, including loop- mediated isothermal amplification (LAMP), real-time polymerase chain reaction, and Luminex [6].

Thirdly, proteomic technology has also been developed to find out the biomarkers using the infected tissues or biological fluids of the host. The aim of this chapter is to highlight conventional as well as recent advanced tools in parasite disease diagnosis in goats.

CONVENTIONAL METHODS

Diagnosis of Parasites Located in Digestive (GI) Tract

The faeces of the infected host may contain the eggs, larva, adult worms, and proglottids of the gastrointestinal parasite. Feces are collected and examined as part of the process for diagnosing parasites and parasitic stages from faeces.

Collection of Faeces

It is best to always inspect a fresh faeces sample while diagnosing parasites/stages. To avoid further development, a faeces sample should ideally be taken per rectum, or directly from the rectum, and preserved in airtight containers [7]. The kid and lambs can be induced to defecate by inserting a moistened finger into the rectum and gentle massaging until the external sphincter relaxes. Older faeces have an unpleasant odour, and the difficult to distinguish eggs in the faeces may develop into larvae. The physical state of the faeces, together with the existence of parasites or their segments, nature of the odour, consistency, colour, the presence of blood, *etc*., should be noted as soon as the faecal sample is received [8].

Transportation of the Sample

The parasitological sample should always be collected in a clean container (glass/plastic bottles), tightly sealed, and stored at 4 degrees Celsius until examination. Cold chain samples should be transported in sealed screw cap vials. By using a 10% formalin or 70% ethanol (1:3) ratio as a preservative, the samples can be rendered non- infectious. Before transportation, the container should be properly labeled with the following information: animal species, gender, age, sex, and clinical history [9].

Gross Examination of Faeces

Examine the physical properties of the sample, such as its consistency (soft, watery, hard and very hard), color (light grey-poor absorption), the presence of blood or mucus, and its dark brown, black, or red color. Gross parasites (larvae, tapeworm segments, roundworms, and so on) are gently removed with a fine brush or forceps and examined under a hand lens or dissecting microscope.

CHAPTER 12

Parasitic Diseases in Goats: Therapeutics and Control Measures

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Abstract: Goats act as a crucial source of meat, milk, and wool for humans worldwide. Due to their browsing and foraging activity, their health and production constantly suffer from the threat of helminth infection and ectoparasitic infestation. However, there is limited and scattered information on the therapeutics and control of parasites in goats. The information available for the sheep and cattle industry is often reinforced in the goat industry without any safety and efficacy trials of particular formulations in goats. This chapter emphasizes the fact that goat metabolism differs widely from other small ruminants. Therefore, the therapeutic dosage regimen of anthelmintics and other oral medications in goats differs significantly from other animals. Secondly, refugia must be maintained in the animal farms to maintain the efficacy of available drugs. The emergence of anthelmintic and acaricide resistance can be delayed by using integrated parasite management practices. Prudent implication of available therapeutics in light of available scientific literature can significantly impact the livelihood of farmers engaged in the goat industry.

Keywords: Anthelmintics, Acaricides, Goat industry, Pasture management.

INTRODUCTION

Globally, the goat population is increasing because of its unique ability to convert low-valued forages into good-quality meat, milk and hide products with higher returns [1] Unlike other livestock species, goats are highly susceptible to endo-parasitic infections and ecto-parasitic infestations, owing to their browsing habits and thin skin [2]. Petite systematic experimental trials have been conducted to address the problems related to therapeutics and the control of parasites in goats. In the goat industry, scant-validated literature and species-focused research are

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available as compared to the ovine species, where detailed experiments and their results are widely deliberated by the scientific community [3]. Goats, with their browsing habits, have developed a peculiar parasite avoidance strategy during the course of evolution [4]. Likewise, parasites have also evolved to sustain within the goat's internal environment. Goat shares a majority of its internal as well as external parasites with the ovine species. There is a vast difference in parasite resilience and tolerance capacity of ovine and caprine hosts, principally due to variations in feeding habits and exposure to varied volumes of parasitic load. The goat industry remarkably suffers from the pathological and economic consequences of parasitic diseases in tropical and sub-tropical countries [5, 6]. Due to differences in the basal metabolic rates, drug dosage for ovine cannot be replicated in the caprine host [7].

Further, under-dosing of the goat herd following sheep deworming protocols has further raised the issue of anthelmentic resistance in goat industry [8]. Therefore, detailed information on therapeutic and control of parasitic disease in goats is the need of the hour. Three fourths of the literature pertaining to small animal industry focused upon ovine host, consequently, the present chapter aimed to highlight the differences in the therapeutic and control strategy of parasitic disease in sheep and goat along with compilation of available literature pertaining to this topic.

Endo-parasite Control

Helminth parasitism of the digestive tract remains a major threat affecting goat health and production. In contrast to cattle, many of the same species of cestodes, trematodes and nematodes infect goat and sheep (Table **1**, Figs. **1** - **3**), although some data suggest the existence of different caprine and ovine strains for some nematode species. Owing to their ubiquitous distribution and high prevalence, infections with gastrointestinal nematodes (GIN) are of major economic importance in goat farming. In developed countries, the main consequences are severe losses of production, whereas in developing countries, some of these GIN species provoke high mortality rates, particularly in kids. Despite the availability of various means of parasite control, chemical control form the backbone of parasite control strategies in small ruminant industry [9].

Since sheep and goats process anthelmintics differently, goats generally need higher dosages of most of anthelmintics, which are metabolised predominantly by liver. For extra-label use, sheep can receive the cattle dosage (in mg/kg), however, goats need to receive twice that amount, with the exception of levamisole, which is given at only 1.5 times the cattle dose due to potential neurotoxicity concerns. Levamisole is toxic in goat on administration of 20 mg/kg body weight. It is

contraindicated in pregnant does during the last 3 weeks of gestation and by injectable route. In general, oral route of anthelmintic medication is preferred in goats. Combining two anthelmintics from different classes (*e.g.*, fenbendazole-levamisole, albendazole-ivermectin) has been shown to increase efficacy in situations where there is known resistance to all classes of anthelmintics. Some narrow spectrum anthelmentics are also given in combination to widen their host range, for instances, chorsulon-ivermectin and oxyclozanide-levamisole. The clinician should use the full therapeutic dosage of each drug when using combined anthelmintics. Secondly, pour-on anthelmintics are usually only marginally effective when applied topically to sheep or goats [10, 11]. During quarantine drench, double the dose of benzimidazole anthelmintic is generally administered owing to low solubility and high safety of this drug as well as aiming at maximum reduction in parasitic load of newly introduced goat in the herd.

Table 1. The main helminth species reported from goats.

Site of Predilection	Helminth Parasite
Oesophagus	• *Gongylonema pulchrum*[N]
Rumen/Reticulum	• *Calicophoron calicophoron*[T], *C. daubneyi*[T] • *Gongylonema monnig*[N], *G. verrucosum*[N] • *Paramphistomum cervi*[T], *P. microbothrium*[T] • *Ceylonocotyle streptocoelium*[T] • *Cotylophoron cotylophorum*[T]
Abomasum	• *Haemonchus contortus*[N] • *Marshallagia marshalli*[N] • *Teladorsagia circumcincta*[N] • *Trichostrongylus axei*[N] • *Parabronema skrjabini*[N]
Small intestine	• *Trichostrongylus capricola*[N], *T. colubriformis*[N], *T. vitrinus*[N], *T. longispicularis*[N] • *Nematodirus filicollis*[N] • *N. battus*[N], *N. spathiger*[N] • *Moniezia expansa*[C] • *Cooperia curticei*[N] • *Bunostomum trigonocephalum*[N] • *Giageria pachyselis*[N] • *Strongyloides papillosus*[N] • *Capillaria longipes*[N] • *Avitellina centripunctata*[C] • *Stilesia globipunctata*[C] • *Thysaniezia ovilla*[C] • *Cymbiforma indica*[T]

SUBJECT INDEX

A

Absorption, low medication 296
Acid 220, 311
  ferulic 220
  nonanoic 311
Allergic reaction 123
Amplified fragment length polymorphism (AFLP) 281
Anaemia 15, 33, 34, 88, 90, 93, 94, 96, 98, 101, 113, 114
  immunologic 15
Anaphylactic reaction 16
Anemia 63, 68, 102, 153, 165, 172, 178, 203, 214, 215, 230, 247
  autoimmune hemolytic 102
  increasing 215
  iron deficiency 214
Angiography 79
Anthropozoonosis 20
Antibodies, foetal 70
Antibody detection 133
Antigen-presenting cells 72
Application 88, 119, 162, 218, 257, 266, 282, 304, 316
  routine 88
  strategic 316
Assays 133, 144, 265, 276, 277
  enzyme-linked immune-sorbent 133, 144
  immunoblot 277
  linked immunosorbent 276
Autoimmunity 80

B

Baermann's technique 275
Bait formulations in snail control 220
Based techniques 279
Biochemical techniques 263
Biocontrol agents 302
Biological control 108, 116, 218, 313
  agents 108, 116, 313
  methods 218
Blood 77, 81, 155
  arteries 155
  oxygenated 77
  theileria lestoquardi 81
Bronchiolitis 184, 185
Bronchitis 184, 185, 193
  eosinophilic 193
Bronchopulmonary lesions 185

C

Calotropis 311
Camellia sinensis 219
Caprine anaplasmosis 98
Carbohydrates 220, 255
Cardiac dysfunction 104
Cardiomyopathy 76, 79
Cattle 29, 30, 31, 36, 37, 39, 49, 80, 81, 85, 86, 87, 91, 103, 127, 157, 168, 204, 205, 222, 224, 227, 289
  breeder 204
  industry 289
  infection 87
Central nervous system (CNS) 121, 122, 123, 124, 132, 134, 139, 146, 153, 159, 163, 303, 318
Cerebral hemispheres 141, 163
Cerebrospinal nematodiosis 130
Cervical 58, 59, 132
  groove 58, 59
  scoliosis 132
Chemicals 179, 217, 218, 219, 256, 302, 305, 309, 310, 312
  inorganic 218
  release cytotoxic 256
Chemoprophylaxis 18
Chemotherapy 302, 318
Chitin 312
  inhibitor 312
Chitin synthesis 305, 312
  inhibitor 312

modulators 305
Chronic 34, 58, 63, 65, 68, 73, 80, 90, 96, 140, 188, 201, 212, 216, 222, 227, 232, 276
autoimmune reaction 80
fascioliosis 276
fasciolosis 216
form infection 222
haemonchosis 34
illness 58
infections 63, 65, 68, 73, 80, 90, 96, 140, 188, 212, 232
interstitial pancreatitis 227
nonproductive cough 201
Cirrhosis 16, 226
liver fluke cause 16
peri lobular 226
Climate 26, 108, 116, 178, 243
temperate 178, 243
Clindamycin 139, 243
Clonorchis sinensis infection 17
Coelozoic parasites 6
Coenurosis 126, 162
Combination 126, 142, 144, 219, 220, 232, 291, 297, 298, 299, 309, 310, 311, 319
acaricide 311
binary 220
racemic 297
Conditions 14, 21, 32, 34, 37, 40, 41, 44, 62, 66, 68, 104, 120, 162, 166, 205, 210, 211, 230, 233, 318
abnormal 104
climatic 14, 120, 205
dry 32, 210
natural 37
pathological 68
skeletal 40
stressor 318
Conjunctivitis 152, 162, 175
infectious 162
Connective tissues 93, 94, 155, 170, 196, 198, 251, 262, 277
fibrous 227
proliferation 198
Control 18, 119, 223, 304, 307, 311, 313, 316
ectoparasite 304, 307, 311, 313
genetic 119, 313, 316
immunological 18, 313, 316
molluscan 223
Copper 134, 301, 302
deficiency 134
oxide wire particles (COWP) 301
sulphate spraying 302
Copro antigen detection 232
Coprophagous insects 66
Cornell Mc-Master technique 270
Coronary sinus 79
Cotylophoron cotylophorum 31
Cow urine 219
Crawling sensation 201
Crypts, intestinal 41
Cutaneous leishmaniasis 23
Cyclodevelopmental transmission 21
Cyclozoonosis 21
Cyst 129, 250
formation 250
leakage 129
Cysticercoids 50, 228
Cysticercosis 126, 230, 277, 284
Cysticercus ovis in goats 261
Cystitis 138
Cystogenous glands 209
Cysts 58, 123, 125, 126, 128, 129, 130, 143, 147, 163, 164, 187, 230, 231, 232, 241, 245, 247, 249, 250, 258, 261
daughter 128, 231
hemorrhage 126
macroscopic 245
microscopic 147, 247
parasite forms 250
parasitic 143
thin-walled 125
Cytokine storm 80
Cytoplasm 24, 98, 100, 143
Cytoplasmic phagosomes 98
Cytotoxicity, mediated 14

D

Damage 5, 14, 16, 28, 68, 79, 131, 132, 135, 177, 218, 224, 230, 232, 249, 252, 256, 298
economic 230
muscular 249, 252
myocardial 79
neurologic 131, 132
retinal 298
Debris 174, 189, 198, 276
cellular 198
dead cell 174
Degeneration 94, 167, 258

cartilage 167
muscular 258
Deltamethrin 110, 174, 219, 300, 306, 309
spot-on 110
sprays 174
Demodecosis 175
Demodex orders 175
Demodicosis 306
Dendritic cells 72
Dependence, metabolic 3
Depression 68, 101, 125, 193, 215, 229, 303
Dermatitis, facial 83
Detection 43, 71, 129, 133, 142, 144, 162, 216, 251, 275, 277, 278, 283, 310
microscopic 129
sensitivity 278
serological 251
Determinants, epidemiological 231
Development 5, 6, 10, 21, 32, 33, 45, 72, 86, 87, 119, 121, 122, 200, 209
inhibition 33
Developmental transmission 21
Diarrhea 39, 58, 69, 145, 215, 319
Digital 279, 280
camera 279
signal processing 280
Diminazene aceturate work 94
Diphyllobothrium latum infection 14
Disease 1, 20, 23, 24, 48, 55, 57, 79, 80, 86, 88, 102, 121, 122, 134, 144, 148, 153, 162, 165, 251, 283, 317, 318
asymptomatic 121, 122
cardiovascular 79, 80
immunological 88
snoring 86
tickborne 153, 165
Disruption, digestion 44
DNA 118, 130, 148, 220, 221, 265, 278, 280, 281, 282
amplification, high-specificity 280
-based molecular methods 265
digestion 281
double-stranded 278
fragments 281
polymerase 280
polymorphism 281
ribosomal 148
segments 278
synthesis 280
Drought conditions development 209
Drugs 18, 134, 139, 162, 167, 205, 217, 291, 296, 297, 299, 300, 304, 309, 318
anthelmintic 205
anti-inflammatory 134, 167
effective anthelminthic 162
effective antiparasitic 18
Ducks, domestic 302
Dynamic interaction 13
Dyshaemopoiesis 33
Dyspnea 86, 184, 189, 193, 196

E

Eating aquatic plants 13
Echocardiography 79
Ectoparasiticides 304, 305, 306, 313
conventional chemical 313
Ectoparasitism 108, 116
Ectoprasites 316
Edema 94, 167, 213, 226
liver cirrhosis 226
severe auricular 167
Eggs 6, 28, 32, 38, 48, 49, 50, 59, 84, 85, 87, 113, 118, 163, 173, 179, 180, 201, 207, 208, 216, 225, 226, 229, 271, 293
amphistomatic 28
helminth 293
hepatica 207
multiceps-contaminated 163
parasitic 216
trichostrongyle 59
Elaeophorosis 83
Elastic cartilage 164
Electrocardiography 79
Electrolytes 154
Electron microscopy 147
ELISA-based assay 278
Encephalitis 138, 143
Endemic fasciolosis 205
Endemicity 190, 196, 199
Endocytosis 98
Endonucleases 281
Endoparasites 4, 62, 306, 307
Endoparasites infect 63
Endopolygeny 64
Environment 1, 62, 220, 280
factors 1
isothermal 280
natural 220
unhygienic 62

Environmental conditions 208, 209
Enzyme(s) 62, 71, 100, 144, 216, 217, 222, 232, 276, 277, 278, 298
-conjugated anti-antibody 277
glycolytic pathway's 298
hepatic 216
linked immuno sorbent assay (ELISA) 62, 71, 100, 144, 216, 217, 222, 232, 276, 277, 278
-linked immunosorbent assay 216
Epidemiology of toxoplasma infection 66
Epithelium, oral 27
Erythrocytes 92, 94, 95, 96, 97, 102, 103
Erythrocyticmerozoites 97
Euzoonosis 20

F

Factors, inflammatory 80
Farmers, marginal 27, 203, 252, 266
Fascia, orbital 153
Fasciola infection 214
Fascioliasis 207, 210, 214, 277, 284
Fatty acid binding protein (FABP) 220, 221
Fever 20, 93, 94, 96, 98, 99, 100, 102, 159, 166, 184, 246, 250, 251
catarrhal 251
relapsing 20
spotted 102
Fibroblasts 79, 249, 250
Fibrosis 213, 214, 226, 230, 250
hepatic 213
mono-lobular 213
Förster resonance energy transfer (FRET) 279

G

Genetic modification (GM) 118, 119
GI nematodes 18
Glycoproteins 157
Goat 28, 317
amphistome-infected 28
theileriosis 317
trypanosomosis 317

H

Hepatic syndrome 88
Humans, immunocompromised 73
Humoral immunity 14
Hyperplastic gastritis 34
Hyperproteinemia 214
Hypoalbuminaemia 88
Hypobiosis 21, 37, 42, 44, 192

I

Immune 15, 16, 72, 117, 212, 242, 256, 319
reactions 117
regulatory mechanisms 256
response 15, 16, 212, 242, 319
sensors 72
system 16
Indirect fluorescent antibody tests (IFATs) 100, 144
Infection 22, 62, 92, 292, 294, 297, 298
endoparasitic 292, 294, 297, 298
immunity 22
trypanosome 92
zoonotic 62

L

LAMP 266, 279, 280
method 280
technique 280
Leishmania 279
Lesions 40, 41, 70, 83, 112, 113, 125, 130, 138, 139, 141, 142, 143, 174, 175, 176, 189, 190, 227
degenerative 227
disease-causing 130
macroscopic 40, 70, 141
microscopic 142, 143
Lice 109, 179
-infested areas 109
populations 179
Light microscopy 253
Livestock production systems 266
Lymphoid hyperplasia 193

M

Malaria infection 277
Manure 118, 203, 266, 312, 315
poultry 118, 312
removal 315
Meat, consuming 130
Mechanical transmission 90, 98
Membrane, nitrocellulose 277

Metamorphosis 21, 82, 116, 132, 312
Methods 277, 282
  microscopic 277
  proteolytic 282
Microscopy, transmission electron 147, 248
Myocarditis, acute 80

N

National dairy development board (NDDB) 205
Necrosis 139, 298
  acute liver 298
  multifocal 139
Necrotic debris 126
Nematodes 6, 7, 8, 10, 26, 59, 60, 117, 118, 184, 185, 194, 290, 296, 297, 298, 299, 300
  gastrointestinal 10, 194, 290

O

Oxitec technique 120

P

Parasite(s) 12, 13, 136, 262, 265, 279, 281
  community 262
  disease 265
  genomes 281
  infection 136, 279
  transmission 12, 13
Parasitic infection(s) 26, 27, 79, 122, 265
  gastrointestinal 26, 27
  in goats 122, 265
  in heart 79
Parasitic nematodes 184, 282
Pneumonia 68, 184, 185, 189, 190, 193, 196
  bacterial 193
  chronic eosinophilic granulomatous 196
  verminous 184
Polymerase chain reaction, real-time 266, 279
Polymerised chain reaction (PCR) 62, 69, 130, 143, 144, 148, 217, 223, 278, 279, 280
Production 16, 27, 33, 58, 72, 104, 145, 153, 203, 206, 284, 289, 290
  erythrocyte 33
  mutton 58
Prophylactic 18, 100, 248
  injections 100
  measure 18, 248
Protozoa 1, 6, 11, 23, 26, 27, 60, 67, 79, 121, 122, 135, 143, 240, 279, 313, 318, 319
  intracellular 240, 318
  infections 143, 319
  parasitic 11, 23, 67
Protozoan parasites 88, 294, 317
Pulmonary 79, 184
  effect 79
  hydatidosis 184

R

Random amplified polymorphic DNA (RAPD) 281
Resistance 290, 295, 299
  anthelmentic 290
  anthelmintic 295, 299
Restriction fragment length polymorphism (RFLP) 279, 281
RFLP technique 282
Rhinitis process 255
RT-PCR system 279
Rumination process 254

S

Sarcocystis 144, 248, 318
  infection 144, 318
  oocysts 248
Sex pheromones 310, 311
Skin 108, 134, 175, 177, 251, 289
  damage 134
  disease 175
  elephant 251
  fluids 177
  irritation 108
  lesions 175
  thin 289
Skin inflammation 83, 109, 152
  granulomatous 83
Spermatogenesis 250
Stoll's technique 271
System 1, 33, 63, 104, 155, 185, 243, 266, 278, 280, 297
  cardiac 104
  erythropoietic 33
  genital 63
  intestinal 63
  luciferase immuno-precipitation 266

neurological 155, 297

T

Techniques 138, 142, 143, 144, 216, 270, 271, 277, 278, 279, 280, 281, 283, 284
conventional parasitological 278
floatation 216
Tolerance, immunological 129
Toxoplasma 16, 138, 240, 242, 243, 249, 252, 283
Transfer, parasite-related disease 181
Trypanosomiasis 23

W

Western blotting (WB) 144

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