

Review on Bovine *Cryptosporidiosis*, its Public Health Importance and Economic Impacts

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Abstract: *Cryptosporidiosis* is among the most important diseases of young ruminant livestock particularly, neonatal calves. It is caused by a monoxenous, unicellular, microscopic, apicomplexan protozoan parasite which is considered to be a significant zoonotic disease throughout the world. The major public health and economic important species in bovine is *Cryptosporidium parvum*. Transmission of the disease is through direct or indirect contact with feces of infected animals or humans while a contaminated food and water are sources of infection. Prevalence of bovine *Cryptosporidiosis* ranges from 6.25 to 39.65% in different parts of the world and 2.3 to 27.8% in Ethiopia as well. Diagnosis of *Cryptosporidiosis* is mostly based on detection of Oocysts from fecal sample since species identification depends on molecular techniques. In this paper, current status of bovine *Cryptosporidiosis*, zoonotic implication, economic and production impacts are brought up and current status of the disease in different countries including Ethiopia are reviewed. As the disease is an emerging global zoonotic infection, further epidemiological and molecular study, collaboration between veterinarian and physician is essential to reduce the burden of disease.

Key words: Calves • *Cryptosporidium* • Diarrhea • *Parvum* • Prevalence • Zoonotic

INTRODUCTION

Cryptosporidiosis is one of the most common causes of gastrointestinal diseases in a wide spectrum of vertebrate hosts, including humans [1]. *Cryptosporidium* was first named and reported in 1907 by Ernest Edward Tyzzer who observed it in the stomachs of mice (peptic glands of laboratory mouse). He detected this parasite to be an extracellular species, which look like the coccidian and named as *C. muris*. Since then, over 30 species have been reported from domestic and wild animals [2]. *Cryptosporidium* get public health and veterinary attention in the 1980s as a result of its increasing impacts on human health and association with the recently depicted acquired AIDS [3].

Bovine *Cryptosporidiosis* caused by a monoxenous, unicellular, microscopic, apicomplexan protozoan parasite (Members of *Cryptosporidium* spp.) Commonly, *C. parvum* and *C. andersoni* has been reported in cattle

all over the world [4]. However, *C. Parvum* was reported to be one of the major zoonotic species which adapt and develop in about 155 species of mammals in addition to many different hosts [5]. The pathogen has a direct life cycle and can develop and multiply in the GIT epithelial cells of infected animals [6]. Different reviews show that majority of the animals between 1-6 months of age were found to have *Cryptosporidiosis* caused by *C. parvum*, compared to those above six months and one year of age [7]. This could be due to the fact that the immature immune system of young calves [8].

Commonly, animals and human acquire infection when they consume food and drink containing Oocysts of these protozoa which are tolerant to several chemicals and disinfectants as well as chlorine which is frequently used to treat in drinking water, water parks and swimming pools [9]. Infected animals may suffer from severe anorexia, profuse watery diarrhea, and dehydration which may result in poor growth rate and high mortality [6].

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Cryptosporidiosis is common in young children, particularly in those under age 5 years, but the disease can also affect healthy people of any age [10]. However, in different regions; most clinical problems are recognized as a major concern, as a result of transmission of the infection through inhalation and increasing cases of HIV/AIDS, immuno-compromised individuals and children particularly, in those under age 5 years [11].

Reducing burden of the disease is challenging as a consequence of environmentally stable *Oocysts*, low infective dose and high levels of excreted sporulated *Oocysts*, transmission of infection is very quickly through direct and indirect ways, the *Oocysts* are resistant to many disinfectants, the only drug currently licensed for treatment of the disease by (FDA) is restricted to human [12].

Various reports indicated prevalence of bovine *Cryptosporidiosis* ranges from 6.25 to 39.65% in different parts of the world [8]. Moreover in Ethiopia, the prevalence ranges from 2.3 to 27.8% and influenced by various factors such as age, hygiene, colostrum feeding, season, management practices, feed and water sources, and climate conditions of the area [8, 13, 14]. Prevalence of bovine *Cryptosporidiosis* is higher in less developed and developing countries where people are lacking of basic infrastructure or essential facilities to avoid food and drinking water contaminated by infectious *Oocysts* in feces and hence, the disease may have severe short and long-term impacts on human specially in children and immuno-compromised persons and animals' (Reduced feed conversion and production efficiency as well as losses of animals due to death) [15].

Therefore, the objective of this seminar is to review the available literature on contemporary understanding of bovine *Cryptosporidiosis* with particular emphasis on its, public health importance, economic impacts and long-term impacts on animal's production.

Historical Background of Bovine *Cryptosporidium*:

Cryptosporidium was first named and reported in 1907 by Ernest Edward Tyzzer who observed it in the stomachs of mice (Peptic glands of laboratory mouse). He detected this parasite to be an extracellular species, which look like the *Coccidian* and named as *C. muris*. Since then other new over 30 species have been reported from domestic and wild animals, humans, birds, fish and reptiles but, *C. bovis* has been described in recent times [2].

The health discipline was not reported the disease for about 75 years, then reported by Mathew *et al.* [16] reported *Cryptosporidium* in calves and Meisel *et al.* [17] reported the first human *Cryptosporidium*, consequently

this two reports are presented most important motivation to veterinary and medical society and then, directed to a great deal on investigation effort. Moreover, *Cryptosporidium* get public health and veterinary meditation in the 1980s as a result of its increasing impacts on human health and association with the recently depicted acquired AIDS [3]. Today *Cryptosporidiosis* is progressively inviting attention as an emerging zoonotic disease of great public health importance due to its dominant involvement in worldwide particularly, in developing countries with poor sanitary conditions [9].

Etiology and Taxonomy: *Cryptosporidium* species was classified under the family *Cryptosporidiidae*, sub-order *Eimeriorina*, order *Eucoccidiorida*, sub-class *Coccidiasina*, class *Sporozoasida*, phylum *Apicomplexa* [18]. At this time 18 names are associated with individual species and 26 species are basically considered as valid on the basis of different *Oocyst* site of invasion, morphology, genetic variation and vertebrate class specificity Bamaiyi and Redhuan [19]. Among described species of *Cryptosporidium* the most species infecting animals and man includes *C. andersoni*, *C. bovis*, *C. canis*, *C. felis*, *C. hominis*, *C. meleagridis*, *C. molnari*, *C. parvum*, *C. scophthalmi*, *C. scrofarum*, *C. suis* and *C. xiaoi*. Moreover, four species of *Cryptosporidium* are commonly found in cattle; *C. parvum*, *C. bovis*, *C. andersoni* and *C. ryanae* but only *C. parvum* is associated with clinical disease in neonatal calves (> 6 weeks), with older animals showing asymptomatic shedding of *Oocysts* [6]. The most current species from cattle with probable global distribution is *C. bovis*, which earlier known as "bovine B genotype" and a deer-like genotype? were recognized [20]. The list of confirmed *Cryptosporidium* spp. based on, biological, and molecular, morphological data of 2014 is shown in Table 1.

Life Cycle and Morphology: Members of the genus *Cryptosporidium* complete all developmental stages in a single host (A *monoxenous* organism) which can be divided into an asexual and sexual [21]. Frequently, animals and humans infected next to consumption of food and drink containing *Cryptosporidium Oocysts* that can excyst in the GIT, release four motile and infective *Sporozoites* through a suture in the *Oocyst* wall (Fig. 1A). The incident of *Excystation* can be provoked by low pH in the GIT and body temperature directly, but other environmental cause may include bile salts, CO₂ and pancreatic enzymes [22].

Table 1: Validated species of *Cryptosporidium*

Species of <i>Cryptosporidium</i>	Major hosts	Zoonotic status
<i>C. andersoni</i>	Cattle	Yes
<i>C. baileyi</i>	Birds	No
<i>C. bovis</i>	Cattle	Yes
<i>C. canis</i>	Dogs	Yes
<i>C. cuniculus</i>	Rabbits	Yes
<i>C. erinacei</i>	Hedgehogs and horses	Yes
<i>C. fayeri</i>	Marsupials	Yes
<i>C. felis</i>	Cats	Yes
<i>C. galli</i>	Birds	No
<i>C. hominis</i>	Humans	Most common in humans
<i>C. meleagridis</i>	Humans and birds	Yes
<i>C. molnari</i>	Fish	No
<i>C. muris</i>	Rodents	Yes
<i>C. parvum</i>	Ruminants	Yes
<i>C. ryanae</i>	Cattle	No
<i>C. scrofarum</i>	Pigs	Yes
<i>C. suis</i>	Pigs	Yes
<i>C. tyzzeri</i>	Rodents	Yes
<i>C. ubiquitum</i>	Primates, ruminants, and rodents	Yes
<i>C. viatorum</i>	Humans	Less common in humans
<i>C. xiaoi</i>	Sheep and goats	Yes

Source: Bamaiyi and Redhuan [19]

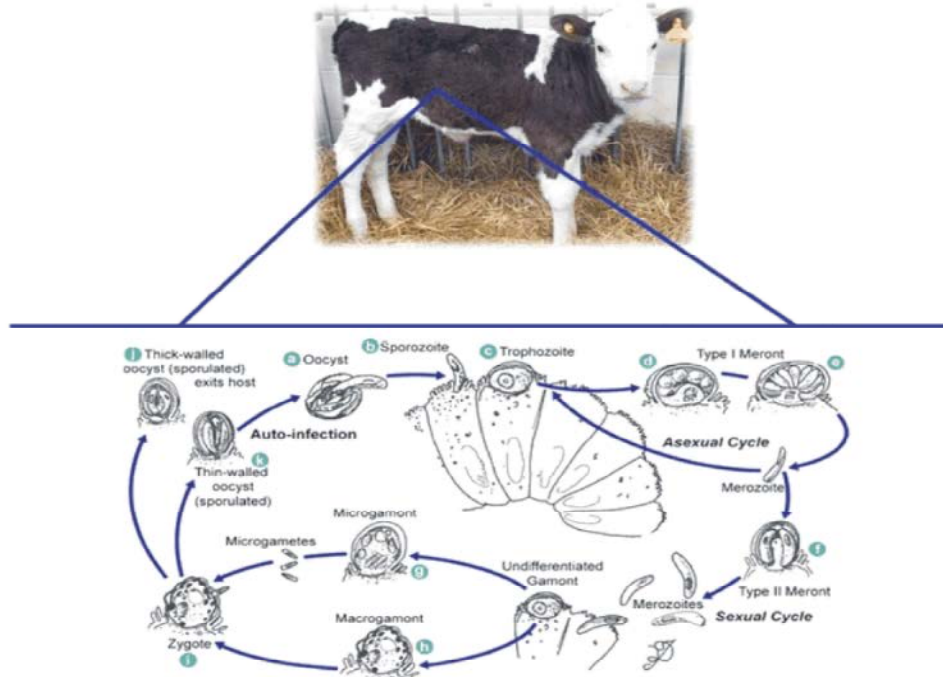


Fig. 1: Life cycle of *Cryptosporidium*

Source: Center of disease control and prevention [23]

The adherence of *C. parvum* sporozoites to the epithelial cells of the ileum predominantly, at the ileocecal junction (Fig. 1B). Succeeding attachment, the Sporozoites is encapsulated by a parasite modified host membrane to form a *Parasitophorous vacuole*; a structure is distinct in that it remains extracytoplasmic yet is

considered intracellular as it maintains its position within the host derived *Parasitophorous vacuole* membrane on top of epithelial cells. The feeder organelle make possible to obtain all necessary nutrients from the host while still being sheltered from the host defensive gut conditions and immune response (Fig. 1).

Next to the growth of the feeder organelle the sporozoite itself turn into spherical shape and forms a *Trophozoite* (Fig. 1C), which undergoes cell divisions resulting in 8 *merozoites* within a type I *meront* (Fig. 1D; E). These *merozoites* can re-infect the epithelium and form either a type I *meront*, effectively rising the infection, or a type II *meront*, ordained for sexual reproduction (Fig. 1F). The *merozoites* derived from type II *meronts* re-infect the epithelium and differentiate into either *macrogamonts* (Fig. 1H) or *microgamonts* (Fig. 1G).

The *Microgametes* are released and fertilize a *Macrogamont* resulting in the only diploid stage of development, producing a *zygote* (Fig. 1I). The diploid *Zygote* undergoes a process similar to *Meiosis* and forms either a thin or thick walled *Oocyst* (Fig. 1K). The previous (thin wall) *Sporozoites* excysts in the gut lumen and re-infects the host, while the thick walled excyst in the environment through feces (Fig. 1J) [24]. The auto-infection capacity of the parasite obtained from thin-walled *Oocyst*, which is one of the reasons why the *Cryptosporidium* parasite is so conquering. While the parasite produces many new *Oocysts* in a moderately short time we can explain as auto-infection [6].

Epidemiology

Geographic Distribution: Bovine *Cryptosporidiosis* has been recognized as an emerging zoonotic threat worldwide [7]. Various reports indicated that the prevalence of *Cryptosporidiosis* ranges from 6.25 to 39.65% in cattle in different parts of the world [8]. However, the prevalence of *C. parvum* infection varies between countries, design of the studies and detection methods used. For instance, according Wells [25] *C. parvum* prevalence rates in pre-weaned calves in the UK range from 28.0 to 80.0%. Studies from other parts of the world had reported prevalence of *C. parvum* in pre-weaned calves from 3.4 to 96.6% [4]. Prevalence of bovine *Cryptosporidiosis* from different parts of the country is mentioned in (Table 2).

Table 2: Prevalence of *Cryptosporidiosis* in different parts of the country

Place of study	Prevalence (%)	References
Canada	18.02	Thivierge <i>et al.</i> [26]
USA	21.2	Becker <i>et al.</i> [27]
Australia	23.8	Kvac <i>et al.</i> [28]
In New Zealand	86.4	Garcia <i>et al.</i> [29]
Bangladesh	77	Korpe <i>et al.</i> [30]
India	11.8	Khan <i>et al.</i> [31]
Iraq	33.83	Rahi <i>et al.</i> [32]
Kuwait	41.4	Iqbal <i>et al.</i> [33]
Tajikistan	63.1	Matthys <i>et al.</i> [34]
UAE	19.4	El-Bakri <i>et al.</i> [35]
Yemen	43.4	Al-Shamiri <i>et al.</i> [36]

Modes of Transmission and sources of infection

Commonly, human and animals usually get infection when they consume food and drink containing *Oocysts* that contain four *Sporozoites* within this protozoan. As a result transmission of the disease can be from animal to human (Zoonotic transmission) and human to human or animal to animal (*Anthroponotic*) [37]. Person to person spread is well described, especially in families and in outbreak settings, including institutions such as day care centers and hospitals [10].

Commonly direct and indirect routes of transmission of *Cryptosporidium* have been recognized. The direct transmission associated with a fecal-oral route by accidental ingestion of the *Cryptosporidium* *Oocysts* excreted from feces of infected host [9, 38]. This type of transmission usually emerges in swimming pools, water parks, day care center, hospital, and during anal sexual contact with human feces and this process is frequently raised by sexual intercourse behavior of men who have sex with men through fecal-oral route [39]. Moreover, the direct transmission can occur through direct exposure to infected animals, for example animal health students or animal researchers are infected by direct contact with infected calves [38].

However, occurrence of indirect transmission, can be by means of cross-contamination of food-stuff, food materials, drinking water, and many fomites such as clothes and footwear used in livestock farm or wildlife park which have been exposed with the feces of an infected human or animal [40]. *Cryptosporidiosis* can infect and live in epithelial surfaces of the intestine in wide range of vertebrate animals including humans and passed from feces or stool, subsequently, contaminate the soil and water sources; pond, river, wastewater, sewage or slurry, even many water containers especially insufficiently treated public water supplies. An additional mode of transmission, via the inhalation of *Oocysts*, was reported for immuno-compromised patients and children [11]. Seasonal variation particularly, high rate of rainfall and flooding event can extremely influence the transmission and distribution of the disease [41].

About 60% of *Cryptosporidiosis* was reported as protozoan parasites of food and waterborne disease outbreak worldwide during 2004 to 2010 years [40]. For example, from 2009 to 2017, public health officials from many countries voluntarily reported to CDC 444 *Cryptosporidiosis* outbreaks, among all 444 outbreaks, 65 (14.6%) were associated with contact with cattle, resulting in 549 cases; 57 (12.8%) were associated with contact with infected persons in child care settings, resulting in 418 cases. Among the 22 food borne

outbreaks, nine (40.9%) were associated with unpasteurized milk and four (18.2%) with unpasteurized apple cider. The source of infection and mode of transmission was unknown for 63 (14.2%) outbreaks; the predominant settings included private homes/residences (18; 28.6%) and (12; 19.0%) in child care [38, 42].

Risk Factors: The host immune capacity is the most important host factor affecting both the probability of an infection and the severity of the subsequent disease. However, occurrence of *Cryptosporidiosis* in the cattle and humans can be determined several factors such as age, colostrums feeding, diarrheic and non-diarrheic, hygiene conditions, management practices, feed and water sources, sewage water management, drinking or using untreated water, climate conditions, contact with suspected animal or human and poor economic status of the families may play a key role in the current prevalence of bovine *Cryptosporidiosis* [8, 42].

Among the species which infects the small intestine of weaned calves' *Cryptosporidium bovis* and *C. ryanae* often have not associated with clinical disease in any age group of cattle. *Cryptosporidium andersoni* is more frequently found in adult cattle than younger animals and infects the abomasums [43].

Clinical Signs

Clinical Signs in Cattle: Although the disease have occasionally been reported in adult animals, the severity of the cases is common in neonatal calves specially, enteritis is usually seen in 1-3 week old calves, in general infected animals with *C. parvum* may suffer from profuse watery diarrhea, inappetence, lethargy, dullness and dehydration as well in some cases death can occur [6]. Affected calves do not respond to antibiotic therapy and in more severe cases, dehydration and cardiovascular collapse lead to mortality [44]. After ingestion of infective Oocysts frequently, diarrhea starts approximately 3-4 days and lasts for about 1-2 weeks or most clinical cases are self-limiting within 1-2 weeks and Oocyst shedding not constantly related with diarrhea but depends on initial face dose and occurs between 4-12 days post-infection [45]. A few observational studies found that cattle infected with *C. andersoni* shows reduced in body weight and milk yield in adult cows [46].

Clinical Signs in Human: *Cryptosporidiosis* is common in young children, particularly in those under age 5 years, but the disease can also affect healthy people of any age. In different regions; most clinical problems are recognized

as a major concern as a result of transmission of the infection through inhalation and increasing cases of immuno-compromised individuals and children. In recent years *Cryptosporidiosis* has been found to not only affect the GIT tract, but also cause respiratory symptoms in human [11].

Cryptosporidiosis causes severe profuse watery diarrhea, dehydration which may result in poor growth rate and high mortality in children [38]. According Pumphuntu and Piratae [9] stated, *Cryptosporidiosis* is a long-lasting debilitating diarrheal infection which is usually acute and self-limiting in immune competent individuals at the same time can be life threatening to the immuno-compromised person, especially in HIV/AIDS and patients who received immunosuppressive drugs. In addition, *Cryptosporidium* species have been isolated from HIV/AIDS cases with the prevalence at 19-34% from 1996 to 2009 in Thailand [47].

Pathogenesis: The Oocysts are ovoid or spherical and measure 5 to 6 micrometers across. When in flotation preparations they appear highly retractile. The oocyst contains up to 4 sporozoites that are bow-shaped attaches [48]. As few as 2 to 10 Oocysts can initiate an infection [49]. The parasite is located in the brush border of the epithelial cells of the small intestine [50]. They are mainly located in the jejunum. When the sporozoites attach the epithelial cells' membrane envelops them. Thus, they are "intracellular but extracytoplasmic" [51].

The parasite can cause damage to the microvilli where it attaches. Among *Cryptosporidium* spp. which infects bovine's *C. andersoni* inhabits the digestive glands of the abomasums and infects the microvillus border of the gastrointestinal epithelium in adult cattle and post weaned calves [43, 48]. The infected host excretes the most Oocysts during the first week [51]. Oocysts can be excreted for weeks after the diarrhea subsides from infections by *C. parvum* [11]. The immune system reduces the formation of Type 1 merozoites as well as the number of thin-walled Oocysts [51]. This helps prevent autoinfection. B cells do not help with the initial response or the fight to eliminate the parasite [49].

Diagnosis: The symptoms of *Cryptosporidiosis* are not pathognomonic therefore; laboratory verification is required to confirm the diagnosis. Detection is made conventionally by microscopy after staining fecal smears with Modified Ziehl-Neelsen or Auromine phenol methods for detection of round, sporulated Oocysts of

4 to 5 μm in size [42]. In different parts of the world, this technique has been widely in use for diagnosis of *Cryptosporidiosis* in animals. However, Antigenic based simple and rapid chromatographic lateral flow immunoassay has got more efficiency for detection of *C. parvum* from buffalo and cross bred cattle calves as compared to modified Ziehl-Neelsen staining [52].

The immunological approaches like direct immune-fluorescence, enzyme linked immunosorbent assay and immuno-chromatography for the detection of *Cryptosporidium oocysts* are useful but inherit the limitation of species identification [53]. In order that molecular methods used to identify *Cryptosporidium* species/genotypes in human and non-human hosts [54]. Further, currently polymerase chain reaction has transformed the field of diagnosis in parasitological study of the parasite by the means of *Cryptosporidium* 18s rRNA gene loci, 20 replicas of which are exist in all *Cryptosporidium oocyst*, provide proper targets for separation of the species. Therefore, different workers from different parts of the world reported the advantages of PCR for the detection of *Cryptosporidium* in clinical and environmental samples. The most well described advantages PCR includes facilitate analyzes of huge numbers of samples at one time, high sensitivity, ease of use, relatively low cost, ability to differentiate species and strain types [9, 18].

Treatment: Although several drugs and drug combinations such as rifaximin, azithromycin, and paromomycin have been tried against *Cryptosporidiosis* unsatisfactory and the same results were observed [19]. However currently, few products are approved in the UK for the treatment or prevention of *Cryptosporidiosis* in livestock or humans nevertheless, they are not very effective and in most cases will only reduce the duration of shedding and have little or no effect in immuno-compromised patients [6].

Treatment in Cattle: The single qualified treatment for *Cryptosporidiosis* in calves is Halofuginonelactate. Even though, mechanism of action of the drug is unidentified; it is thought to affect the *Sporozoite* and *Merozoite* stage of the parasite [55]. In calves prevention and treatment of *Cryptosporidiosis* can be made by this drug but cannot be used in animals have shown signs of diarrhea for > 24 hour, as a prophylactic measure the drug should be given within 48 hour of birth and as a therapeutic agent, within 24 h of the onset of symptoms [6]. Nevertheless, treatment with halofuginone lactate

does not completely prevent or cure disease but can reduce Oocyst shedding and the duration of diarrhea [44].

Moreover, according Viu *et al.* [56] stated, several other chemotherapeutic agents experimentally infected calves treated with 100 mg/kg paromomycin twice daily for 11 days shed significantly less Oocyst than untreated calves. Significant reductions in severity of diarrhea were observed in treated calves. Yet, Oocysts were detected in fecal samples from all calves but the shedding of Oocysts in treated calves was significantly later than in untreated calves [57]. In addition, a few *Coccidiostats*, such as decoquinate have been tested against *Cryptosporidium* in neonatal calves with limited or no reduction in Oocyst [58]. However, more recent studies which have evaluated novel bumped kinase inhibitors (BKIs) as a potential treatment for bovine *Cryptosporidiosis* showed that experimentally infected calves treated with BKIs had a reduction in Oocyst shedding when compared with untreated controls [59].

Treatment in Humans: The only anti *Cryptosporidial* agent which has been approved for the treatment of *Cryptosporidiosis* in humans by the US Food and drug Administration is Nitazoxanide. This is the most effective drugs for treating patients who infected with *Cryptosporidium* species but it is not commercially available or not yet widely used at the present time [60]. Moreover, the drug is not effective with less immune response of the host in order that it cannot be used effectively in immuno-compromised patients or animals [61]. There are few reports that studied the effect of nitazoxanide against clinical infections of *Cryptosporidium* in animals which verified that nitazoxanide could decrease *Cryptosporidium* Oocyst excretion. However, presently it is not approved for use in cattle [9].

Prevention and Control Measures of Bovine *Cryptosporidiosis*: Reducing the disease burden of this pathogen is challenging as a consequence of environmentally stable Oocysts, low infective dose and high levels of excreted sporulated Oocysts, the Oocysts are resistant to many disinfectants and infection may be transmitted to a group of susceptible hosts very quickly through direct and indirect transmission, the only drug currently licensed for treatment of the disease by (FDA) is restricted to human [12].

Prevention and Control in Livestock's: Since the Oocysts of *C. parvum* are very difficult to eliminate from

the environment, the preventive measures that reduce transmission of bovine *Cryptosporidiosis* are effective farm management practices or frustrating to reduce fundamental risk factors by prevention of the environmental contamination through, regular removal of faeces and contaminated bedding from calving areas and calf houses, combined with steam-cleaning and disinfection with a suitable disinfectant such as Hydrogen Peroxide based disinfectants can help to reduce environmental build up [6]. In addition, limiting the amount of animal density in the farms or stocks, minimizing a contact between personnel, calves and other herds, keeping young animals or susceptible hosts that have high risk of infection separated from adult animals, and keeping a short calving period of animals which may decrease the opportunities for *Cryptosporidium spp.* to spread within animal herds [62].

At present, there are no commercially available vaccines to prevent *Cryptosporidiosis* in either farm livestock or humans. However, several attempts to develop such vaccine have been made, some of which were partially successful under experimental conditions. Calves that were immunized with killed (γ -irradiated or lyophilized) *C. parvum* Oocysts showed reduced Oocyst shedding and diarrhea when compared to non-immunized calves [63]. Since, *Cryptosporidiosis* is frequently arise in the first week of life, trying to immunize the neonatal calves is doubtful to be successful because this will not give enough time to persuade a important immune reply prior to infection hence, immunizing of pregnant cows can produce antibodies against *Cryptosporidium* which can be passed via colostrums to their calves and then as a result, calves receiving colostrums from cows vaccinated in this method with recombinant *C. parvum* were reported to protect against diarrhea and also had reduced Oocyst shedding, while compared to those calves that received colostrums from non-vaccinated cows [64].

Prevention and Control in Humans: The best applicable strategy to prevent transmission of *Cryptosporidium* species between humans are a practice of good personal hygiene, including hand washing before preparing and consuming food, after using a toilet and contacting with diarrhea patients (Children) and some animals or livestock's, raw food and water must be appropriately cleaned, washed, heated, cooked, or boiled before consumption and drinking, respectively [9].

More than that, patients who have diarrhea symptom should understand not to swim in a public swimming pool, public water park, or river for preventing a

transmission to others and people who swim in a swimming pool, water park, or river should recognize a potential risk of disease infection if they swallow the water [65].

Moreover, in human living areas, livestock husbandry, and their drinking water, the destruction of *Cryptosporidium* oocysts can be managed by heat or chemical disinfection such as hydrogen peroxide, sterilization processes using steam, ethylene oxide, chlorine dioxide, ozone (O₃) and ultraviolet light (UV light) which have been used to sterilize drinking water, but some of the disinfectants are not commonly practical procedure. However, all of the chemical disinfection can be used to prevent and control the occurrence of *Cryptosporidiosis* and to reduce mortality and morbidity rate in both infected in both human and animals [66].

Public Health Importance's of Bovine *Cryptosporidiosis*:

Bovine *Cryptosporidiosis* is progressively inviting attention as an emerging zoonotic disease of great public health importance due to its dominant involvement in worldwide mainly, in developing countries with limited infrastructure and poor sanitary conditions [67]. Globally, the *Cryptosporidium* infection is estimated and accountable for about 30-50% of deaths in young individuals and found to be the second highest reason of diarrhea and deaths in children after rotavirus [38]. *Cryptosporidium* spp. that infects immuno-competent and immuno-compromised humans includes, *C. andersoni*, *C. hominis*, *C. parvum*, *C. meleagridis*, *C. felis*, *C. canis*, *C. muris* and *C. suis* but, the majority human cases are caused by either the zoonotic species *C. parvum* or the human adapted species *C. hominis*. Collectively these two species account for > 90% of human infections worldwide [68].

Frequently people at risk of exposure for *Cryptosporidiosis* are people who swim regularly in pools with insufficient sanitation (Most *Cryptosporidium* Oocysts are chlorine resistant), child-care workers, parents of infected children, people caring for other people with *Cryptosporidiosis* backpackers, and campers who drink unfiltered, untreated water, petting farms and open farms with public access, including swimmers, who swallow water from contaminated sources, people handling infected cattle, people exposed to human feces [69]. In addition outbreaks associated with petting zoos or farm and veterinary students which exposed to Zoonotic transmissions while they are studding were fine reported [70, 71].

In immune deficient individuals, the illness may cause death as a result of prolonged diarrhea, which does not respond to antibiotic treatment. Nevertheless, infection of immuno-competent people with *Cryptosporidium* has a propensity to cause self-limiting diarrhea [38]. Moreover, children less than four years of age and the elderly are extremely susceptible to disease but, young adults are less susceptible [68]. A child tends to acquire the infection shortly after, or during weaning [72]. According Liu *et al.* [73] stated, in 2010, it was confirmed that diarrhea accounted for 10.5% of the 7.6 million deaths of children under the age of 5 years hence, diarrhea caused by *Cryptosporidium* can result in a large number of deaths.

A seasonal incidence of infection and zoonotic transmission is often observed, possibly corresponding to rainfall peak. For example according Chalmers *et al.* [74] stated, in UK, zoonotic transmission of *C. parvum* peaks in the spring months and is thought to be related to springtime calving and lambing, and an increase in people participate in farming at this time of year. However, cases of *Cryptosporidiosis* decreased in the spring of 2001 during the foot and mouth disease outbreak, almost certainly due to restriction of farm animal movement and reductions in the number of young farm animals [75].

Economic and Long-Term Impacts of Bovine *Cryptosporidiosis*: The economic costs, incurred by bovine *Cryptosporidiosis* have not been inspected in detail. However, it comprises diverse costs which includes, costs incurred in management of enteritis, physician's time, laboratory costs, drug costs, hospitalization and nursing costs, transportation costs, home care costs and other costs involves government cost which includes disease investigation costs, costs spent on controlling outbreaks, cost of cleanup. A study on economic losses due to calf enteritis in Scottish beef herds, examined 212 calf diarrhea outbreaks during veterinary practices, estimated that the typical cost associated with management of disease was a minimum of £34 per calf affected, without labor [76]. Taking into consideration in some case, it is probable that if almost all calves within a herd may suffer from diarrhea this cost is insignificant.

A cohort study in infants younger than 12 months in Peru, Bangladesh and Kenya which were infected with *Cryptosporidiosis* suggested that direct treatment costs per symptomatic *Cryptosporidiosis* occurrence were

\$59.01, \$23.32, and (\$7.62), Kenya, Peru and Bangladesh respectively. In addition the study shows total annual economic impacts for the 0-11 month cohorts were (\$41.5M; range \$0.88-\$599.3M) in Peru, (\$37.4M; range \$1.6-\$804.5M) in Kenya and (\$9.6M, range \$0.28-\$91.5M) in Bangladesh [77]. Suppose, if alike financial losses in bovine affected by *Cryptosporidium* also occurs, this may lead to significant economic losses to the farmer as well as country.

There is scarce of data on study looking at the long term effects of *C. parvum* infection in calves but infection can impair growth rates in calves and children as well, it may hamper development of heifers which leads to reduction in the productivity and food supply in veal producer. Moreover, a cohort study of slum-dwelling in Bangladesh children which were infected with *Cryptosporidium* spp. showed that children that had suffered from multiple bouts of *Cryptosporidiosis* in the first 2 years of life were much lighter and shorter than children who had only a single occurrence at 2 years of age [30].

Additionally, study in Australia showed that lambs which were positive for *Cryptosporidium* were up to 1.65 kg lighter than uninfected lambs at slaughter [30]. A following study involving > 1000 lambs from eight farms in Australia reported that shedding of *C. parvum* pre-slaughter was associated with a lower carcass weight of up to 2.6 kg compared to lambs which did not shed *C. parvum* [78]. Accordingly, if comparable reduction on growth of calves affected by *Cryptosporidium* also occurs, this may show costly for farmers due to loss of income from lower carcass weights, treatment cost or additional feed costs required to get calves to market weight.

Status of the Disease in Ethiopia: According to various reports indication, prevalence of *Cryptosporidiosis* ranges from 6.25 to 39.65% in cattle in different parts of the world [8]. However, in Ethiopia even though, there was over 50 million cattle are raised under a variety of agro-ecological zones, a few research works have been done on bovine *Cryptosporidiosis* in different parts of the country. A cross-sectional which was undertaken on 40 dairy farms in central Ethiopia was reported 17.6% prevalence of the *Cryptosporidium* infection [13]. An additional cross sectional study in Haramaya, eastern Ethiopia estimated the prevalence of *Cryptosporidiosis* in calves 27.8% (The study basically not only in calves) [79].

Moreover, recently Ayele *et al.* [8] reported, *Cryptosporidium* infection is common in northwest of Ethiopia, out of the 360 examined calves, *Cryptosporidium* Oocysts were recorded in 67 (18.6%) calves (Its prevalence found to be 18.6%) and risk factors such as age, hygiene, fecal consistency, feed source, water source and contact with other domestic animals were significantly affected the occurrence of *Cryptosporidium* infection. Molecular characterization of *Cryptosporidium* isolates from nine regions and central part of the country confirmed the existence of four species: *C. parvum*, *C. andersoni*, *C. bovis* and *C. ryanae* in the Ethiopian cattle [13]. Thus, depend on existing report bovine *Cryptosporidiosis* prevalence ranges from 2.3 to 27.8% in Ethiopia [8, 13]. Status of bovine *Cryptosporidiosis* from different parts of Ethiopia is mentioned in (Table 3).

CONCLUSION AND RECOMMENDATIONS

Bovine *Cryptosporidiosis* is an emerging global zoonotic infection that is still scantily understood and largely neglected. The occurrences of infection may be due to the lack of appropriate personal and environmental hygiene, poor farm management practices and lack of awareness within community. Animals that are severely affected die due to mal-absorption and dehydration hence, causing severe economic losses. However, the exact economic losses and the long term effects of bovine *Cryptosporidiosis* have not been inspected in detail. *C. parvum* appears to be the most important *Cryptosporidium* species because of its widespread geographical distribution, the number of animal species affected and its zoonotic potential. Currently, available treatments are unsatisfactory and there are no vaccines available to prevent *Cryptosporidiosis* in either farm livestock or humans.

Therefore, based on the above conclusion the following recommendations are suggested:

- As the disease is an emerging global zoonotic, collaboration between veterinarian and physician is essential to reduce the burden of disease.
- Creating community awareness, effective farm management practices and appropriate personal as well as environmental sanitation is obligatory for the control and prevention of infection in either livestock or humans.

- Further studies are required to verify the economic and production impacts of bovine *Cryptosporidiosis*.
- It is necessary to carry out further epidemiological and molecular study of the diseases so that novel successful treatment and vaccine can be developed.

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