Introduction

The chicken was once considered a sacred animal symbolizing the sun. Breeds were developed to provide plumage for ceremonial costumes. Later on, it was incorporated in the food habits. Eventually, it became a conspicuous part of flourishing poultry industry in the entire world serving as a major source of animal protein in human diet. Still there are more chickens than people in the world.

Poultry industry has taken fifty years to reach its present status in India. The poultry farmers and veterinarians have put an immense effort to bring the poultry industries to the present status to produce cheap poultry meat and other products as a source of animal protein. The poultry industry in India has emerged as the most dynamic and rapidly expanding segment of the livestock economy as evident from the production level touching about thirty-seven billion eggs and seven hundred and ninety-one million tons of broilers with a compounded annual growth rate of eight and fifteen percent respectively. Today India is the fifth largest egg producer and nineteenth in broiler production in the world. Also India is one of the few countries to possess the technology for production of pathogen-free eggs. Despite this achievement, the annual per capita consumption in India is only thirty-six eggs and eight hundred and fifty grams of poultry meat. This is much lower, as compared to the world average of one hundred and twenty-four eggs and 5.9 kg meat. Even the consumption levels of neighboring developing countries like Pakistan (2.3 Kgs), China (4 Kgs), Thailand (9 Kgs) is quite higher than India's, hence the potential for growth is quite big. As per the recommendations of the National Committee on Human Nutrition, the eggs and broiler meat requirement will be one hundred and eighty billions and 9.1 million tons by the end of 2010 A.D. The estimated production may only be around 46.2 billion eggs and 3.04 million tons poultry.
meat. This shows there is tremendous scope for growth. At present, poultry meat production in the world is estimated sixty six million tons and it is expected to grow to ninety four million tones by 2015.

The poultry sector in India is able to contribute twelve to fifteen percent of agricultural gross rate domestic product, drive the growth of agriculture and allied sectors and provide higher jobs for farmers.

The poultry sector in India reflects the dual sources, i.e., commercial poultry and backyard poultry. The commercial sector depends on imported pure lines and grand parents. The parents and commercial birds from these imported lines are multiplied in commercially run hatcheries mainly in and around cities and semi-urban areas. Nearly eighty five per cent of total egg production and almost the entire commercial broiler production are from improved poultry birds in this organized sector. On the other hand, even today more than forty per cent of the poultry population in the country consists of different types of indigenous chicken, which thrives only on scavenging. The thrust from this area is, therefore, very evident that this low yielding domestic population is replaced with the moderately yielding cross-breeds. There are over five hundred parent stock farms or hatcheries established by private and government sectors all over the country. States of Karnataka, Kerala, Tamil Nadu, Andhra Pradesh and western region of Maharashtra account for more than fifty six percent of total national egg production and sixty percent of total broiler production in the country.

India's broiler industry is highly unorganized especially in north India though in south India, the players of the industry have come together for integrated operations. However, layer industry is totally in hands of unorganized sector. Poultry farming is hampered in northern regions due to extremely cold conditions during certain period of the year despite that Punjab alone contributed more than six percent of the total egg production in the country.

The poultry farming in India has transformed from backyard venture into a dynamic agro industry over the last four decades. This sector had emerged as one of the fastest growing segments in agriculture, contributing about Rupees sixty five billion to the national economy (Anon, 2000). In fact, smallholder
chicken production plays an important role in the agricultural system of developing countries. Farmers, in village areas, beside their plant production have their poultry flock mainly dominated by chickens. The system is characterized by low external production inputs and low outputs (Rushton and Ngongy, 1998; Gueye, 2000). Village chicken production system used essentially the indigenous scavenging domesticated fowl *Gallus domesticus*; which constitutes the predominant species in rural poultry sector. Horst (1988) reported that the genetic resource base on indigenous chicken is rich and should form the basis for genetic improvement. However, the economic losses arising out of poultry diseases continue to be a threat to the industry. There is enormous wastage from diseases, making the economic assessment of diseases vital to aid in policy making (Peter, 1992). Measurement of economic losses caused by diseases would provide information useful in determining research priorities, because the optimal amount of resources to be invested in controlling a disease depends on the likely annual costs of the disease and of control measures (Brennan et al. 1992).

Though studies have been done in developed countries to assess the extent of disease losses (Ngategize and Kaneene, 1985), not many studies were directed towards this branch of animal health economics, except a few as done by Patel et al. (1994), Palanivel (1996), Thirunavukkarasu and Prabaharan (1999), Jeyakumary et al. (2003), Selvam et al., (2004), Jeyakumary et al. (2004), Thirunavukkarasu and Kathiravan (2005) and Thirunavukkarasu and Kathiravan (2006). Among the diseases affecting the profitability of layer farms, Infectious Bursal Disease (IBD), Ranikhet Disease (RD), Escherichia coli (E.coli) infection and coccidiosis are considered to be the most harmful diseases.

Among the many diseases of economic importance to poultry industry, in this thesis, I have put an emphasis on coccidiosis. Coccidiosis is usually a disease of young birds, but birds can be infected at any time if never exposed before. Coccidia populations take time to build to dangerous levels, therefore, outbreaks usually occur when birds are between three and eight weeks of age. Coccidiosis goes hand-in-hand with gut diseases, because it damages the gut
and allows bacteria to enter and cause secondary infections. Furthermore, coccidia are "species specific"—coccidia that affect chickens do not affect other livestock, and vice versa.

Knowing how coccidia develop helps to understand and control the disease. Coccidiosis is caused in poultry by a one-celled parasite of the genus *Eimeria*. The life cycle of *Eimeria* takes about four to seven days to complete. It begins when active "oocysts" are picked up by the bird and swallowed. An "oocyst" is a capsule with a thick wall protecting the parasites. They "sporulate" or become infective if moisture, temperature, and oxygen become conducive to growth. After a bird eats the oocysts, coccidia invade the intestinal lining and multiply several times, damaging the tissue. Coccidia are parasites, so they get their nutrients from the chicken host. The multiplication eventually stops, usually before causing death of the bird. The bird sheds the parasite in its droppings. These new oocysts can infect other birds. A coccidial infection differs from bacterial and viral infections because coccidia are "self-limiting" and usually stop multiplying before killing the bird.

Chicken get coccidiosis by eating oocysts that have been shed in the droppings of infected chicken. Infected chicken shed oocysts for several days or weeks. Oocysts sporulate within two days under the proper conditions and become infective. Chicken pick them up by pecking on the ground or in litter used for bedding in the house. Oocysts can also be spread by insects, dust, wild birds, and human (from shoes and equipment). Oocysts can survive many weeks in the soil outdoors—as long as six hundred days (Farr and Wehr, 1949). The optimum temperature for sporulation is around 72°F. The rate of sporulation is slower if temperature is increased or decreased than the optimum one. Oocysts are killed either by freezing or at very high temperature. Sporulation also requires oxygen and moisture (at least twenty percent moisture in the litter for optimal sporulation). Waldenstedt et al. in 2001 reported that sporulation of *E. maxima* was most efficient under the driest conditions studied (sixteen percent moisture content), and poorest in the samples with the highest moisture content (sixty-two percent). Once sporulated, the oocyst remains infective for months if protected.
from very hot, dry, or freezing conditions. In very large poultry houses, oocysts do not last long in the litter because of the action of ammonia released by decomposition of litter and manure and by the action of molds and bacteria. However, there are usually so many oocysts that birds continue to pick them up and get sick.

Coccidia are very prolific parasites. A single sporulated oocyst can have a major impact when eaten by a chicken. Each oocyst has four sporocysts in it, and each sporocyst has two sporozoites in it. The digestive tract releases the eight sporozoites from the oocyst, and they move into the cell lining of the digestive tract. Inside the cell, the parasite divides and invades more cells. There may be several generations of asexual multiplication; however, this stage is self-limiting and eventually stops. Finally, a sexual stage occurs in which male and female organisms unite and form new oocysts that are protected by a thick wall. These oocysts are shed in the feces.

Almost all livestock are affected by different types of coccidia. There are seven different *Eimeria* that infect chickens, but only three cause most of the trouble: *Eimeria tenella*, *Eimeria maxima*, and *Eimeria acervulina*. Immunity to one type does not provide immunity for other types. Turkeys, ducks, geese, and other types of poultry are all infected by different types of coccidia.

Chicken coccidia species are *Eimeria acervulina*, *Eimeria maxima*, *Eimeria tenella*, *Eimeria necatrix*, *Eimeria mitis*, *Eimeria brunetti* and *Eimeria praecox*.

Outward signs of coccidiosis in chickens include droopiness and listlessness, loss of appetite, loss of yellow color in shanks, pale combs and wattles, ruffled, unthrifty feathers, huddling or acting chilled, blood or mucus in the feces, diarrhea, dehydration, and even death. Other signs include poor feed digestion, poor weight gain, and poor feed efficiency. Some symptoms can be confused with other diseases. For example, necrotic enteritis is a gut disease that also causes bloody diarrhea. Producers in the past identified coccidiosis outbreaks as either severe-acute or chronic, which was less severe but more widespread. Coccidiosis causes a thickening of the intestines, which make them
feel like a sausage. There may be light-colored spots on the surface of the gut, and inside the gut, hemorrhages and streaks.

According to Levine (1963), most coccidians are intracellular parasites of the intestinal tract, but some minor groups occur in the endothelial cells of the blood vessels of the visceral organs; a few species occur in the parenchymal cells of liver or kidney, the mucosa of the gall bladder, or other locations. Even within the intestinal tract, each species is usually found in a specific location. Some are found in the caecum, others in the duodenum, still others in the ileum. In each location, they may invade different cells, some occur only in the epithelial cells at the tip of the villi, others in the crypts, still others in the endothelial cells of the capillaries and lymphatics within the villi, etc.

Their location within the host cells may sometimes be specific. Some species are found above the host cell nucleus (i.e. in the cytoplasm between the nucleus and lumen of the intestine), others are found below the nucleus, or within it (Kheysin, 1972).

As far as distribution of coccidial parasites is concerned, Table I includes a list of coccidial species in various host groups of the World and Table II incorporates the distribution of coccidial parasites in different host groups from India, prepared after Becker (1956) and Mandal (1976) respectively.
Table I: Number of Coccidian species in various host groups (after Becker, 1956)

<table>
<thead>
<tr>
<th>Genus of Coccidium</th>
<th>Vertebrates</th>
<th>Mammals</th>
<th>Birds</th>
<th>Reptiles</th>
<th>Amphibia</th>
<th>Fish</th>
<th>Crustacea</th>
<th>Arthropods</th>
<th>Annelids</th>
<th>Molluscs</th>
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</table>

Table II: Showing the distribution of Coccidian parasites in different hosts from India (after Mandal, 1976)

<table>
<thead>
<tr>
<th>Name of the Genera</th>
<th>Vertebrates</th>
<th>Molluscs</th>
<th>Arthropods</th>
<th>Fish</th>
<th>Amphibia</th>
<th>Reptiles</th>
<th>Birds</th>
<th>Mammals</th>
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<tbody>
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<tr>
<td>Loxospora</td>
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<td>Oxyuris</td>
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<tr>
<td>Emmera</td>
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<td>Spinurina</td>
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<td>Adelaia</td>
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<td>-</td>
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<tr>
<td>Karygus</td>
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</table>
Classification

Before describing the present study, it is important to classify the term 'coccidia'. The class Sporozoa of the phylum Apicomplexa includes the subclass Coccidia. Thus, all the representatives of this subclass may be called as Coccidia. But, the term coccidian is better applied to the more limited group of sporozoans included in the order Eucoccidida. Very often only representatives of the suborder Eimeriina are referred to as Coccidia. This suborder includes numerous representatives which cause disease in various animals and man.

The inclusion of coccidia under the phylum Apicomplexa Levine, 1980 and to the class Sporozoa Leuckart, 1879 has now been accepted by the taxonomists. A thorough survey of literature, in connection with the classification of Coccidia, may be elucidated here.

Class Sporozoa was first established by Leuckart (1879). He included in it only the gregarines and coccidia. Five orders of Sporozoa were recognized: Gregarines, Coccidia, Sarcosporidia, Myxosporidia and Microsporidia. Sub class Gregarinida, Myxosporidia and Sarcosporidia were included in the class Sporozoa Coccidia was placed as a family under the gregarine order Monocystidea. In the classification of the class Sporozoa, new groups known as the Haemosporidia and Cnidosporidia were added to the gregarines and coccidia, and divided the class into two sub classes- Telosporidia and Neosporidia. Gregarines, haemogregarines and coccidia were placed in the subclass Telosporidia.

Hall (1953) gives Sporozoa the rank of a sub phylum and divided it into three classes viz, Telosporidia, Cnidosporidia and Acnidosporidia. Telosporidia was further divided into three sub classes, Gregarinida, Coccidia and Haemosporidia. The sub phylum Sporozoa was divided into three classes viz., Telosporidia, Cnidosporidia and Acnidosporidia. The class Telosporidia was divided into two sub-classes- Gregarinida and Coccidia. Honigberg et al. (1964) introduced a new classification, where Sporozoa was considered as a sub-phylum. Levine (1970) placed class Sporozoa under the new sub-phylum Apicomplexa and divided the class Sporozoa into two sub-classes viz,
Gregarnia and Coccidia. The subclass Coccidia contained two orders viz, Eucoccidiorida and Protococcidiorida. However, Sporozoa was considered as a class under the phylum Protozoa and divided it into four orders viz, Gregarnnida, Coccidia, Haemorpsoridia and Haploparidia. Five families were recognized under the order Coccidia.

In 1980, the Committee of Systematists and evolution of the Society of Protozoologists under the chairmanship of Prof. N D Levine proposed a newly revised classification of the Protozoa where seven phyla have been accepted viz., Sarcomastigophora, Labyrinthomorpha, Apicomplexa, Microspora, Ascetospora, Myxozoa and Ciliophora. The phylum Apicomplexa is further divided into two classes, Perkinsea and Sporozoea. The sub-classes included under the class Sporozoea are Gregarina, Coccidia and Piroplasmia. Under the sub class Coccidia are included three orders viz., Agamococcidiida, Protococcidiida and Eucoccidiida. Sub order Eimerina is included under the order Eucoccidiida. This is further divided into four families viz., Selenococcidiidae, Aggregatiidae, Dobellidae and Eimeriidae. In the present study, the newly revised classifications of Levine et al (1980) has been considered upto the rank of suborder and have included the coccidians under the family Eimeriidae Leger, 1911.

The family Eimeriidae is divided into a number of genera of which four are of veterinary interest. These are:

1. **Cryptosporidium**: These are with four sporozoites but no sporocysts.
2. **Isospora**: In this genus, the ripe oocysts contain two sporocysts, each of which contains four sporozoites.
3. **Eimeria**: The mature oocyst contains four sporocysts, each of which contains two sporozoites.
4. **Tyzzeria**: In this genus, the mature oocyst contains eight free sporozoites.

Of these, *Cryptosporidium* includes small parasites found exclusively on the surface of mucous membranes. They are seldom associated with disease in domestic animals but must be differentiated from developmental forms of the other coccidia. The *Isospora* includes a group of parasites which are found...
principally in carnivores. Their pathogenicity is not very great, as a rule, and the group is of small practical importance in comparison with the members of the genus *Eimena*. However, majority of the parasites known as ‘coccidia’ belong to the genus *Eimena*.

From the perspective of effect of parasitism on host, coccidiosis is a self-limiting disease, because after a given number of schizont generations, all merozoites are transformed into gametocytes. Under such circumstances, the life cycle of the parasite is completed. Thus, in case of coccidiosis, the severity of the disease depends largely upon the number of organisms that initiate the infection. The effect of coccidiosis varies widely with the species of host, species of coccidia, age and resistance of host, degree of infection, and many other factors (Noble and Noble, 1982). One result of infection is the rise in blood sugar level of the bird (Noble and Noble, 1982). There is some evidence that *Eimena tenella* within macrophages of domestic fowl causes enhanced ribonucleotide protein production by the host cells, and that this protein is incorporated into the newly formed merozoites.

Host specificity issues dissolve without accurate host and parasite identifications. Therefore, it is important to note as many of the morphological details of sporulated oocysts as can be identified when describing eimeriid coccidia. Life cycle details and cross transmission studies (Hnida and Duszynski, 1999) can greatly aid one’s decisions in making specific identifications of morphologically similar sporulated oocysts from closely related hosts, and are also essential for identification of the potential host range of polyxenous coccidia (Tenter and Jhonson, 1997). Thebo et al in 1998 identified seven *Eimena* species in Swedish domestic fowl based on the criteria of oocyst morphology, location and characteristics of intestinal lesions and prepatent time.

Coccidiosis is primarily a disease of young animals, while adults are generally symptomless carriers. Those animals which recover from an infection develop immunity to the species which infected them. It is not an absolute immunity; however, recovered adults are continuously reinfected and commonly carry light infections which do not harm them but which make them a source of infection for
their young. Under conditions of stress, the adults' immunity may break down and they may suffer from disease again (Levine, 1963).

Modern intensive poultry production is largely dependent upon chemoprophylaxis for the control of coccidiosis (Chapman, 1999). Anticoccidial drugs have been used for the control of coccidiosis for more than fifty years, and today almost all commercial broilers are reared with an anticoccidial agent in their feed (Chapman, 2001). Unfortunately, in due course of time, antibiotic and anticoccidial resistance has added fuel to economic loss in poultry industry due to infections caused by many harmful diseases. Reduced sensitivity to non-therapeutic antibiotics, plus the concern that feeding these drugs to poultry and livestock may increase the risk for antibiotic-resistant infections in people, is initiating significant changes in the poultry industry. Waldenstedt et al. in 1999 reported that routine use of feed antibiotics for domestic animals has been prohibited by law since 1986 in Sweden. For many years, antibiotic growth promoters and ionophore anticoccidials, which have antibacterial action, have had the inadvertent benefit of controlling a variety of diseases in poultry. With prolonged use, however, antibiotic resistance has developed, minimizing their effectiveness. Though controversial, there is also concern that antibiotic-resistant infections in poultry and livestock could transfer to people, which has already prompted European regulators to ban the use of several in-feed antibiotics in food animals. A similar movement is under way in the United States, where it has largely been instigated by consumers and is evidenced by the soaring growth of organic poultry sales. In addition, U.S. legislators have proposed The Preservation of Antibiotics for Medical Treatment Act, which would prohibit the use of several non-therapeutic antibiotics in food animals.

From the perspective of coccidiosis, different types of drugs to control the disease are as follows:

**Sulfa drugs:** An exciting discovery in the 1930s was that sulfa drugs would prevent coccidiosis—the first drugs shown to do so. Sulfa drugs also have some antibacterial action. However, a relatively large amount of sulfa was
needed (ten to twenty percent of the diet) and could be tolerated by the bird for
only a short time, since it caused rickets (Reid and Malcolm, 1990). Sulfa drugs
had to be used intermittently (e.g., three days on and three days off) Nowadays,
comparatively small amounts of sulfamonaides, such as sulfaquinoxaline, are
used They work only against *Eimeria acervulina* and *Eimeria maxima*, not
against *Eimeria tenella* Sulfamonaides are used to treat coccidiosis

*Amprolium:* Amprolium is an anticoccidial drug. It has also been used for
many years and needs no withdrawal time to guard against residue in the meat
It is given in the drinking water and interferes with metabolism of the vitamin
thiamin (vitamin B1) in coccidia Amprolium treats both intestinal and cecal
coccidia.

*Quinolones:* Quinolones are "coccidiostats" that arrest the coccidia in an
early stage of development. An example is decoquinate (Deccox®). The drugs
are used for prevention.

*Ionophores* Ionophores are anticoccidials commonly used in the large-
scale industry. They alter the function of the cell membrane and rupture the
parasite. Ionophores also have antibacterial action and help prevent secondary
gut diseases Ionophores are not synthetic drugs; they are produced by
fermentation and include monensin (Coban®) and salinomycin (Sacox®)
However, some ionophores are now completely ineffective because of resistance
the coccidians have developed. They are used for prevention.

*Other drugs:* There are many other anticoccidial drugs in various chemical
classes with various modes of action. Examples are Nicarb® (nicarbizone) and
Clinicox®.

These trends are prompting an increasing number of poultry producers to
search for alternative methods of disease control, such as vaccination, better
quality nutrition, herbal medicines and other management changes.