ORGAN-SPECIFIC PARASITES OF CATTLE

Editor:
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Organ-specific Parasites in Cattle

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FOREWORD

The well-being and health of livestock constitute crucial pillars for implementing sustainable agricultural practices within the intricate domain of animal husbandry and agriculture. Cattle, recognized as key components of global agriculture, play an essential role in supplying meat, milk, and other indispensable by-products. Despite their significance, various challenges often undermine the optimal productivity of cattle, and among these concerns, parasitic infections emerge as a noteworthy issue.

The book titled "Organ-specific Parasites of Cattle" delves into the intricate realm of parasitism, centering its attention on those elusive organisms that target specific organs within the host bovine. This thorough inquiry, undertaken by a team of experts in parasitology, veterinary medicine, and animal health, seeks to elucidate the intricacies of the biology, impacts, and control measures associated with these organ-specific parasites.

This groundbreaking publication provides valuable perspectives for cattle farmers contending with the persistent challenge of parasite-related diseases, while also serving as a repository of information for veterinary professionals, researchers, and students. The book's concentration on organ-specific parasites contributes to a deeper understanding of the intricate dynamics between hosts and parasites, enriching our comprehension of these complex interactions.

The pages that follow are evidence of the contributors' unwavering commitment as they have painstakingly collected and synthesized the most recent findings from research and field observations and practical experiences. We sincerely hope that this compilation will prove to be a useful tool, promoting a more thorough understanding of the intricacies related to organ-specific parasites and, in the process, aiding in the creation of more robust and long-lasting control methods.

"Organ-specific Parasites of Cattle" serves as a beacon in the constantly changing field of agriculture and animal health, pointing the way toward a more sophisticated and all-encompassing strategy for reducing the negative effects of these parasitism on the well-being and output of the bovine species. In the continuous search for the welfare of cattle and the resilience of our agricultural systems, may this work serve as an inspiration for more research, creativity, and cooperation.

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PREFACE

Parasitic infections, a major global concern, adversely affect cattle health as well as production by losing the economic status of the farmers significantly in terms of declined milk production, inferior meat quality, depreciation of hide, loss of manure production, and draught power. A significant pinpoint evaluation of diseases as well as confirmatory diagnosis is required for specific treatment of both ecto- and endo-parasites. In addition, morphological identification of parasites is a basic important tool for the standard methods for diagnosis. Histopathological analysis of parasitic diseases may play an important role in the diagnosis as well as in providing knowledge of the severity of complications of parasitic diseases. It also provides insights into the interactions between parasites and animal hosts and their impact on infected animals. Interestingly, parasites in cattle can cause delayed growth rates, poor physical development and fertility, serious health-related issues, and death in infected cattle. Besides, several parasites may infect both animals and humans, causing public health concerns. The pathological changes are also observed through toxic, subtractive, inflammatory, allergic, obstructive, traumatic, necrotic, and immunosuppressive pathogenic mechanisms caused by parasites in cattle in a wide diverse host/parasite relationships. Parasites may also have the ability to cause tumors or tumor-like lesions in infected cattle.

The present book is organized with the aim to provide a comprehensive approach used in the identification of various images of parasites, the diagnosis of parasites, and prevention and control strategies to counteract parasitic diseases of cattle. It also provides knowledge of its distribution, epidemiology, lifecycle, morphology, clinical manifestations, diagnosis, prophylaxis, and therapeutic measures of parasitic diseases of cattle. The book also covers numerous informative tables and color images for the easy identification of parasites, their induced diseases, and updated information on suitable prevention and control measures. The book is well acceptable as both a textbook and a reference guide for students, academicians, researchers, field veterinarians, veterinarian nurses, laboratory staff, farm managers and also livestock owners. The book is systematically arranged and provides high-quality literature of international standards on organ-specific parasites and parasitic diseases in cattle and their diagnosis and therapeutic management. The book serves as a useful basic resource for all researchers, academics, and postgraduates wishing to gather knowledge on parasitic diseases, diagnosis, treatment, and prevention of cattle parasites and parasitic diseases with an aim to develop new antiparasitic drugs.

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CHAPTER 1

Introduction

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Abstract: Bovine parasitism presents a complex and variable disease condition affecting grazing cattle, encompassing both internal and external parasites. Internal parasites reside within the animal, while external parasites inhabit the animal's exterior. Both types can significantly impact cattle health. Understanding internal parasites and their control in natural field conditions necessitates awareness of external parasites and their role in cattle production cycles. The economic significance of different parasitic worms in cattle hinges on factors such as parasite species, the damage they cause, and parasite numbers within the animals at any given time.

Keywords: Cattle, Control, Diagnosis, External parasites, Internal parasites.

INTRODUCTION

Livestock is a crucial part of the agricultural sector, significantly contributing to the rural economy, especially for small and marginal farmers. Parasites are organisms that inhabit or feed on another species, known as the host, for sustenance. Typically, helminths and protozoa are endoparasites, residing within the host's body, while ectoparasites present over the host's external surface (Fig. **1**) [1, 2]. Haemoparasites, on the other hand, inhabit the host's bloodstream, often causing clinical or subclinical parasitic infection.

The impact of internal parasites (Table **1**) on cattle is influenced by factors such as the severity of infection, the age of the animal, and its stress levels. Typically, younger animals and those experiencing stress are more prone to displaying signs of parasitic infection. Mature cows tend to develop a degree of immunity against parasites residing in the lower gastrointestinal tract. However, parasite burdens

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can be particularly detrimental to mature cows nearing parturition due to suppressed immunity during this critical period [3, 4]. Parasitism's effects can be categorized into two types: subclinical and clinical. Subclinical effects encompass losses in animal productivity such as reduced milk production, weight gain, altered carcass composition, and conception rates. On the other hand, clinical effects manifest as visible disease-like symptoms including roughness of coat, anemia, edema, and diarrhea. The subclinical effects hold significant economic importance for producers. In dairy animals, subclinical gastrointestinal parasitic infections represent the primary health challenges limiting productivity [5, 6]. and is considered one of the major challenges in the development of dairy cattle globally [7, 8]. Subclinical infections result in illness and death among young animals, along with significant production losses in adults. While parasitic infections may not always manifest as apparent diseases, they lead to decreased production, including stunted growth, decreased appetite, and poor feed efficiency. The severity of the disease depends on factors such as the type of parasite or the number of parasites present [9, 10]. It is undeniable that, whether mild or severe, the disease causes infected animals to experience slower growth rates, preventing them from reaching their full growth potential. This inevitably results in economic losses for producers [11, 12]. Calf diarrhea stands out as a prevalent animal health issue among dairy farmers, with high mortality rates observed within the first year of life. In numerous cases, gastrointestinal parasite infections are a leading cause of this mortality. The economic impact of calf diarrhea can reach up to a 20% loss, significantly reducing dairy net profits by 38% [13, 14]. The repercussions extend to the loss of future breeding stock and dairy cows, ultimately affecting milk production. It is estimated that the cattle industry invests approximately USD 2.5 billion in pharmaceutical products for parasite control [15, 16].

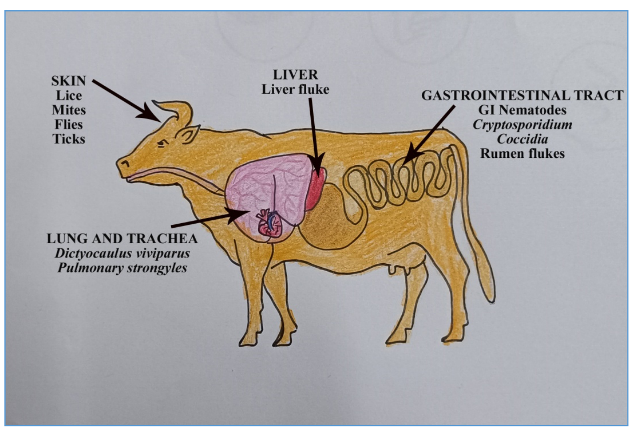

Fig. (1). Types of parasites and location.

Table 1. Major classes of internal parasites.

Roundworms or Nemathelminthes
Strongyles.
Gastrointestinal worms
Abomasum worms: *Haemonchus, Trichostrongylus, Ostertagia*.
Duodenum worms: *Trichostrongylus, Nematodirus, Cooperia, Strongyloides*.
Large intestine worms: *Oesophagostomum, Trichuris*.
Small intestine worms or Ancylostomatidae (hookworm): *Ancylostoma, Necator, Bunostomum*.
Lungworm or metastrongyles: *Dictyocaulus, Metastrongylus, Protostrongylus*.
Flatworms or platyhelminthes
Cestodes (tapeworm): *Moniezia, Stilesia, Avitellina*.
Trematodes (Flukes): *Fasciola, Dicrocoelium* (liver), *Paramphistomum, Schistosoma nasale*.

More than 2000 years ago, Hippocrates proposed that "all disease begins in the gut." While modern science has revealed this statement to be not entirely accurate, substantial evidence supports the significant association between many diseases and the intestine. Cattle can contract infections from various internal parasites, including roundworms (nematodes), tapeworms (cestodes), and flukes (trematodes) (Fig. **2**). Protozoans, such as coccidia, represent another category of internal parasites [17, 18].

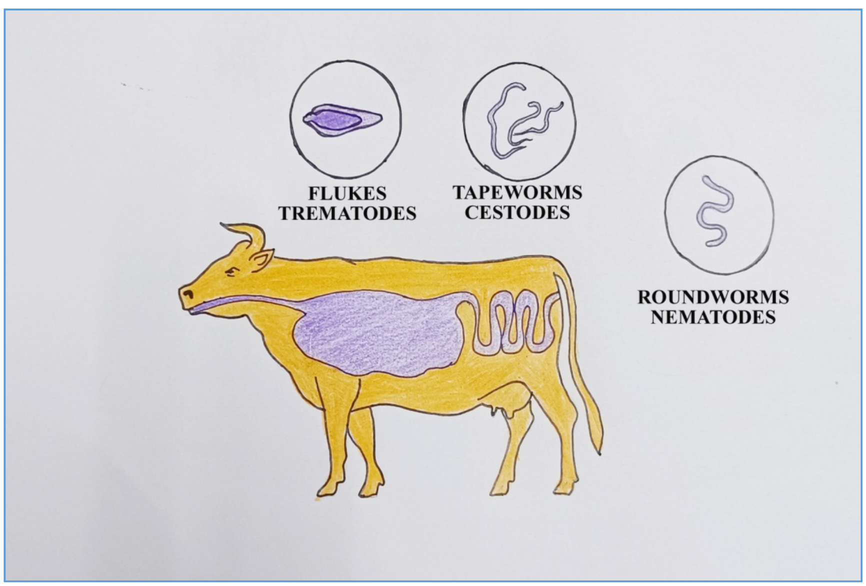

Fig. (2). Types of internal parasites.

CHAPTER 2

Parasites of the Gastrointestinal Tract Infection

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Abstract: Gastrointestinal parasites pose a significant threat to cattle health, welfare, and productivity worldwide. This chapter describes the major gastrointestinal parasites affecting cattle, their impact on the industry, current management strategies, and potential future directions for effective control. The economic implications of parasite infections in cattle production systems are explored, highlighting the need for integrated approaches to combat these parasites. Key aspects, such as grazing management, anthelmintic treatment, genetic selection, and emerging research, are discussed in the context of sustainable parasite control. The chapter underscores the importance of continued research and collaboration to mitigate the impact of gastrointestinal parasites on cattle populations.

Keywords: Aanthelmintics, Cattle, Control, Economic impact, Gastrointestinal parasites, Management.

INTRODUCTION

Cattle play a crucial role in the global food supply, providing meat and dairy products for human consumption. However, their productivity is threatened by a diverse range of gastrointestinal parasites. These parasites, including *Ostertagia spp., Cooperia spp., Haemonchus contortus, Trichostrongylus spp., Oesophagostomum spp*., *Bunostomum spp., Strongyloides spp.* Infections with these parasites are the major cause of monetary loss on farms globally. The losses are mainly caused by clinical disease or reduced growth rates in young animals and milk yield losses in adult cattle [1, 2]. The adverse effects of Gastrointestinal (GI) parasitism on production are attributed to a reduction in feed intake and the energy requirements of the immune response raised against these infections [3]. Understanding the impact of these parasites and implementing effective management strategies is imperative for sustaining cattle production systems.

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COMMON GI PARASITES OF CATTLE

Ostertagia ostertagi

This is one of the most economically important gastrointestinal nematodes affecting cattle. It resides in the abomasum and can lead to weight loss, decreased feed intake, and even death in severe cases. This disease is most common in late summer and autumn and often causes profuse watery diarrhea in calves in grass. The infective L3 are ingested and they migrate to the abomasum, where they borrow into the gastric glands where they moult to L4 and L5 and erupt out of the gland as an adult [4].

Trichostrongylus spp.

These nematodes can be found in the abomasum and small intestine of cattle. They can lead to reduced growth rates and overall poor health. *Trichostrongylus* infection can include weight loss, poor growth, reduced feed efficiency, anemia, diarrhea, and overall poor condition. Severe infections can lead to significant economic losses in terms of decreased milk production and meat quality [5].

Cooperia sp.

These nematodes also inhabit the gastrointestinal tract, specifically the small intestine. They can cause diarrhea, weight loss, and reduced feed efficiency. *Cooperia* parasites have a direct lifecycle. Ingested L3 exsheath, migrate into the intestinal crypts for two moults, and then the adults develop on the surface of the intestinal mucosa. The prepatent period is around 3 weeks [6].

Haemonchus spp.

While more commonly associated with sheep and goats, this blood-sucking nematode can also affect cattle. It causes anemia, and weakness, and can be fatal in heavy infections. *Haemonchus contortus* is a blood-sucking gastrointestinal parasite that resides in the abomasum of cattle and other ruminants. It feeds on blood, causing anemia, weakness, and potentially death in severe cases. Cattle become infected by ingesting the infective larvae of *Haemonchus contortus*, which are present in contaminated pastures. These larvae can survive for weeks to months in the environment under suitable conditions. Common clinical signs include anemia, weakness, decreased appetite, weight loss, bottle jaw, diarrhea, lethargy, and in severe cases, death. Various dewormers are effective against *Haemonchus contortus*, however, resistance to these drugs has been reported in some regions, so proper drug rotation and use are crucial [7].

Paramphistomum spp.

Paramphistomosis, caused by various species of the genus *Paramphistomum*, affects cattle and other ruminants. *Paramphistomum spp.* are flatworms known as rumen flukes or amphistomes. These parasites primarily inhabit the rumen and reticulum of the host's stomach and can cause significant health issues if left unchecked. Cattle become infected when they ingest aquatic plants contaminated with the infective cercariae released by infected snails. The clinical signs of *Paramphistomum spp.* infection in cattle can vary in severity. Common symptoms include reduced appetite, weight loss, decreased milk production, diarrhea, abdominal discomfort, anemia, in severe cases, dehydration and death [8].

Strongyloides papillosus

Strongyloides papillosus is a parasitic nematode that can infect cattle. This nematode primarily affects the small intestine of cattle and can cause a condition known as strongyloidosis. The life cycle of *Strongyloides papillosus* involves both direct and indirect transmission. The parasitic females release larvae in the host's faeces, and these larvae can develop into either free-living male or female adults or infective larvae, depending on environmental conditions. The infective larvae can directly penetrate the skin of the host or be ingested by the host. If ingested, the larvae migrate to the small intestine, where they develop into adults, lay eggs, and continue the cycle. Clinical signs of *Strongyloides papillosus* infection in cattle can vary and may include diarrhea, weight loss, reduced growth rate, decreased appetite, rough hair coat, lethargy, and suboptimal milk production. Diagnosing *Strongyloides papillosus* infections can be challenging due to the intermittent shedding of larvae and the variable clinical signs. Fecal examination to detect larvae or eggs may help confirm the presence of the parasite [9, 10].

Bunostomum phlebotomum

Bunostomum phlebotomum, commonly known as the hookworm, is a parasitic nematode that can affect cattle and other ruminant animals. This parasite primarily inhabits the small intestine of its host and can cause significant health issues, including anemia and decreased growth rates. The life cycle of *Bunostomum phlebotomum* involves several stages. Adult worms live in the small intestine of cattle, where they attach to the intestinal wall and feed on blood. Female worms lay eggs that are passed out in the host's feces. Under suitable environmental conditions, the eggs hatch, and the resulting larvae develop into the infective stage. Cattle become infected by ingesting these infective larvae while grazing. The clinical signs of *Bunostomum phlebotomum* infection in cattle include anemia, decreased appetite, weight loss, rough hair coat, diarrhea, and decreased growth rates especially in young animals. Diagnosis is often based on

CHAPTER 3

Parasites in the Urogenital Tract Infection

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Abstract: Gastrointestinal parasites pose a significant threat to cattle health, welfare, and productivity worldwide. This chapter describes the major urogenital parasites affecting cattle, their impact on the industry, current management strategies, and potential future directions for effective treatment and control measures. The economic implications of parasite infections in cattle production systems are also elaborately explored by highlighting the need for integrated approaches to combat parasitic diseases. Key aspects including proper grazing management, treatment of anthelmintic drugs, selection of genetic variables, and emerging research, are properly discussed in the chapter. The chapter also underscores the importance of continued updated research and collaboration to mitigate the impact of urogenital parasites on cattle populations.

Keywords: Anthelmintics, Cattle, Control, Economic impact, Management, Urogenital parasites.

INTRODUCTION

The term “parasite” refers to a creature that inhabits or lives on another organism and depends on it for sustenance and other benefits, frequently at the host's expense. There are many different kinds of parasites, including protozoa, helm-

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inths (worms), insects, and even some plants. By spreading illnesses, impairing the host's immune system, and interfering with regular physiological processes, they may harm the host [1]. In a biological connection known as parasitism, one organism gains while the other suffers consequences. The host gives the parasite a home and access to nutrients, and the parasite in exchange may impede the host's well-being, development, or reproduction. In order to take advantage of their hosts, parasites have developed a variety of tactics, from subtle interactions to dangerous pathogenic effects [2].

Cattle urinary system parasites present serious problems for the livestock business. *Trichomonas foetus* (*T. foetus*), a protozoan that causes trichomoniasis, is one such parasite. It mostly affects the reproductive tract but has the potential to spread to the urinary system (Fig. **1**). This can cause infertility and miscarriages in cows, which has an effect on the productivity of the herd [3]. Strongyle nematodes, such as *Haemonchus placei* and *Oesophagostomum radiatum*, which are typically linked to digestive issues, can also infiltrate the ureters and bladder, resulting in irritation and potential obstructions [4]. Flukes, especially *Fasciola hepatica* and *Fasciola gigantica*, have the ability to spread from the liver to nearby organs, including the urinary tract, and can harm those tissues as they do so [5]. Another genus of protozoan parasites, *Sarcocystis* spp., can indirectly affect the urinary system by causing inflammation and subsequent problems in neighboring organs. Even though coccidian infections predominantly affect the intestinal tract, they can cause considerable stress, which has unintended effects on the urine system. Increased urination, painful urination, and blood in the urine are some of the signs of these infections, and severe instances can result in renal failure [6]. Strategies like biosecurity precautions, routine deworming, pasture management, and selective breeding are used to manage these parasites. Combining these methods helps keep the cow herds healthy and productive by preventing the entrance and spread of these parasites.

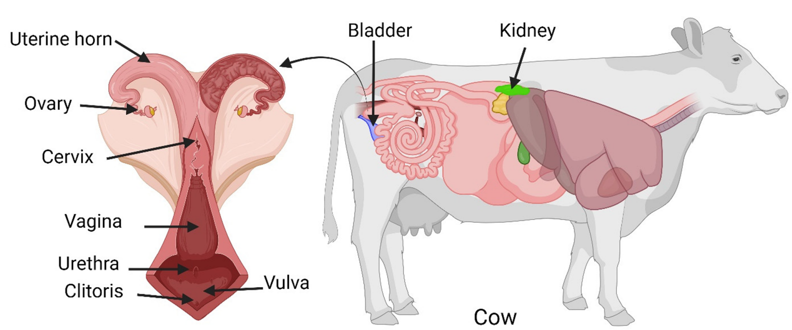

Fig. (1). Urogenital system of cattle.

Urinary parasites can have a significant negative influence on cattle farming, affecting the production, health, and overall economics of the farm. Despite not receiving as much attention as gastrointestinal parasites, urine parasites can nonetheless have serious repercussions (Table **1**). The effects of urinary parasites on cows include cattle can get urinary tract infections and other related health problems as a result of urinary parasites including *T. foetus* and certain nematodes [7]. These infections may cause discomfort, irritation, and inflammation in the urinary tract, which may have an impact on the animals' general health. *Trichomonas foetus* is one of the urinary tract parasites that specifically affect cattle reproduction. Trichomoniasis can impair a cow's ability to conceive and induce miscarriages, which can result in severe financial losses for breeding herds. Reduced reproductive success can impede the herd's growth and development [8]. Due to discomfort and the overall physiological stress brought on by the infection, cattle with urinary parasites may consume less feed, lose weight, and produce less milk. The farm's overall production and profitability suffer as a result. Increased veterinary expenses may result from the treatment and control of urinary parasite infections. The financial capacity of the livestock enterprise may be strained by diagnostic procedures, treatments, and probable problems resulting from these infections. Cattle with persistent urinary parasite infections might not be as healthy or productive, which would lower their market value [9]. When purchasing cattle from farms with a history of parasite problems, buyers are likely to be cautious. Urinary parasite control entails more work and management efforts. To reduce the risk of new infections, this entails locating affected animals, putting treatment plans into place, and modifying herd management procedures. Animals' overall welfare may be impacted by stress, which can also weaken their immune systems and increase their susceptibility to other illnesses. The normal dynamics of the herd can be changed by parasite infections. The requirement for treatment and quarantine procedures to prevent the spread of infections to other animals may make management challenges worse [10].

A proactive strategy for the prevention and management of urinary parasites is essential to reducing their negative effects on cow production. It can be useful to regularly check the herd for symptoms of urinary parasite infections, including changes in urination patterns and general health. The introduction of urinary parasites to the farm can be avoided by putting biosecurity procedures in place. If infections are found, it is crucial to collaborate with a veterinarian to create efficient treatment and control plans [11]. The danger of urinary parasite infections can be decreased by using proper herd management techniques, such as keeping clean and dry living conditions. Cattle farmers may protect the wellbeing, productivity, and financial success of their herds by being aware of the possible

CHAPTER 4

Parasites in the Circulatory System

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Abstract: Parasitic diseases affecting the circulatory system of cattle are a significant concern in veterinary medicine. The impact of these parasites on cattle health can be significant, resulting in decreased productivity, anaemia, and, in extreme cases, death. Haemoprotozoa like *Trypanosoma, Theileria, Babesia*, and *Anaplasma*, as well as helminths like *Schistosoma* and *Onchocerca*, are among the parasites that impact cattle's circulatory systems. Because the majority of these diseases are transmitted by invertebrate vectors, a comprehensive approach comprising vector control targeted medicine administration, and biosecurity measures is required to ensure cattle health and productivity. Regular monitoring and early action are critical for reducing the parasites' influence on cattle herds.

Keywords: Abortion, Cattle, Circulatory system, Death, Production.

INTRODUCTION

Parasitic diseases of the circulatory system are among the most economically important diseases of cattle. Haemoprotozoan parasites such as *Trypanosoma, Theileria, Babesia*, and *Anaplasma*are among them, as are a few helminths such as *Schistosoma* and *Onchocerca*. The disease manifestation caused by these parasites ranges from anorexia, mild fever, anaemia, and threatening abortion to death in acute cases. These parasites have a significant impact on the health and productivity of cattle.

Schistosoma

Schistosomiasis is common among cattle in Africa and Asia, caused by members of the genus Schistosoma commonly known as blood fluke due to its location in the blood vessel of its host. Six species have been reported in cattle, namely

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Schistosoma bovis, S. mattheei, S. spindale, S. intercalatum, S. indicum and *S. nasalis*. *Schistosoma* produces severe disease in dairy cattle and work bullocks.

The parasite is slender, elongate, unisexual, and dimorphic trematodes that inhabit the blood vessels of their hosts. The female is thin and usually longer than the male, and the female is usually carried by the latter in a ventral, gutter-like groove, the gynaecophoric canal produced by the body's incurved lateral borders. Adult Schistosomes are blood-feeders that dwell in the portal and mesenteric veins of the host, with the exception of *S. nasalis*, which lives in the nasal mucosa veins [5]. The female lays eggs with a distinctive terminal or lateral spine that is excreted. The eggs are non-operaculate, with a thin shell and a lateral or terminal spine. The *Schistosome* egg morphologies are characteristic, therefore used to differentiate across species. The intermediate hosts include aquatic snails such as *Indoplanorbisexustus* and *Lymnealuteola*, as well as *Biomphalaria, Bulinu*s, and *Oncomelania*. The disease transmission is dependent on three major factors:

- Pollution of fresh water with cattle faeces containing *Schistosoma* eggs.
- Presence of intermediate snail host.
- Contact of a definitive host with cercaria-infested water.

Schistosomes are the only trematodes that are transmitted through cercariae skin penetration of their host, although in cattle, the infection can also be acquired orally while drinking water. Cercariae evolve into schistosomula upon penetration and are transferred to their preferred sites *via* lymph and blood. The prepatent period varies between species but typically ranges between 45-70 days.

The disease is manifested in three forms depending on the species involved:

1. Nasal Schistosomiasis: Nasal Schistosomiasis is caused by the eggs of *S. nasalis* irritating the nasal mucosa, resulting in cauliflower-like growths that partially block the nasal cavity causing snoring sounds when breathing. Hemorrhagic and/or mucopurulent nasal discharge is a common feature of the condition. After the abscesses rupture, eggs and pus are released into the nasal cavity, extensive fibrosis develops at the lesion. The clinical presentation of the illness is used to make the diagnosis, and confirmed by the presence of distinctive Boomerang eggs in the faeces of the infected animal. Adult worms could be found on macroscopic examination of mesenteric veins at necropsy.

2. Intestinal syndrome is an acute form of Schistosomiasis that most commonly affects young calves. There have been isolated epidemics of symptomatic intestinal schistosomiasis caused by *S. mattheei, S. bovis*, or *S. spindale*. in endemic areas, occasional incidences of clinical intestinal schistosomiasis caused

by *S. mattheei, S. bovis*, or *S. spindale* occurs. The disease is characterised by diarrhoea, weight loss, anemia, hypoalbuminemia, hyperglobulinemia, and severe eosinophilia that develop after the onset of egg excretion. Symptoms start 7-9 weeks after infection and last depending on the severity of the infection. Health of the animals that are severely infected declines quickly and usually die within a few months of illness, but those that are less severely infected acquire chronic disease with growth retardation. Pathological and histological examination of the intestinal mucosa revealed extensive hemorrhagic lesions. The mucosa of the intestine is oedematous and coated in hemorrhagic foci. Adult parasites induce mesenteric vein phlebitis. Granulomatous lesions in the mucosa and submucosa, as well as infiltration of eosinophils, lymphocytes, macrophages, and plasma cells, may occur surrounding the eggs in the lamina propria.

3. Hepatic syndrome: It is an immunological disease caused by the host's cell-mediated immune response to *Schistosome* eggs in the liver. The immunologically specific host reaction to the eggs leads to extensive damage to the portal vascular system. Soluble antigens escaping through pores in the eggshell sensitise the host, causing lymphocytes, eosinophils, and macrophages to gather near the eggs. The soluble antigens escaping through pores in the eggshell sensitise the host and stimulate the accumulation of lymphocytes, eosinophils and macrophages around the eggs. The inflammatory response becomes persistent, with the presence of epitheloid cells, giant cells, fibroblasts and avascular granuloma can grow to be 100 times the size of the eggs. Large numbers of these egg granulomas grow and heal in heavy infections, causing enormous fibrosis in the portal triads of the liver and the appearance of “Clay Pipe stem” fibrosis.

Diagnosis in the endemic area is based on a clinicopathological picture of diarrhoea, wasting and anaemia, coupled with a history of access to natural water sources in the endemic area. Diarrhoea is persistent and often with blood stains and contains mucous. The detection of characteristic eggs (spindle/ oval shaped with terminal/ lateral spine) in the faeces could be confirmatory of the disease.

Praziquantel at the dose rate of 60 mg/kg body weight is highly effective and is the drug of choice. Other drugs like Oxyclosanide (10 mg/kg thrice at weekly intervals) and Triclabendazole (20 mg/kg) are also effective. For nasal schistosomiasis, intramuscular injection of anthiomaline (15 ml) is effective in reducing the size of the nasal granuloma. Complete recovery could be achieved through two or three injections of Anthiomaline at weekly intervals [5]. Although treatment options are available, in endemic areas, control efforts must be directed towards.

CHAPTER 5

Parasites in the Integumentary System

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Abstract: The integumentary system is the largest organ system in the body and a physical barrier to the external environment. This intricate system maintains the animal's body in a state of homeostasis thanks to its many vital activities and complex structure. Worldwide, a wide range of parasitic diseases significantly increase the morbidity and mortality rate of cattle. Through the various ways that parasitic illnesses infect their host to collect nutrients and complete their lifecycle, as well as the possibility of becoming infection vectors, they have an impact on the health and productivity of cattle. Numerous protozoa, ectoparasites, and helminths mostly affect the integumentary system. A number of diseases have the potential to seriously affect both public and animal health; some are notifiable, while others are zoonotic.

Keywords: Cattle, Health, Homeostasis, Integumentary system, Parasite.

INTRODUCTION

The integumentary system is the largest sophisticated organ that protects the body and controls numerous vital functions [1]. It includes the glands that create sweat and oil as well as the skin, hair, and hoof. Together, these tissues safeguard the body against illness and damage and control physiological functions. The skin acts as the body's first line of defence against the outside world by protecting and maintaining the health of the inside organs. Although, the integumentary system is prone to a number of illnesses, conditions, and wounds.

EFFECT OF PARASITIC DISEASE ON INTEGUMENTARY SYSTEM

Animals' health is impacted by parasitic infections of the skin because they result in tissue loss, blood loss, and discomfort. Pests can make it difficult for an animal to survive quietly, which can lead to weight loss and loss in production. Ectopara-

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sites including flies, lice, ticks, mites, and leeches are most widely prevalent amongst cattle creating havoc with their infestations [1, 2]. Cattle are also commonly affected by different genera of skin helminths; *Parafilaria, Onchocerca, Stephanofilaria, Strongyloides,* and *Nasal schistosomes.* Protozoan pathogens affecting the skin are less frequent but *Besnoitia* and *Theileria* are capable of causing diseases affecting the skin and integumentary system. The main effect of parasites on the integumentary system has been described in Fig. (**1**).

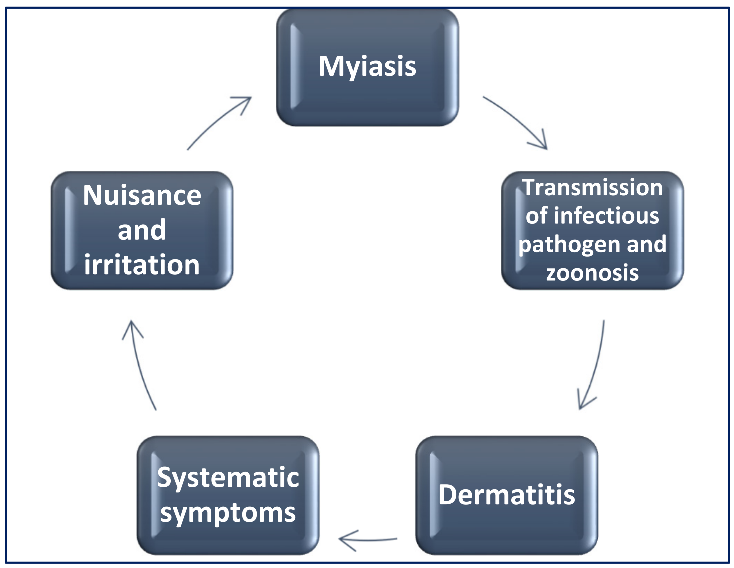

Fig. (1). Effect of parasitic pathogen on skin.

Helminth Parasite Affecting Integumentary System

a. *Parafilaria bovicola:* Cattle parasite, *Parafilaria bovicola* causes subcutaneous lesions that resemble bruises. Additionally, it has been noted in water buffalo (*Bubalus bubalis*). The adult males and females of the worm are 30-35 mm and 50–65 mm long, respectively. It is found in Africa (Morocco, Tunisia, Rwanda, Burundi, South Africa, Namibia, Botswana, Zimbabwe), Europe (Bulgaria, Romania, France, Sweden), and Asia (the Philippines, Japan, Russia, Pakistan, India). It has been determined that *Parafilaria* infection causes the beef industry to suffer significant financial losses. Cattle infected with *Parafilaria* only show outwardly as focused cutaneous haemorrhages (sometimes called “bleeding spots”) that leak for a few hours before clotting and drying in the coat's matted hair. The cause of bleeding patches is the female worm, which pierces the skin, develops a tiny nodule, and oviposits in the blood dripping from the core lesion [3, 4]. The parasite's microfilariae first larval stage is present in the small eggs. Bleeding spots are distinctly seasonal, occurring most frequently in the spring and early summer in both the northern and southern hemispheres [5, 6]. The majority of bleeding areas are seen in the animal's dorsum, notably in the forequarters. Face flies of the genus *Musca* (subgenus *Eumusca*) are the invertebrate hosts, and they consume the eggs while eating at the bleeding sites. It takes the fly 10–12 days to develop into infectious third-stage larvae. When the flies feed on wounds, *Parafilaria* bleeding spots, or eye secretions, transmission to cattle most likely happens. However, the main significance of *Parafilaria* in beef-producing countries is damage to the subcutaneous tissues. Severe infections of *P. bovicola* have been found to limit the production of working bullocks in India due to seasonal bleeding and cutaneous nodules [7, 8]. Lesions that resemble bruises are irregular, edematous, greenish-yellow, and present on the carcasses of sick animals. These are often superficial, although on rare occasions, deeper muscles are also heavily implicated. The spring and summer months are when lesions are at their worst. Trimmed carcasses are frequently severely deformed and subsequently devalued. The carcass may be condemned in extreme situations. Bulls experience lesions more frequently and severely than steers, who in turn experience less severe effects than female animals. The diagnosis can be done by examination of blood from dermal lesions for parasitic eggs and microfilariae and also histopathology to identify nematodes or ELISA can be performed. The subcutaneous administration of nitroxynil (20 mg/kg) or ivermectin (200 mcg/kg) reduces the quantity and surface area of *Parafilaria* lesions. Animals should receive therapy for at least 70 to 90 days before death to allow the lesions to heal [9, 10].

b. *Onchocerca* species: *Onchocerca* (Filariidae) is a genus of parasites found in, cattle, sheep, horses, donkeys, and goats. The parasite is responsible for causing dermatitis in ruminants including cattle caused by microfilariae produced by adult *Onchocerca*. The adult worm resides in the nodules, and the fertilised females release microfilariae into the tissue lymph spaces from where an insect vector serves as the intermediate host by ingesting them [11, 12]. Although *Onchocerca* species are generally considered of little veterinary interest due to their low pathogenicity, *O. ochengi* is common in African cattle and is a human vector. For co-infection with onchocerciasis [13, 14] and its potential as a model for *O. volvulus* [15, 16]. The midges of the genus *Cullicoides* are the most prevalent vectors. The intermediary hosts can be other biting flies. In these insect vectors, the larvae grow into the infective stage. When these biting flies feed on cattle while carrying the infectious larvae, cattle become infected. The hosts' connective tissue has nodules where the adults reside. Depending on the *Onchocerca* species involved, these nodules

CHAPTER 6

Parasites in the Nervous System

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Abstract: Parasitic disease of the nervous system of cattle is generally caused by migrating nematodes, cestode cysts, or protozoa in the central nervous system. The parasites namely Hypoderma larvae cause neurological diseases. The toxins liberated by *Dermacentor* ticks, and metabolic changes associated with intestinal coccidiosis are the key factors for neurological complications.

Keywords: Aanthelmintics, Cattle, Control, Economic impact, Mmanagement, Nervous system, Parasites.

INTRODUCTION

The management of parasitic diseases in cattle continues to be a substantial concern with significant effects on animal health, productivity, and financial stability. Due to their complicated interactions with the neurological architecture of the host, neurotropic parasites that target the cow nervous system have drawn the most interest among these illnesses [1]. In order to cross the blood-brain barrier and establish themselves within the central and peripheral nervous sys-

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tems, these parasites have evolved sophisticated tactics, which have resulted in a variety of neurological symptoms. The investigation of these interactions throws light on the basic tenets of neuroimmunology and neuropathology as well as the complex coevolution of parasites and their bovine hosts. A critical hub for an organism's physiological and behavioral functions, the central nervous system coordinates intricate reactions to both internal and external inputs [2]. This complex network is not immune to the influence of parasitic invaders. A wide variety of taxonomic groups of neurotropic parasites have developed varied adaptations to enter and take advantage of the host's brain environment. These parasites, which range in form from protozoans like *Trypanosoma* spp. and *Neospora caninum* to metazoans like *Taenia saginata* and *Setaria digitata*, have developed unique adaptations that let them move through the complex environment of the nervous system (Fig. **1**) [3].

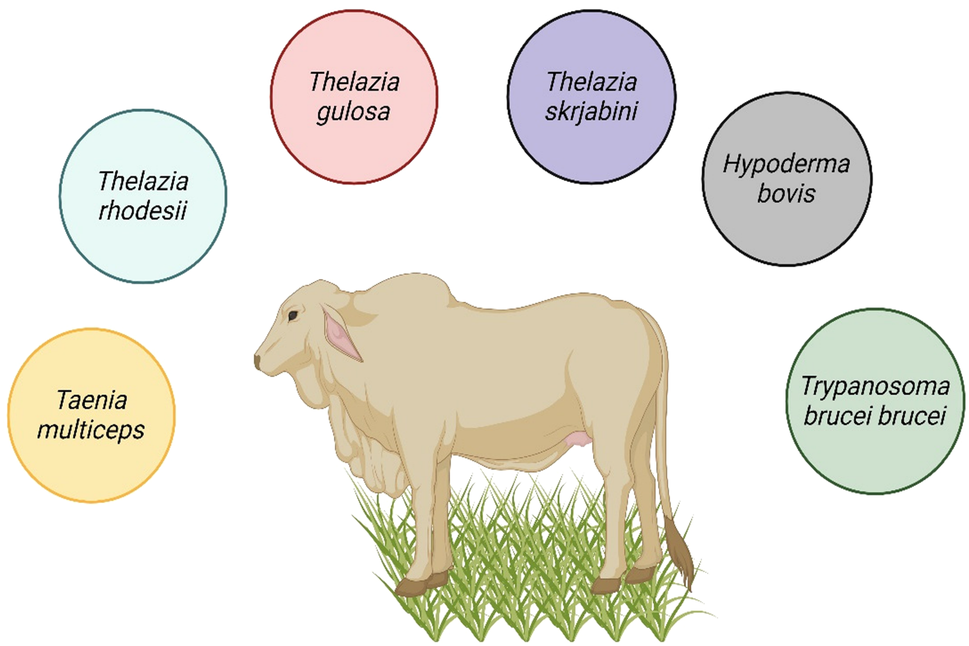

Fig. (1). Parasites affecting the nervous system of cattle.

Infections with neurotropic parasites in cattle can have a variety of negative effects, including neurological dysfunction, changed behavior, impaired motor skills, and even death (Table **1**). The dynamics of infection-induced neuroinflammation, neuronal injury, and subsequent repair processes can be better understood by understanding the complex interactions between the parasites and the host's immune responses in the context of neuroinvasion. These interactions also highlight the complex balancing act between immunological privilege in the

CNS and the requirement to establish strong defenses against invasive infections [4]. Promising paths for therapeutic approaches can be found by investigating the molecular and cellular mechanisms underlying host-parasite interactions in the neurotropic setting. The development of focused antiparasitic drugs is made possible by the identification of critical chemicals and signaling pathways that promote parasite entry and establishment within brain tissues. Deciphering the immunological responses that are brought on by these parasites may also help in the development of immunomodulatory techniques that will strengthen the host's defenses while reducing damage to crucial neurological regions [5].

Table 1. Parasites in the nervous system, site of predilection, symptom, diagnosis, and treatment.

Parasite	Predilection site	Symptoms	Diagnosis	Treatment	References
Taenia multiceps	Muscle, subcutaneous tissue, CNS	Decreased coordination, bizarre behavior, convulsions, and paralysis	Biopsy, autopsy, microscopy	Surgery, anthelmintic drugs	[13 - 16]
Thelazia rhodesii	Eye, conjunctival sac, lacrimal duct	Conjunctivitis, lacrimation, photophobia	Clinical examination, microscopy	Manual removal of larvae, and anthelmintics such as levamisole.	[23 - 26]
Thelazia gulosa	Eye, conjunctival sac, lacrimal duct	Conjunctivitis, lacrimation, photophobia	Clinical examination, microscopy	Manual removal of larvae, and anthelmintics such as levamisole.	[32 - 37]
Thelazia skrjabini	Eye, conjunctival sac, lacrimal duct	Conjunctivitis, lacrimation, photophobia	Clinical examination, microscopy	Manual removal of larvae, and anthelmintics such as levamisole.	[43 - 45]
Hypoderma bovis	Larvae: Epidural fat of spinal cord	Decreased milk production, fluid filled swelling on the back	Presence of larvae under the skin, eggs on hair, immunodiagnostic tests	Organophosphate insecticide, macrocyclic lactone	[47 - 51]
Trypanosoma brucei brucei	Blood, central nervous system, reproductive tract, or myocardium	Intermittent fever, anemia, abortion, edema, decreased fertility	Clinical history, microscopy, ELISA, PCR	Isometamidium and diminazene aceturate.	[52 - 57]

African animal trypanosomiasis, also called Nagana, is brought on by the protozoan *Trypanosoma brucei*. Cattle's central nervous system may become

CHAPTER 7

Parasites in the Eye and Ear

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Abstract: The eye and earworms are responsible for ocular infections and ear infections in cattle. Larva can migrate the anterior chamber of the eye and can cause severe ocular inflammation in cattle. The antigen present on the surface of the parasite can cause an immune-mediated response with uveitis and keratoconjunctivitis. The transmission occurs through a housefly which feeds on the excretions/ lacrimal/ear discharge and the larva develops in the fly and lodges in mouthparts and when the same fly feeds another animal, the infestation is established. Proper anthelmintic treatment with correct management protocol is needed to combat the parasitic diseases of the eye and the ear.

Keywords: Anthelmintics, Cattle, Control, Economic impact, Eye and ear, Management, Parasites.

INTRODUCTION

The term “parasite” refers to a creature that inhabits or lives on another organism, often known as the “host,” from which it derives its nutrition and frequently infl-

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icts harm. Different tactics have been developed by these creatures to take advantage of their hosts in order to survive and reproduce [1]. Various health problems for the host might result from interactions between parasites and their hosts. They might vary from minor annoyance and discomfort to more serious illnesses and even death. While some parasites are more specialized, others have complex life cycles involving various host species. Due to lower productivity, increased veterinary expenses, and compromised animal welfare, parasitic infections in cattle can result in large financial losses for the livestock industry [2]. Cattle's eyes and ears are particularly susceptible to parasite infestations among the different organs impacted. These illnesses affect the animals' general health and well-being in addition to causing them anguish and pain. Conjunctivitis, keratitis, and more serious disorders that can result in partial or total blindness are just a few of the parasite infections that cattle's eyes are vulnerable to [3]. *Thelazia* worm, a nematode that infests the conjunctival sac and other ocular tissues, is one of the most frequent offenders. Conjunctival egg-laying by adult worms causes discomfort, severe tearing, and corneal injury. Additionally, Musca flies can spread these parasites, aggravating the issue, particularly in areas with large fly populations [4]. Cattle with parasitic infestations in their ears may experience anything from minor discomfort to excruciating pain. The surrounding tissues, the eardrum, and the ear canal can all be impacted. The ear tick, *Otobius megnini*, is one of the main parasites that afflict cattle's ears. This soft tick enters the ear canal and attaches, causing swelling, itching, and a waxy discharge. Constant irritability may impair an animal's ability to hear because it may result in secondary infections or even eardrum damage [5].

Vectors including flies, ticks, and mites are frequently used in the transmission of parasites that harm cattle's eyes and ears. For instance, flies have been known to transmit infectious larvae or eggs to the ears and eyes, beginning the parasitic life cycle inside the host. Ticks find that direct attachment to the ears offers the best conditions for feeding and reproduction [6]. These parasites can result in secondary illnesses that further jeopardize the health of the animal in addition to doing physical harm. Cattle eye and ear parasites have a complicated life cycle that involves several stages and frequently requires intermediate hosts or vectors. Consider the *Thelazia* worm, a typical parasite that affects cattle's eyes. Adult worms that are living in the host cattle's eyes usually start the life cycle. Through the host's tears, these mature worms generate eggs that are released into the environment. By consuming the eye fluids that contain the eggs, flies of the genus Musca serve as intermediary hosts [7]. The eggs are consumed by the fly, and once inside, they hatch into infectious larvae. These larvae eventually reach an infection-causing stage. These larvae are spread onto the surface of the eyes of cattle by the infected fly as it feeds or looks for moisture. The cycle is subsequently completed when the larvae enter the eye and mature into worms [8].

Otobius megnini, an ear tick, is a parasite that affects the ears. When female ticks lay their eggs in the host's ears or adjacent locations, the parasite's life cycle begins. Larvae developed from the eggs cling to the host's ears after they have hatched. The larvae feed during this period and go through a number of molts before becoming nymphs. The nymphs keep eating and molting until they reach adulthood [9]. When a tick reaches adulthood, it separates from the host's ear and looks for a place where it can lay eggs. As the eggs are laid and the cycle starts over again, this completes the life cycle. In all instances, the host's general health and well-being are impacted by the parasites' pain, irritability, and potential harm to their eyes and ears. To reduce the effects of parasite infections on cattle, it is essential to employ effective preventative and control techniques [10].

Infections with parasites in cattle's eyes and ears have significant negative economic effects. The stress and suffering brought on by these infections may lead to reduced milk production, weight loss, and poor reproduction. Cattle producers may also be severely burdened by the expenses related to veterinary care, drugs, and preventative measures. Prompt resolution of these problems is essential to preventing financial losses and protecting the general welfare of the cattle. To effectively manage parasite diseases in cattle, preventive measures must be put in place [11]. The availability of good hygiene and routine cleaning of cow living facilities might lessen the number of parasite breeding sites. By reducing the number of flies, ticks, and mite populations, insecticides and acaricides can reduce the spread of these parasites. The introduction of new cattle to a herd under quarantine conditions can also aid in halting the spread of parasites from carrier animals [12].

Parasite infections in cattle's eyes and ears pose a serious problem for livestock farmers (Table **1**). These illnesses not only endanger the health and welfare of the animals but also cost the industry money. Implementing efficient management measures requires a thorough understanding of the parasite life cycles, their routes of transmission, and the possible effects of infestations. The impact of parasitic diseases on cattle can be reduced by good cleanliness, routine veterinary care, and the use of preventive measures, enhancing the general success and sustainability of the livestock business. The parasites affecting the eyes and ears of the cattle are discussed below.

Raillietia auris

A parasite mite called *Raillietia auris*, also referred to as “aural ear mites,” can infest the ears of many different animals, including cattle. The Raillietiidae family

CHAPTER 8

Parasites of the Respiratory System

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Abstract: The breeding of livestock, particularly cattle, is one of the oldest agricultural activities that have been used to raise farmers' living standards all over the world, particularly in developing nations, however, this activity faces a number of challenges, one of which is the risk of disease transmission to the cattle. Numerous diseases can reduce an animal's productivity; harm its overall health, or even cause their death. Parasites are one of the greatest challenges to the development of cattle husbandry. One of these diseases is caused by parasitic agents, especially respiratory tract disease. There are numerous ways that these parasites can spread from one animal to another and affect cattle both internally and outwardly. In this section of the book, parasites that affect the respiratory system are discussed from the aspect of clinical, treatment, and control measures. These parasites can be classified as primary parasites that directly infect the respiratory system, secondary parasites that infect other parts of the body but also cause respiratory problems, or tertiary parasites that cause respiratory problems while they are passing through or developing. Parasites are considered the most challenging infections because the clinical symptoms are typically subclinical.

Keywords: Livestock rearing, Parasitic agents, Respiratory disease, Parasite, Cattle.

INTRODUCTION

Cattle livestock rearing is one of the world's most traditional forms of agriculture. Most rural households in developing countries, particularly in Africa, keep cattle, and it has proven to be quite resilient to prior economic crises [1, 2], where cattle production provides food and income to both urban and rural inhabitants, cattle livestock production is a crucial aspect of agriculture and has a significant impact on a country's natural economy, Therefore, the management's key responsibility in the cattle sector is to maintain breeds that are free of disease, especially the parasitic disease. Cattle are still susceptible to disease and have a range of diseases with different etiological reasons. One of the main obstacles to the

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expansion of cattle husbandry is parasites. These parasites have an impact on cattle both internally and externally, and there are several ways in which they might transfer from one animal to another. Parasites that represent a risk to the respiratory system are one of the many etiological variables that lead to respiratory diseases in cattle. The way that respiratory parasites affect cattle varies [3, 4]. Some like *Dictyocaulus viviparus*, live in the respiratory tract as adults, while others, like *Ascaris* species, *Ancylostoma* species, and *Strongyloides* species, do not, but do pass through the tract while migrating. While others, like *Fasciola species*, may enter the system accidentally. The respiratory tract involving both the upper and lower respiratory tracts is affected by a parasite agent; according to clinical standards, a parasite respiratory infection can cause either mild coughing, while the main clinical signs of concurrent bronchopneumonia include dyspnea, nasal discharge, weight loss, fever, and death. The severity of the clinical symptoms depends on the number of parasites present and the region of the tract that they commonly infect [5, 6]. It is also influenced by individual differences among hosts in the morphological and physiological characteristics of the respiratory tract or in the way, an infection is responded to. The history of grazing and clinical symptoms may be utilized to make the diagnosis, and several methods of fecal analysis and postmortem examination can be used to confirm the presence of a respiratory parasite, although clinical signs, the time of year, and grazing history are often enough to make the primary diagnosis. The parasite affecting the respiratory system of cattle can be classified into three groups as follows: (1), Primary parasites of the respiratory system, (2), parasites that affect the lungs through normal migration or proliferation and (3), Parasites of another organ system that produce respiratory symptoms. Cattle become infected when they consume grass that has been contaminated by infectious larvae that have been excreted in the feces of other diseased animals. In mild, moist conditions, these larvae are more likely to survive on the grass. The current warm and rainy weather conditions are favorable for this situation, thus caution is suggested. After being exposed to lungworms, animals typically develop resistance to re-infection. However, if young calves are not exposed, elderly cattle may develop a clinical condition [7, 8]. Further lungworm exposure is necessary to maintain immunity. Both elderly cattle who have never been exposed to the disease before and those whose immune systems have weakened because they have not been exposed again are being diagnosed with it more frequently. Both deworming all cattle right before the rain starts at the end of the dry season and deworming all cattle at the end of the rainy season to prevent a significant parasite burden while grazing, are effective approaches to managing and preventing parasitic respiratory diseases. These actions are essential to reducing pasture pollution, providing a balanced diet to keep animals healthy, and helping them develop the necessary resistance to external infections, but a vaccination that offers cattle significant parasite protection is the more effective course of action [9, 10].

Primary Parasite of the Respiratory System

Husk Disease

(Verminous bronchitis, Verminous pneumonia ‘hoose’).

Definition

Parasitic disease of the lower respiratory tract is characterized by a persistent cough, particularly at night during larval migration, dyspnea, and a normal body temperature but concurrent bacterial or viral infections can complicate the condition and cause the body temperature to rise [11].

Etiological Agent

Nematode parasites (*Dictyocaulus Viviparus*), which is a member of the subfamily Trichostrongyloidea.

Life Cycle

The adult worm in the lung lays eggs containing larvae, which cough and swallow. Eggs hatched into L1 larvae, which passed with feces and developed into second-stage larvae and third-stage larvae. The third stage larvae (infective stage) can attach to (*Pilobolus fungal*) sporangium growing on feces to become aerosolized and widely spread in the environment. The sensitivity of infective larvae to dehydration is high. Therefore, most of them die after 2-3 weeks in the summer if conditions are dry, although survival in autumn can be much longer [12]. During grazing, cattle ingest infective third-stage larvae with the herbage, and the third-stage larvae travel to the lung through the lymphatic system, where they mature into adults and show respiratory symptoms.Cattle that have been exposed to lungworms often become resistant to re-infection. However, if young calves are not exposed, old cattle could become clinically sick. Further lungworm exposure is necessary to maintain immunity [13] (Fig. **1**).

Epidemiology

Cattle infection with lungworms occurs in temperate regions with considerable intense irrigation. Despite the fact that ideal conditions can accelerate a rapid increase in pasture larval numbers, changes in temperature and rainfall can significantly modify the amount of infectious larvae present in pasture. Infected animals can support a small number of adult worms and hypobiotic larvae that can

CHAPTER 9

Parasites of Liver and Pancreas

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Abstract: Infestation with parasites is incredibly widespread on a worldwide scale. Nematodes, cestodes, and trematodes are three types of helminths (parasitic worms) that can infect the liver and hepatobiliary systems. The host immunological response to the larvae or adult worms is the main source of morbidity and mortality from these infections. Asymptomatic carriage to cirrhosis and decompensated liver disease are the two extremes of parasitic disease presentations. Improvements in medical therapy, widespread screening and chemoprophylaxis, and the creation of preventative vaccination techniques are the main topics of current basic science and clinical research. This chapter discusses the general morphology, pathology, clinical symptoms, diagnosis, and treatment aspects of liver and pancreas-associated parasites of cattle.

Keywords: Cattle, Control, Disease, Diagnosis, Liver, Parasite, Pancreas.

INTRODUCTION

Food animals have always been the main source of milk and meat. Notwithstanding these, the growth and development of healthy ruminants have not been completely utilised by poorer countries due to obstacles such as famine, bad management, and infections. The liver, the largest organ in the body, carries out several metabolic, excretory, synthetic, detoxifying, and catabolic functions. On the other hand, the pancreas creates and secretes digestive enzymes that support an animal's digestive system as a whole. Diseases, such as pancreatic and liver parasite infections, can have a detrimental impact on animal reproduction

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and productivity. Rumination in large, intensive systems makes ruminants more susceptible to parasitic helminths. The usual clinical consequences observed in ruminants are decreased rates of development, reproduction, feed conversion, genetic potential rate, and milk or meat output. The economic consequences of ruminant husbandry include decreased genetic potential rate, feed conversion, development, reproduction, and lower milk or meat output; on the other hand, abnormal signs of the gastrointestinal and cardiovascular systems are frequently observed clinically. Owners of ruminants lose money in the majority of infections and fatalities. Understanding the interplay between nutrition, livestock management, and parasitism is key to limiting economic loss.

Parasites that Directly Affect the Liver and Pancreas

Fasciola gigantica

Introduction

Fasciola gigantica is a well-known parasite of domesticated ruminants that cause major economic losses in some nations' cattle and sheep industries [1]. Clinical symptoms of digestive inefficiency can be seen in both young calves suffering from acute liver disease and older cattle suffering from chronic liver disease [2]. *F.gigantica* metacercariae ingestion by the ultimate host causes excystation and the release of freshly excysted juveniles (NEJs), which burrow through the duodenum wall into the peritoneum (Fig. **1**). They then go to the liver, where they penetrate the liver capsule. After passing through the liver for 11 weeks, the juvenile flukes grow in the bile ducts 12-16 weeks after infection (WPI), when they start laying eggs [3]. The complicated life cycle of *F. gigantica* requires an intermediary host, the family of aquatic snails Lymnaeidae, which reproduces asexually, and an initial vertebrate host, in which the liver flukes reproduce sexually [4, 5].

Morphology

The morphological characteristics and sizes of adult *Fasciola* species differ. *F. gigantica*, which measures 7.5 cm in length and 1.5 cm in breadth (Fig. **2**) [6], is larger than the two enormous leaf-shaped worms. These multiply in the gall bladder and biliary ducts of the main host (Fig. **3**). Although *Fasciola* spp. are hermaphrodites, meaning they may reproduce by self-fertilization, the most frequent method of reproduction is cross-fertilization between two adult flukes, contributing to the gene polymorphism seen in these species [7].

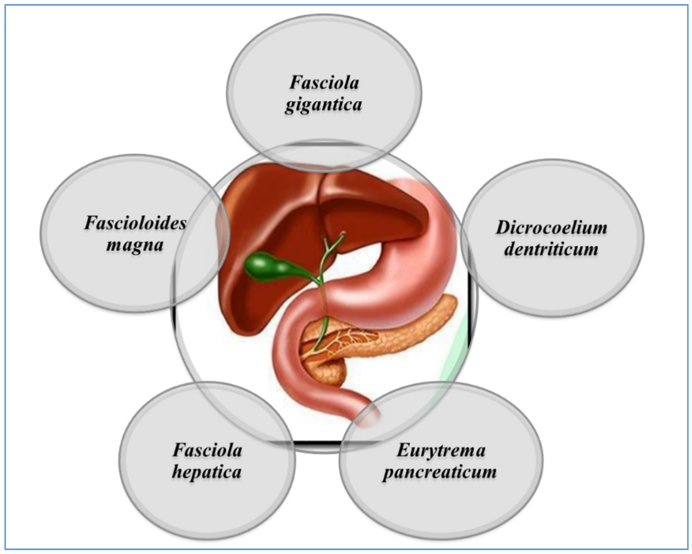

Fig. (1). Parasites that directly affect liver and pancreas of cattle.

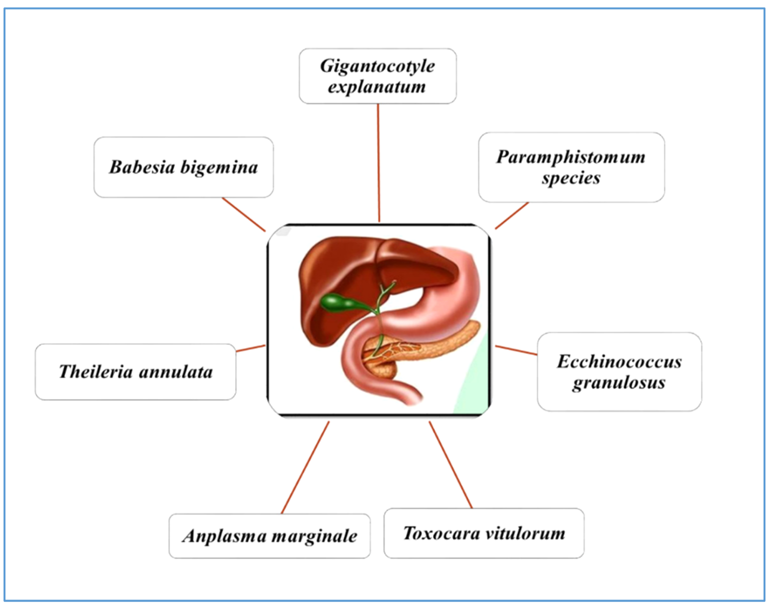

Fig. (2). Parasites that indirectly affect liver and pancreas of cattle.

Lifecycle

The flukes can lay up to 25,000 eggs a day and stay in their host for decades [8]. The intestine releases these eggs, which are then expelled into the surrounding area. After a week of consumption, the parasite passes through the peritoneum

CHAPTER 10

Parasites of the Musculoskeletal System

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Abstract: Parasitic diseases are still a common occurrence in cow herds, both in conventional and organic systems, and understanding these diseases is a prerequisite for putting in place effective management measures and boosting farm profitability. The evolution of diagnostic techniques has allowed for a deeper understanding of the aetiology through the identification of parasite strains. Their epidemiology has altered over time in response to factors that are both human and environmental in origin. A reappraisal of the zoonotic danger of consuming beef has also been prompted by the recent rise of parasitic diseases including cysticercosis, sarcocystosis, toxoplasmosis, hydatidosis neosporosis, besnoitiosis, hypodermosis, toxocarosis, hookworm, and aberrant ascarid infection. The purpose of this book chapter is to focus on parasites that can directly or indirectly affect the musculoskeletal system, which can update our understanding of the state of parasite infections in cattle today.

Keywords: Cattle, Diagnostic techniques, Infection, Musculoskeletal system, Parasite.

INTRODUCTION

The musculoskeletal system is rarely involved in the presentation of parasite infections. The majority of these acute, subacute, and chronic illnesses are found in tropical and subtropical regions. They develop as a result of an immunological disorder or the invasion of a parasite into the musculoskeletal system's supporting structures. The daily activities of animals are negatively impacted by parasites that indirectly damage this system. These parasites enter the musculoskeletal system either through oral or cutaneous invasion. Few parasites have been found in the musculoskeletal system, according to reports. This chapter discusses major parasites that directly affect the musculoskeletal system of cattle as well as parasites that indirectly affect the musculoskeletal system.

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Transmission of Parasites through Musculoskeletal System

The process of transferring a parasite from one host to another is known as parasite transmission. It is understood that parasites can spread in two main ways: horizontally (from one person to another) and vertically (from one host generation to the next). Our ability to limit the spread of parasitic diseases depends on our ability to fully comprehend these transmission techniques, which are used by different parasites in various ways. Horizontal transmission necessitates time spent away from the host body and may be mediated by vector species, other hosts, or environmental factors. Therefore, a parasite must have developed the tools to exploit these in order to ensure transmission. On the other hand, parasites that use vertical transmission must adapt transmission methods from one generation to the next (Fig. **1**). In order to facilitate transmission, the parasite may then hijack or even take control of its host's physiology. It is feasible for some parasites to use both horizontal and vertical modes of transmission [1].

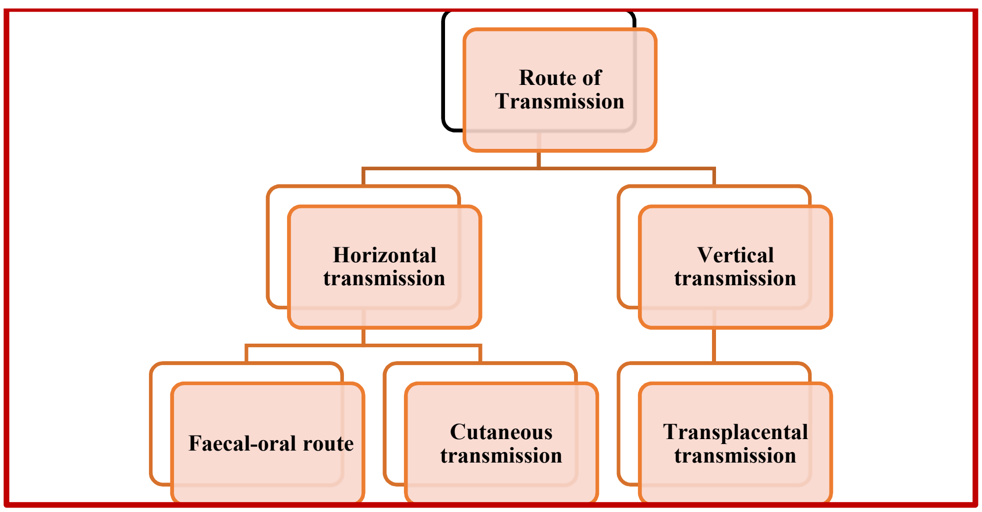

Fig. (1). Transmission pattern of parasites into the musculoskeletal system.

Horizontal Transmission

A. *Through oral route*: The most typical way that parasites are transmitted is orally, or *via* the faeco-oral route. By consuming food, water, or vegetables infected with parasite faeces, which contain the infective stages of the parasite, an infection is transferred orally.

B. *Cutaneous transmission*: The parasites can enter a person through unbroken skin (for example, hookworm can enter a person through the skin over feces-contaminated soil) or through the bite of bloodsucking insect vectors, which introduces the parasites into the body.

Vertical Transmission

Highly effective vertical transmission and transmission during pregnancy may be the most crucial distribution strategy in some parasites. This type of parasite is a major contributor to foetal infection during pregnancy, which results in abortion and musculoskeletal affection in cattle. Interesting issues are raised about the ways in which this parasite manipulates pregnancy to pass from generation to generation. It might happen through exogenous transplacental transmission from eating oocysts while pregnant or endogenous transplacental transmission from activating a quiescent stage during pregnancy. In order to control these economically significant parasites, an understanding of these pathways is crucial.

Impact on the Musculoskeletal System

In cattle, parasites migrate into different muscles and skeletal systems of the body, generally after entering through various transmission routes. In the migratory process, the main pathogenesis starts in the form of gelatinous tracts to the formation of cysts of varying sizes. The human and other carnivore gets the infection after consuming the infective stage in the form of meat.

Parasitic Diseases that Directly Affect the Musculoskeletal System

Taenia Saginata

In cattle with metacestodes of the human tapeworm *Taenia saginata*, cysticercosis most commonly affects the various muscles [2]. The cysticerci are usually discovered during meat examination at the regularly inspected localization sites, such as the heart, skeletal muscle, and diaphragm [3]. Meat containing living cysticerci, such as the meager beef in *T. saginata* that is consumed raw or improperly cooked can cause the disease. The larval or metacestode forms of *T. saginata* are called cysti, which are oval, transparent cysts with clear fluid that are about 5 X 10 mm in size and contain an opaque, invaginated protoscolex that is visible inside [4]. The only naturally vulnerable ultimate host for any species of Taenia is humans. Following ingestion by the host, the cysticercus evaginates in the small intestine of humans and develops over the course of two to four months to become a fully differentiated adult tapeworm. Infections with *T. saginata* are typically isolated. The tapeworm attaches to the intestinal mucosa of the jejunum by the scolex, and then spends the majority of its length lying along the mucosa and following the small intestine loops. In *T. saginata*, between 10 and 15 terminal segments are lost on average per day before being evacuated. Segments of *T. saginata* have a tendency to voluntarily crawl out of the anus or away from the faecal bolus (adapted to cattle's open-range grazing behaviour). 50,000–100,000 eggs are transported in each phase. *Taenia* species' eggs are

CHAPTER 11

Faecal Examination for Diagnosis of Parasitic Diseases

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Abstract: In veterinary medicine, faecal examination is an important technique for detecting parasite infections. It is a basic marker for the parasitic infection in cattle. It is an affordable and non-invasive method that helps detect parasites across different body systems. Parasites residing in the digestive tract release eggs, larvae, or cysts in faeces, while adult helminth parasites may be visible during enteritis. Additionally, parasites such as worms, eggs, or larvae can be expelled from the respiratory system through coughing and subsequently swallowed, appearing in faeces. Mange or scab mites may be ingested through licking or nibbling, also manifesting in faeces. Various parasite forms with distinct morphological features can be identified in faeces, serving as diagnostic markers for specific species. However, some parasites may produce similar eggs or oocysts, making species-level detection challenging. Overall, faecal examination is a fundamental diagnostic tool for identifying parasitic eggs.

Keywords: Anthelmintic, Cattle, Control, Diagnosis, Economic impact, Faecal examination, Gastrointestinal parasites, Management.

INTRODUCTION

Parasites are a common concern in cattle production and endoparasites are a leading cause of economic loss due to reduced productivity, poor growth, and sometimes death of the affected animals. The most widely used tool for diagnosing parasitic diseases in cattle is faecal examination. The primary objective of a faecal examination is to detect and identify the eggs, larvae, or cysts of parasites [1]. It is most appropriate for parasites that live in the gastrointestinal tract, bile duct, mesenteric artery, portal vein, *etc*. as their eggs, trophozoite, cysts or oocysts are found in the faecal matter. Knowledge of the type of parasite and

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the severity of infection is crucial to effective treatment, control and management. Though it is quick, inexpensive and a relatively easy method of diagnosis, it has certain limitations. A correct faecal exam merely detects parasitic forms in the dung, however their excretion is dependent on many factors. This chapter includes diagnostic techniques for parasitic diseases of cattle by faecal examinations, methods of sampling and points to be considered for making correct diagnosis.

FAECAL SAMPLING, PRESERVATION AND TRANSPORTATION TO LABORATORY

Faecal samples should always be collected fresh either directly from the rectum or freshly voided using examination gloves. Old samples can get dehydrated and can make it hard to form a uniform suspension. In old samples, the helminth eggs and coccidian oocysts may undergo further development making it difficult for correct identification or adult parasites may disintegrate to an extent that diagnosis is virtually impossible.

About 20-30 gm of faecal matter is collected in a sterile plastic bag/jar and adequately labelled for identification. The sample container is closed, packed in a cooling box for maintaining a cold chain and transported to the laboratory for examination at the earliest to prevent further development of the parasitic stages. It is best to examine the samples right away but properly sealed faecal samples could be stored in the refrigerator for several days.

The faecal parasite egg output is connected to a variety of host and parasite-related factors. The host-related factors include the natural rhythm of faecal voiding, age, host immune status, effect of recent anthelmintic administration and host's hormonal status. The parasite-related factors are infection load, different developmental stages, predilection site and response to the environment. Some parasites show diurnal fluctuations in egg shedding in cattle, like *Fasciola hepatica* [2]. Dorsman, 1956 recorded a gradual rise in *F. hepatica* egg count during the morning hours and then fell gradually in the afternoon after reaching a peak at 12:30 pm. In general, early morning spontaneous faecal voids are preferred and recommended for the diagnosis of parasitic infections. For sending a sample to a reference laboratory, about 20-30 gm of freshly voided faecal samples packed in a sterile leak-proof container with appropriate labelling and a letter describing the content is to be promptly sent through the mail. In cases when the laboratory is situated at a distant location and the transportation is anticipated to take a few days, 10% formalin may be added to the samples and sent to the laboratory with a clear mention of the preservative in the labels.

METHODS OF FAECAL EXAMINATION

A faecal exam begins with a gross examination of the sample. Samples should be looked for consistency, colour and odour of the faecal matter, presence of mucous, blood, live or dead worms or segments of tapeworms. The observations are recorded to be correlated with the findings of the microscopic examination and clinical findings for correct diagnosis.

A microscopic examination of faeces is performed to detect and identify parasite eggs, larvae, or cysts that suggest an active infection. There are several methods of faecal examination, each with its own set of benefits and drawbacks. They are broadly categorised into qualitative and quantitative methods. The direct smear, floatation and sedimentation techniques are examples of qualitative approaches that are frequently employed in clinical diagnostics to determine if parasite eggs or oocysts are present or absent in faecal samples. On the other hand, the quantitative method involves determining the number of eggs or oocysts per unit weight of faeces [3]. The quantitative approach greatly aids in assessing the effectiveness of antiparasitic drugs and they are frequently used in research of anthelmintic resistance and antiparasitic efficacy of herbal products. Commonly detected parasite eggs in cattle faeces are presented in Fig. (**1**).

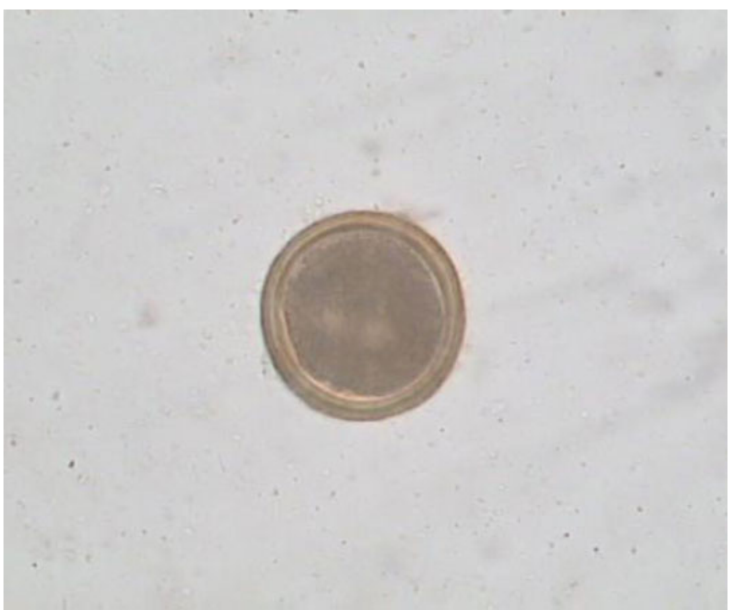

Fig. (1a). *Toxocara vitulorum* egg.

CHAPTER 12

Histopathological Diagnosis of Parasitic Diseases

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Abstract: In the bovine industry, histopathological diagnosis plays a crucial role in the identification and characterization of parasitic diseases. Parasites can infect various organs and tissues in the cattle body, causing a wide range of pathological changes. This manuscript aims to provide an overview of the histopathological techniques employed in the diagnosis of parasitic diseases of cattle. It discusses the common parasites encountered, the associated histopathological findings, and the methods used to identify and differentiate these parasites. Understanding the histopathological features of parasitic infections is essential for accurate diagnosis and appropriate management of these diseases.

Keywords: Cattle, Histopathological diagnosis, Microscopic evaluation, Parasitic diseases, Tissues.

INTRODUCTION

Preserving the well-being of animals requires collaborative efforts. An essential component of this process involves the laboratory-based identification of diseases or pathogen(s) responsible for causing the disease that can be of any aetiology such as infectious, neoplastic, parasitic, deficiency disease or intoxication. Parasitic diseases are infectious diseases, which result from infections caused by parasites that sustain themselves by feeding off on their host. One of the laboratory-based tests is histopathological examination of tissues [1]. Before histopathology, diagnosis was made based on macroscopically visible lesions at the time of necropsy. However, based solely on gross examination it was difficult to rule out the actual cause of disease from the other diseases producing similar lesions. Histopathology is a subspecialty of pathology that focuses on the study of

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changes in the cells or tissues caused by a disease. Histopathology offers the benefit of being a versatile diagnostic tool as it is non-specific and can be used for the diagnosis of a broad range of diseases [2]. The majority of the time, parasitic infections go undiagnosed, and superficial diagnosis frequently results in prolonged or even unsuccessful treatment. Histopathological examination makes it feasible to determine the type or species of parasite involved the location of the pathological lesions, any potential bacterial or viral consequences, and the prognosis of the disease [3]. Hence, pathologists can assume a significant role in diagnosing parasitic infections, especially when parasites have not been taken into account by the clinical team and the necessary microbiology tests have not been requested (Boland and Pritt, 2017). Histopathology includes collection and preservation of samples, processing of tissues, tissue sectioning, tissue staining, and microscopic examination to identify the changes. Pathological changes associated with helminth infection in cattle are mechanical obstruction of the lumen of gastrointestinal tract passage and interfering with functions of the organs involved in producing pathogenesis in the host. For instance, schistosomes are responsible for the obstruction of mesenteric blood vessels. Helminth parasite, *Toxocara vitulorum* leads to obstruction of intestinal tracts in young calves. Hydatid cysts in the liver, lung, and brain invade and destroy the cattle tissue and cells. Haemoprotozoan parasites such as *Trypanosoma evansi*, *Theileria annulata,* and *Babesia* spp. devour blood and cause anaemia in cattle. Parasites such as *T. vitulorum* and *Sarcocystis* secrete certain toxins in the body of the cattle. Among inflammatory cells, eosinophils, basophils, and mast cells played a vital role in host defence against the helminth parasites. In the case of observation of helminth parasites in the tissue section, either solid-bodied acoelomates or tubes within a tube (Pseudocoelomates) are noticed. Nematodes are often filled with organs, eggs, and larvae, whereas, trematodes and cestodes have organs embedded in parenchymatous tissue. Members of the phylum Platyhelminthes have a syncytial tegument, however, nematodes and acanthocephalans secrete acellular cuticles.

There are essentially two sorts of helminth sections during the histopathological examination. In the first case, the section showed parasites with solid bodies (the acoelomates) of trematodes and cestodes. In the second case, there are sections where tubs within a tube plan are observed, for instance, nematodes and acanthocephalans tissue sections. Flatworms tissue section may possess cavities within the different organs, whereas, roundworms and acanthocephalans are generally packed with eggs and larvae. Further, thick acellular cuticles outline the body of nematodes and acanthocephalans, however, syncytial tegument is observed in the case of Platyhelminthes. Fortunately, acanthocephalans are rarely encountered in large ruminants. Common trematode parasites encountered in the cattle tissue section are *Fasciola* spp., *Schistosoma* spp., and *Amphistomes*. Likewise, the Metacestode stage of *Echinococcus granulosus* is most frequently encountered in the lung, liver, and brain tissue section of cattle. Among nematodes, life cycle stage of *Toxocara vitulorum, Strongyloides papillosus, Ostertagia* spp.*, Trichostrongylus* spp.*, and Bunostomum phlebotomum* are more often seen in tissue sections of cattle.

Histopathological research is critical in the diagnosis of human and animal illnesses. Histopathological alterations detected during specific parasite invasions are very significant for differential diagnosis and frequently establish the presence of parasitic illnesses. Such investigations also enable the identification of the disease's root cause. Many pathogenic organisms induce inflammatory lesions, and microscopic findings can help with aetiological identification. However, histological lesions are restricted in terms of various biological agents that might cause tissue injury. The most common histologic feature of parasite infections is granulomatous inflammation [4]. It is distinguished by a concentrated infiltration of macrophages and epithelioid cells. There are several large cells, lymphocytes, plasma cells, fibroblasts, and granulocytes. Helminths and parasites that multiply intracellularly are among the agents that cause granulomas. In histopathology, several unique stains are used, such as Giemsa's stain, which is beneficial in identifying *Leishmania*. Immunohistochemical approaches give an aetiological diagnosis by using particular antibodies. Tissue damage can sometimes be immune-mediated, dependent on the presence of circulating immune complexes or the participation of T-lymphocytes, rather than caused by direct parasite harm. In general, the lesions seen include vasculitis and inflammatory responses mostly constituted of mononuclear cells, as seen in many viral or bacterial infections. In some circumstances, *in situ* PCR improves aetiological diagnosis. To identify parasites in tissues under the microscope, the observer must have preliminary information on the gross and internal morphological details of the parasite, which are expected to be detected in the tissue under consideration and in that particular host. Parasite localization can result in hyperplastic-neoplastic lesions. Many parasites have been linked to the emergence of various types of neoplasms, but the processes involved remain unknown. Chronic inflammation and/or immune suppression appear to promote tumor growth [5].

Numerous animal parasites, protozoans, metazoans, and, in particular, helminths, can produce granulomatous lesions in humans. The study of two instances, *Ieishmania granuloma* and *Schistosomia granuloma*, would appear to imply that interactions between the host and the parasite at different phases of development are based on facilitation or rejection events involving both humoral and cellular processes. Thus, the emergence of the granuloma is determined by the host's reactional capabilities. The lesions found in these granulomas may be associated with a number of fundamental processes, including necrosis, fibrosis, specific or

CHAPTER 13

Anti-parasitic Drugs

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Abstract: Gastrointestinal parasites pose a significant threat to cattle health, welfare as well as productivity throughout the globe. This chapter describes the major gastrointestinal parasites that affect cattle, their impact on the industry, proper management strategies, and also potential future directions for effective control and preventive measures. The economic upliftment of parasite infections in cattle production systems is generally explored, highlighting the major need for integrated approaches to combat these potential parasites. Key and major aspects including grazing management, proper anthelmintic treatment, genetic selection criteria as well as emerging research, are elaborately discussed in the context of sustainable parasite control strategies. The chapter magnifies the importance of continued updated research with major collaboration to mitigate the impact of gastrointestinal parasites on cattle populations.

Keywords: Anthelmintics, Cattle, Control, Eeconomic impact, Gastrointestinal parasites, Management.

INTRODUCTION

The increased population of humans in the world also increased the demand for milk and meat therefore, the productivity of farm animals must be at an optimum

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level to fulfill such increasing demands. Their productivity could be affected by the presence of internal and external parasites such as gastrointestinal nematodes *Haemonchus, Cooperia, Oesophagostomum,* and *Trichostrongylus*, as well as *Rhipicephalus microplus* ticks and *Haematobia irritans* flies. These parasites lower the productivity of livestock in countries situated in tropical and subtropical regions of the world [1]. The parasitic problem among livestock could be controlled by synthetic drugs having antiparasitic activities such as *endodectocidal* drugs, ectoparasiticide, and endoparasiticide. Endoparasiticide specifically targets internal parasites while ectoparasiticides are used against ectoparasites. The third category is endodectocidal, which is equally effective against both external and internal parasites and is most widely used in animals for the control of parasites such as gastrointestinal nematodes, ticks, mites, flies, lice, and myiasis. However, the extensive and irrational use of *edodectocidal* drugs leads to the emergence of drug-resistant strains of parasites in animals, which are difficult to control [2]. Regarding the susceptibility of animals to parasites, the Indian breed of cattle (*Bos taurus indicus*) demonstrates greater resistance and resilience to ticks and gastrointestinal nematodes respectively. On the other hand, the taurine breed (*Bos taurus taurus*) is more susceptible to these parasites. However, the productivity of the Indian breed is less as compared to the taurine breed [3].

The world population of large ruminants is increasing to get surplus food of animal origin for humans. According to the Food and Agriculture Organization of the United Nations (FAO), worldwide the number of cattle and buffalo has increased from approximately 1.03 billion head combined (942.15 million cattle and 88.32 million buffalo) in 1961 to approximately 1.72 billion head combined (1.52 billion cattle and 203.93 million buffalo) in 2021. The production of meat has increased by approximately 28.75 million tons (Mt) combined (27.68Mt cattle meat and 1.07Mt buffalo meat) in 1961 to approximately 76.76 Mt combined (72.44Mt cattle meat and 4.32Mt buffalo meat) in 2021. Similarly, the production of milk from animal origin has increased from approximately 331.47 Mt combined (313.62Mt cattle milk and 17.85Mt buffalo milk) in 1961 to approximately 883.81 Mt combined (746.05Mt cattle milk and 137.76Mt buffalo milk) in 2021 [4]. An increase in trends is given in Figs. (**1**-**3**). As there is an increase in the food of animal origin, people's interest in disease-free food is increasing [5]. Therefore, the health of the animals is important and could be maintained by controlling infection *via* chemotherapy and prevention.

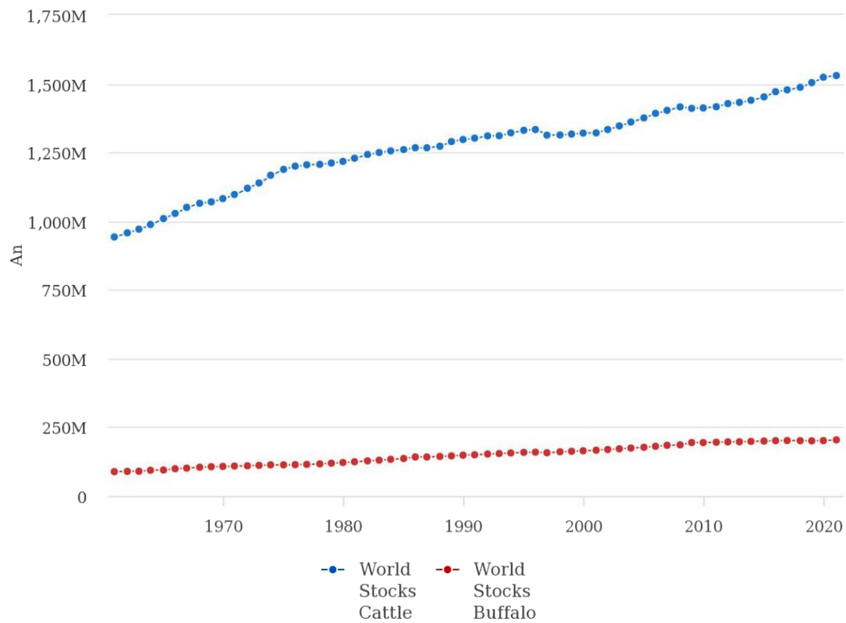

Fig. (1). A trend in increased production of cattle and buffalo from 1961 to 2021.

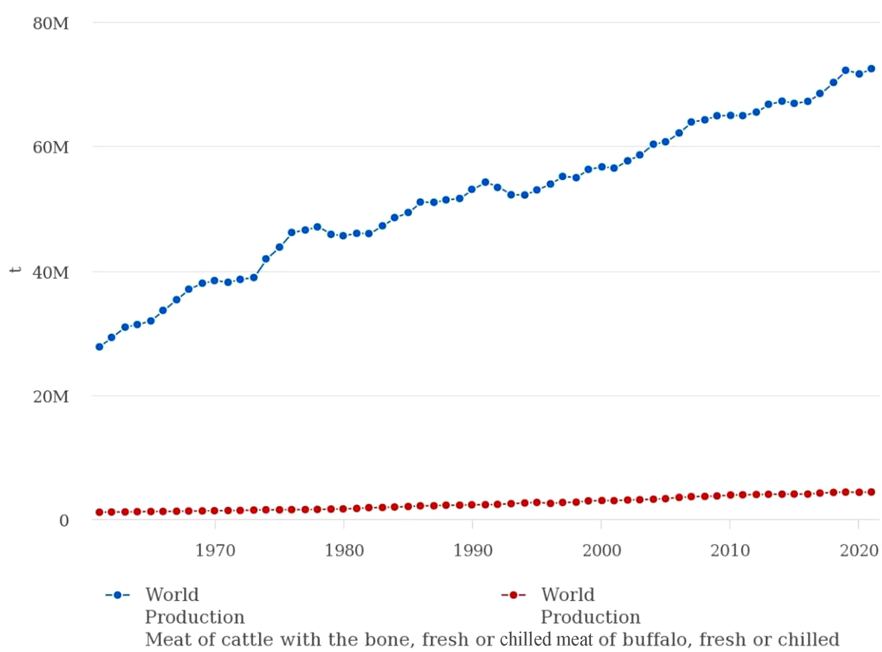

Fig. (2). A trend in increased production of cattle and buffalo meat from 1961 to 2021.

CHAPTER 14

Host Resistance to Parasitic Diseases

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Abstract: Resistance to parasitic infections falls under two main domains. The first is known as innate resistance, it comprises age resistance, breed resistance, and in some situations, species resistance which does not have an immunological basis. The second category is termed as acquired resistance and it depends on humoral and cell response. However, for reasons elaborated in this chapter, parasitic diseases can be countered by a few vaccines. The main role of protecting animals against infections and modulating the spread of parasitic diseases is contributed by the natural expression of acquired resistance. Host-parasite relationships are mostly perceived as a defense race, where parasites are continuously trying to take over host machinery. A common source of parasite spread is herbivory, which constitutes the most prevalent challenge to mammalian growth and reproduction. Factors affecting the immune response against infection include (a) genetics, (b) host status at the time of exposure comprising age, disease, and underlying illness, and (c) transmission and population of parasite loading dose.). The immune system works in the same fashion against parasites as for other pathogens, but there are some major changes depending upon the nature of the response. Different antigens show up as a parasite develops through certain stages of its life cycle. This results in the occurrence of many antibodies dependent and independent responses. The immune system of the host becomes confused in certain infections, progressing to conditions where the host is targeted rather than supported.

Keywords: Evolution, Host, Infection, Interaction, Immunity, Parasite, Strategy.

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INTRODUCTION

Understanding the host-parasite coevolution is a time-honored goal of evolutionary biology. There is a well-established conceptual framework to explain the host-parasite relationship under the inference of two-species relatedness, that can lead to defense race kinetics or persistent genotype variations [1, 2]. Although a lot of hosts depend on symbionts for countering the parasitic attacks. The potential significance of defensive symbionts against disease control is greatly recognized, but there is still much confusion about how symbionts regulate and play a role in host-parasite coevolution [3, 4]. Theoretical and empirical studies help us address these questions by synthesizing information from available data. Firstly, we generate theories on how mutual defensive approaches originated from host-parasite interactions. All important determinants of evolutionary dynamics are influenced by defensive symbionts [5]. The underlying mechanism of defense influences parasitic virulence [6]. Many mechanisms are involved in parasitic infestation which are likely to be regulated by certain complex factors. Many of the processes of host immunity and their regulating factors have been recognized, however much is left to be elaborated. The diversity in protective mechanism against tick infestation is mostly noticeable in *Bos taurus* and *Bos indicus* cattle, there are five to ten times more tick attacks in taurine cattle as compared to indicine given the same exposure. Parasitic infection is manifested by attaching larvae, which struggle to feed and infect the host. The main responses against parasitic attack are innate and adaptive responses and their relative significance differs in taurine and indicine cattle. The role of humoral immunity against infection has conflicting evidence, the latest research tells that a significant IgG response against parasitic attack is not effective. T-cell response mounted by indicine cattle against larval stages is more protective. The role of innate resistance is critical against parasitic infections, while adaptive immunity mainly plays a role in long-term or chronic infections [2].

Early studies focused on the mechanical and physical qualities of indicine and taurine skin. Further studies concerning innate responses to infection and the potential role of the physical qualities of skin against parasitic infestation have been conducted [4].

Resistance against parasites in cattle is manifested in decreased tick population feeding to get engorged, less egg production, and less viability of eggs. Various animal species react differently to parasitic infections. Some breeds have innate resistance to pathogenic consequences of infection and there is no decline in their productivity and growth. Some breeds exhibit more rapid and documented responses against infection [3].

The most common route of transmission is the gastrointestinal tract, which later spreads *via* the bloodstream and lymphatics. The parasite can also spread by the ingestion of oocytes that are present in the fecal matter of acutely infected animals or by transplacental infection from mother to fetus. Consecutive pregnancies act as a source of continuous transmission through the placenta. This consistent transmission is seen in cattle that are naturally infected, and it indicates that it is a significant challenge to exhibit a resistance strategy [1].

The main characteristics of parasites that make them difficult to control are the size of the parasite, life cycle, and antigenic complexity. Parasites escape the host immune response in several ways: (a) They prefer to be at such body locations that are comparatively safe from an immune response. (b) Certain changes in surface antigens. (c) Different processes alter immunity [5].

Evolution of Resistance

Many breeds of cattle belonging to endemic disease areas have developed strategies to adapt them to co-exist with parasites. Genes responsible for resistance and tolerance can offer new mechanisms of health improvement and livestock welfare. The Sahiwal express a low level of pathology as compared to Holstein and can survive an infection [7]. To develop effective eradication programs, understanding the process of resistance to nematodes is essential. Most animals are categorized for their immunity nematodes [8]. Ruminants have a natural genetic variation that effectively avoids gastrointestinal parasites without using anthelmintics [9].

The heterogeneity of the ecosystem is believed to have direct implications for the evolution of the host and parasite [10]. The geographical distribution of the genetic variation is formed by various phenomena that interrelate with each other and affect the adaptive traits' selection. The magnitude of such processes can be understood by analyzing the population patterns of the genetic framework and it is helpful in forming an assumption about the evolution of traits [11].

The parasites affecting the mating system and transmission processes have variations in their life cycle which can lead to variations in the genetic structure of the population because the rate of gene flow is influenced by it [12]. The phenotypic specialties formed by genetic signals have just started to be revealed and important evolutionary clues are expected from reproductive and morphologic traits [13].

An important role in the maintenance and distribution of genetic variability is played by mating systems. Hurdles in adapting standard procedures of secondary deductions about the life cycle of parasites certainly elaborate the present lack of

CHAPTER 15

Antiparasitic Vaccines

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Abstract: Cattle farming plays a vital role in global agriculture, providing meat and dairy products to meet the growing demand for protein. However, the industry faces significant challenges posed by parasitic infections that lead to economic losses, reduced productivity, and compromised animal welfare. To combat these issues, researchers have been exploring the development of antiparasitic vaccines for cattle. In the realm of helminths, efforts have been made to identify specific antigens from nematodes, trematodes, and cestodes that can stimulate protective immune responses in cattle. The transition from whole-organism vaccines to subunit vaccines has shown promise, with several candidates in various stages of development. Protozoal infections, including Neospora caninum and Theileria species, have been targeted with vaccines designed to reduce abortions and mortalities in cattle. Live-attenuated and subunit vaccines have been explored with varying levels of success. Achieving consistent protection across diverse parasite strains remains a challenge. Ectoparasitic arthropods like ticks and flies have also been the focus of vaccine development. Bm86-based vaccines for ticks have shown partial success but face limitations in terms of tick species and strains. Combinatorial vaccines and *in silico* approaches offer potential solutions for broader protection. Despite these advancements, several challenges persist in the development of antiparasitic vaccines for cattle. These include the need for rigorous field testing, addressing antigenic diversity, optimizing vaccine formulations, and ensuring cost-effectiveness for widespread adoption.

Keywords: Cattle, Commercialized, DNA vaccines, Killed vaccines, Lyophilization, Live vaccines, Premunitio, Subunit vaccines, Vaccine candidate.

INTRODUCTION

The ruminant world is plagued by a variety of infections, but none causes more damage to their productivity and health than parasitic infections. The majority of these infections are caused by trematodes, cestodes, nematodes, protozoans, and

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external parasites [1 - 4]. Both endo and ecto parasites are responsible for huge economic losses in animal production by lowering production (milk, meat, and reproduction), damaging by-products (hides), and affecting the health (treatment, control, and mortality) of animals. The estimated economic losses due to parasitic infections in cattle revealed an average reduction of 1.16 liters of milk production and a 12.95% increase in organ condemnation per animal per day [5 - 8]. Additionally, the calculated losses amounted to an average of US$50.67 per animal per year, accounting for a 17.94% decrease in financial returns [1, 2]. Traditional methods of controlling parasitic infections in cattle have often involved the use of chemotherapy, like anthelmintics, antiprotozoals, and acaricides. However, these approaches have raised concerns about the development of resistance and environmental impact [3, 4]. The emergence of drug resistance, coupled with the intricate life cycles of parasitic diseases, has posed formidable challenges to their effective control. Simultaneously, the growing demand from the public for animal products untainted by drugs has underscored the need for alternative solutions. In response to these pressing concerns, vaccination has assumed a pivotal role in the comprehensive management of parasitic diseases. The development of antiparasitic vaccines for cattle has emerged as a promising alternative, aiming to provide sustainable and effective solutions to combat parasitic infections while minimizing adverse effects [5, 6]. Vaccines have a long, successful history of preventing and controlling diseases in farm animals. Vaccines stimulate the immune response in the animal without causing disease. Immunization stands as a pivotal approach in combating infectious agents, primarily due to its potential safety, affordability, and prophylactic efficacy compared to drugs. However, the application of vaccines has mainly been successful with antimicrobial vaccines. In endeavors to create commercial vaccines targeting economically significant parasites, researchers have primarily concentrated on pinpointing specific antigen targets [9 - 12]. As a result of these endeavors, numerous potential antigens have been discovered, vaccines have been formulated using them, and their suitability and effectiveness have been assessed through testing. Despite the development of several vaccines and their subsequent testing for effectiveness, they have not been brought to the commercial market due to various technical obstacles. Consequently, only a limited number of vaccines are currently accessible for commercial utilization. While factors contributing to market failure are recognized, other influential aspects impact commercial success, such as quality, safety, efficacy, potency, consistency of production, product profile definition, onset and duration of immunity, compatibility with other products, and routes of administration [13 - 18].

Development of Parasitic Vaccines and Challenges

Vaccine development against parasites has had both successes and failures. Successful vaccines have used various technologies, including crude vaccines with irradiated nematode larvae and recombinant antigen vaccines for metazoan parasites. However, recent recombinant lungworm vaccines have not been as effective as whole organism vaccines and similar challenges exist for nematode vaccines. Subunit vaccines have been attempted, but they face obstacles such as incorrect strains, production issues, and inadequate antigen levels. Immune suppression and other factors can also hinder vaccine effectiveness. Helminth infections in cattle, particularly *Cooperia* spp and *Ostertagia ostertagi*, are increasingly resistant to antihelminthic drugs. Resistance to flukicides has also been observed in *Fasciola hepatica* [19 - 22]. To address these challenges and ensure sustainable control, alternative strategies like bioactive forages, selective breeding, nematophagous fungi, and vaccine development are needed. However, developing helminth vaccines is complex due to the parasites' intricate life cycles, diverse antigenic elements, and protein polymorphism, making it challenging to identify suitable targets. Protozoan parasites in cattle cause significant losses and pose zoonotic risks [23 - 27]. Vaccine development strategies for protozoa include using whole organisms, attenuated strains, killed organisms, subunit vaccines, and vector vaccines. Recombinant DNA technology has been used but with limited success due to the complexity and antigenic diversity of these parasites. Developing vaccines against ectoparasitic arthropods is difficult due to their size, complexity, and preference for life on the host's surface. Some research has identified immunocompetent molecules in arthropods, but challenges remain [28 - 33]. Despite these challenges, vaccination remains a promising approach for parasite control in animals, with the potential for improvement through regulatory changes and advancements in molecular techniques.

Helminth Vaccines

Fasciolosis

Liver flukes, specifically *Fasciola hepatica* and *F. gigantica*, are parasites with a wide range of hosts, and they cause significant economic losses globally. In tropical regions, fasciolosis is a prominent helminth infection in cattle, with prevalence ranging from 25% to 100% in the Middle East, Southeast Asia, and Africa. Numerous studies have explored the potential for candidate antigens from either *F. hepatica* or *F. gigantica* as vaccines for livestock (Table **1**). Prominent candidates among these antigens include fatty acid binding proteins (FABP), glutathione S-transferase (GST), Cathepsin L1 (CatL1), and Leucine aminopeptidase (LAP) [34 - 37].

CHAPTER 16

Preventive Measures and Control of Parasites

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Abstract: Parasitism is one of the greatest challenges faced by the cattle industry worldwide. Parasites and parasite-borne infections not only pose various adverse impacts on the health of cattle but also affect the marketing and import-export of animals and their products, which lead to the loss of billions of dollars on an annual basis. Therefore, devising appropriate preventive measures and control strategies is direly needed in order to fight against these devils that affect cattle health. As the kinds of parasites and the degree of their impacts on cattle vary significantly according to climatic conditions, geography, genotype of cattle, production environment, cattle age, and management approaches, precise and suitable preventive and control measures must be adopted according to faced factors and situations. Nowadays, many approaches are extensively utilized for parasitic control, like pasture management, waste management, deworming, grazing management, nutritional management, management of dwelling places or sheds, immunization, and biological control. It is not possible to issue general guidelines and recommendations for parasitic control in cattle due to diverse geo-climatic conditions and methods opted for rearing the cattle. Due to the increasing incidence of anti-parasitic drug resistance in animals, it is crucial to design a sustainable parasite control approach, which must involve the host as well as the host control measures to achieve maximum productivity from cattle for an indefinite time period.

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Keywords: Biological control, Cattle, Control, Endoparasites, Ectoparasites, Economic losses, Management, Parasites, Prevention.

INTRODUCTION

Parasitism is one of the biggest challenges faced by the cattle industry globally [1, 2]. Parasites and parasite-borne infections not only pose various adverse impacts on cattle health but also affect the marketing and import-export of animals and their products [3]. The cattle industry faces the loss of billions of dollars on an annual basis due to parasitism [4]. Parasitic diseases cause a reduction in weight, feed utilization efficiency, and milk production [5 - 8]. These are also considered one of the main causes of liver rejections in abattoirs and mortality in young and adult cattle [9 - 16]. The reproduction and defense response of animal's body to immunization and infection are also affected badly due to parasitic infestations [17 - 23]. Additionally, some cattle parasites are also zoonotic in nature, which may threaten human health [4]. The health and welfare of the cattle kept on farms are also compromised because of parasitic infestation. According to the definition proposed by the World Organization for Animal Health, "good animal welfare is considered when an animal is in good health condition, well fed, safe, comfortable, is not suffering from discomforting conditions like pain, fear, and distress, and is able to manifest behaviors that are essential for its physical and mental well-being". Suitable veterinary care, management, shelter, nutrition, and prevention of disease are the basic requirements of good animal welfare [24]. Cattle infected with gastrointestinal nematodes and liver fluke may contribute to increased greenhouse gas emissions compared to uninfected ones [25, 26].

Enormous production and economic losses associated with parasitic infections in cattle provide ground for the application of strategies to control the key parasites affecting the cattle in order to ensure profitability, improve animal welfare, and potentially play a part in minimizing greenhouse gas emissions. Still, cattle operations face limited operating margins [27, 28], so the methods used to alleviate losses arose due to parasitism need to be cost-efficient. Effective, cost-efficient, profit-generating management of parasitic diseases depends upon the comprehension of various variables impacting the level of disease. The kinds of parasites, the degree of their impacts on cattle, and the steps taken for their control vary according to climatic conditions, geography, genotype of cattle, production environment, cattle age, and management approaches (Fig. **1**). For instance, the environmental conditions in the tropical and sub-tropical regions are generally favorable for the developmental stages of many parasites. For this reason, the prevalence and diversity of parasitic infections present in those regions are significantly greater as compared to those in temperate climate regions [3, 29 - 32]. As a result, the control strategies developed for parasite control in temperate regions will not be effective in other climates [31]. Cattle genotypes vary in their vulnerability to different parasites. For example, *Bos taurus* cattle are often seen to be more susceptible to tick infestation than *Bos indicus* breeds [12, 33, 34]. *Bos taurus* cattle have also been suggested to exhibit resistance against the gastrointestinal nematodes as compared to *Bos indicus* breeds [35]. Young cattle, particularly those grazing on the pasture for the first time, are seen to have a higher chance of acquiring gastrointestinal nematode infection than adult cattle [35 - 37]. Cattle grazing on pastures have increased exposure to helminths than cattle feeding in feedlots [38 - 40]. Moreover, nutritional status and seasonality also influence the exposure of cattle and response to parasitic activity [41].

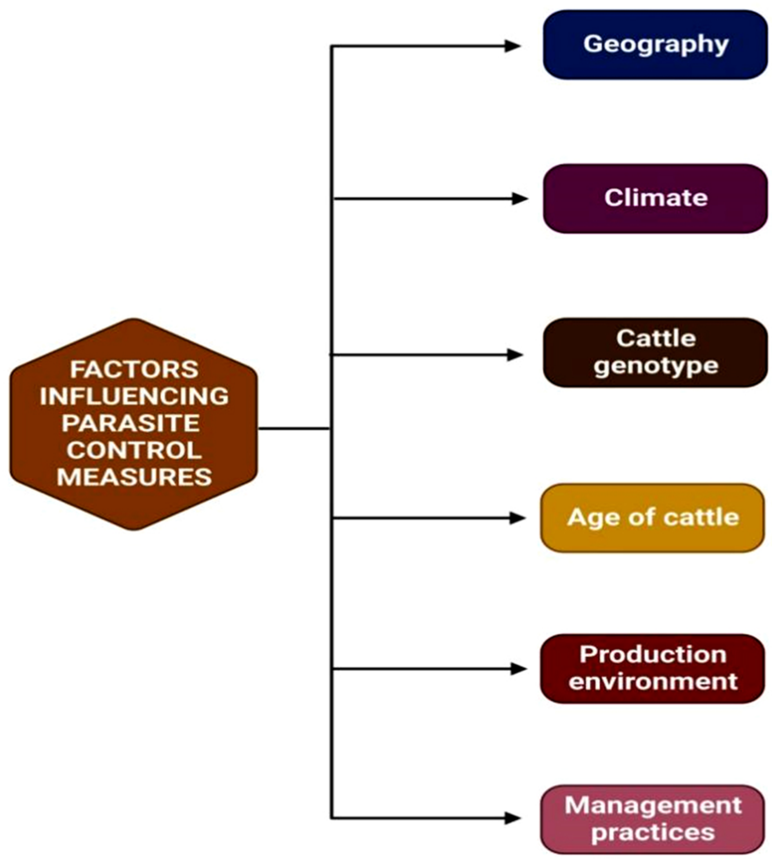

Fig. (1). Various factors affecting the parasite control measures.

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