Vol. 12(4), pp. 183-194, October-December 2021
DOI: 10.5897/IJLP2021.0786
Article Number: 4C5E20F68398
ISSN 2141-2448

http://www.academicjournals.org/IJLP

ACADEMIC JOURNALS
expand your knowledge

International Journal of Livestock Production

Full Length Research Paper

Economic loss associated with bovine campylobacteriosis in selected districts of Bangladesh

Nazmul Hoque[1], Sk Shaheenur Islam[1], A. K. M. Ziaul Haque[1], Md. Mehedi Hossain[2] and S. M. Lutful Kabir[1*]

[1]Department of Microbiology and Hygiene, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.
[2]Krishi Gobeshona Foundation (KGF), Farmgate, Dhaka-1215, Bangladesh.

Received 2 August, 2021; Accepted 11 November, 2021

Bovine campylobacteriosis is considered to be common disease in farmed female cattle of Bangladesh with various effects on animal productivity. However, no economic impact assessment labeling the burden of this disease has been conducted. Secondary data combined with the primary data on different financial parameters of livestock goods and associated parameters collected through stakeholder interviews were utilized in economic impact assessment for a year in two cattle-dominant districts of Bangladesh. The study confirmed an annual estimated economic loss of this disease in farmed cattle was BDT (Bangladesh Taka) 1,282.26 million (95% CI: 1,120.41-1,448.00), Equiv. USD 15.09 million (95% CI: 13.18-17.04). The study has shown the highest economic loss due to restocking cost (BDT 703.89 million, 95% CI: 615.12-794.98) of heifer and cows. However, decreased milk production was evaluated as second position (BDT 395.25 million) between the loss categories. Among the districts, higher economic loss was estimated in Mymensingh district (BDT 935 million, 95% CI: 817.07-1059.17) than Dhaka due to the large number of cattle population. The study provides a detailed understanding of the impact of *Campylobacter* on livestock productivity that will support for formulating and implementing prevention and control strategies in high yielding farmed cattle of Bangladesh.

Key words: Bovine campylobacteriosis, *Campylobacter*, economic loss, farmed cattle, livestock productivity, Bangladesh.

INTRODUCTION

Bovine campylobacteriosis is an infection caused by the bacteria of the genus *Campylobacter*. These organisms are connected with number of disease conditions in cattle, especially related to reducing fertility in breeding cows and heifers, and diarrhea in the young animals. Moreover, these pathogens having zoonotic importance can cause diarrhea in humans, and are considered to be the primary cause of foodborne gastroenteritis in developed countries. These pathogens are connected with commonly occurring zoonoses in the European countries (EFSA and ECDC, 2018). The poultry is considered to be the main source of human infection.

*Corresponding author. E-mail: lkabir79@bau.edu.bd.

However, *Campylobacter* is also highly prevalent in ruminant species throughout the world. Therefore, there is a growing concern of transmission of these pathogens from ruminant animals to humans. The cattle are the second most important reservoir animals next to the broilers for *Campylobacter jejuni* infection in humans, and sheep are the main source of *Campylobacter coli* infections in humans (Sheppard et al., 2008; Roux et al., 2013).

Bovine genital campylobacteriosis (BGC) is a venereal disease of cattle (OIE, 2021a) caused by *Campylobacter fetus* Subsp. venerealis and *C. jejuni* are the most important species associated with the abortion and decreased fertility in cattle causing reduce calf crop percentage, late calving, or abortions/stillbirth (Seid, 2019; Irons et al., 2020). This disease has been included in the list of notifiable diseases of the World Organization for Animal Health (OIE), and is significant for the international trade of animals or animal products (OIE, 2021a). This disease has impact on socio-economic and zoonotic implications. A number of countries have successfully eradicated this disease; however, in many countries in the world especially in low and middle income countries (LMICs), this disease is still endemic (McDermott et al., 2013). In fact, this disease is more prevalent in the territories where the natural breeding program is usually practiced in cattle compared to the developed countries (More et al., 2017). However, the economic burden of this disease may vary due to affected animal type and husbandry pattern including the capacity of the national animal health services in different geographical locations (Mshelia et al., 2010). The loss related with the disease is directed to the elimination of non-productive animals by culling to enhance the profitability of a dairy farm (Seid, 2019). However, due to resource constraints, the control programs could not even be implemented in the low resource settings.

Because of limited active surveillance in Bangladesh, the actual burden of bovine campylobacteriosis is still unknown. However, the country is routinely notifying on the presence of BGC in cattle as per standards set by the OIE (2021b). A cross-sectional survey was conducted between July-December, 2020 in two districts (Dhaka and Mymensingh) of Bangladesh with an aim to estimate the prevalence, isolation, identification, and further characterization of *Campylobacter* spp. in farmed cattle. The study established an overall prevalence of *Campylobacter* spp. in dairy cattle 30.9% (Hoque et al., 2021). Above 15% of cattle of the national herd are crossbred high yielding stock in Bangladesh (Hamid et al., 2017), however, 100% crossbred cattle are being reared in the urban settings of Dhaka city corporation (DCC) area due to higher demand for cow's milk and meat (DLS, 2020b).

Since the indigenous cattle breed is less productive and unable to fulfill the country's demand of milk and meat, to mitigate such nascent demand, artificial insemination (AI) using exotic breed (predominantly Holstein Friesian) targeted to enhance productivity of indigenous cattle has been adopted since the last decades (NDDP, 2016). For this reason, the number of crossbred animal populations is increasing steadily in

Bangladesh, and ensures reorganization to the high density of cattle population as 145 large ruminants in km^2 area (WB, 2018). This change enhances the likelihood of the emergence of cattle adapted *Campylobacter* species like *C. jejuni* strains (Mourkas et al., 2020). The economic burden of *Campylobacter* spp. is mostly associated with livestock production losses in female cattle, viz. milk production (Akhtar et al., 1993), abortion (Silveira et al., 2018), infertility/decreased pregnancy (Silveira et al., 2018; Michi et al., 2016) along with other pertinent losses like the cost for veterinary health care facilities, cleaning and disinfection cost, and restocking cost (Seid, 2019). Infection is usually not measured until a reduced calving rate is noticed in a herd, while financial losses will be incurred over time (van Bergen et al., 2005). Bulls infected with *C. fetus* Sub.sp. *venerealis* do not associate with any clinical manifestations, deteriorate semen quality or even breeding capability (Seid, 2019; Clark, 1971; Skirrow, 1994), or gross genital anomalies (Bier et al., 1977). This disease is transmitted mostly by natural service; however, infection may also be transmitted by the semen of infected bulls during artificial insemination (AI) or by contaminated equipment (Modolo et al., 2000). Assessment of these losses is essential for the countries where a large number of livestock are kept (Azami and Zinsstag, 2018).

As a part of prevention and control activities, routine screening in breeding bulls of artificial insemination (AI) has been implemented at a limited scale. However, inadequate testing facilities have underestimated the true burden of bovine campylobacteriosis in low resource settings like Bangladesh (Michi et al., 2016). Bangladesh has 24.2 million cattle, 1.5 million buffaloes, and 26.0 million goats. The contribution of livestock to the national economy was estimated as 1.43% for the year 2019-2020 and it is increasing at 3.04% annually. The country has fulfilled the demand of meat recently, and efforts are underway to optimize milk production (DLS, 2020b). So, the impact of the disease would also affect the suitability of meat production and food security.

Several studies have been conducted in different geographical locations of the world which have marginally estimated economic losses of bovine campylobacteriosis (Silveira et al., 2018; Jimenez et al., 2011; Hum et al., 1994), however, such study is yet to be conducted in Bangladesh. This is the first report to estimate the economic impact of *Campylobacter* in farmed cattle of Bangladesh. The objective of this study was to estimate economic losses incurred due to this disease in two study districts (Dhaka and Mymensingh) as promising cattle rearing areas. The finding of this study will help in formulating a strategic document towards taking prevention and control initiatives on bovine *Campylobacter* in farmed cattle as a proof-based decision-making option.

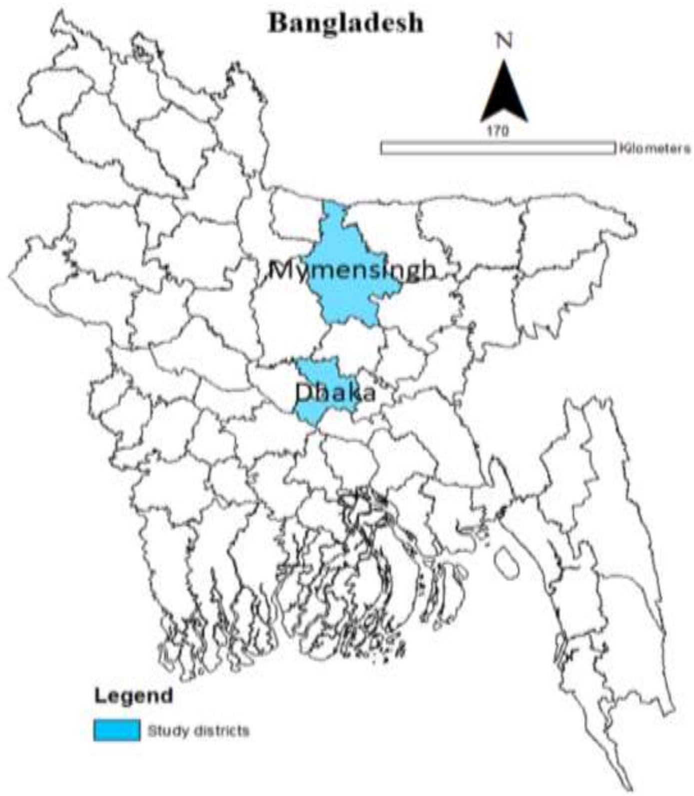

Figure 1. Map shows two districts (Dhaka and Mymensingh) in Bangladesh where economic impact of bovine campylobacteriosis was conducted.

MATERIALS AND METHODS

Ethical approval and informed consents

The research was approved by the Animal Welfare and Experimentation Ethical Committee (AWEEC) of Bangladesh Agricultural University (AWEEC/BAU/2019/45). The participants were adequately informed on the study. A verbal consent was obtained during field observation data collection as some of the participants could not read and write.

Study area and population

The study was carried out in two districts: Dhaka (23° 47′ 24″ N, 90° 18′ 0″ E), and Mymensingh (24° 38′ 3″ N, 90° 16′ 4″ E) of Bangladesh (Figure 1). Dhaka district is located in Dhaka division in the central part of the country, whereas, Mymenisngh district is located in Mymensingh division in the northern part of the country. These two districts are considered as part of the favorable cattle rearing zone of Bangladesh with more than 1 million heads of cattle (DLS, 2020a), of which approximately 15% are crossbred (Hamid et al., 2017). These crossbred cattle population was used as a study population for this economic loss assessment model.

Data used for economic loss assessment

The economic loss analysis used the data of different parameters collected from different sources, that is, primary and secondary (Figure 2). The list of questions and its corresponding data requirement for estimation of economic loss of *Campylobacter* in farmed cattle of selected districts (Dhaka and Mymensingh) of Bangladesh conducted between July - December 2020 were utilizedinitially in the process of data collection.

Secondary data

The study utilized the secondary data from multiple sources, viz: secondary data/published data from the peer review journal articles (n=8) and government document/unpublished data (n=2) from the government offices (Table 1).

Primary data

A field survey (face-to-face interview) was conducted with different stakeholders (farmers/ cattle handlers/farm manger) (n=75) from study districts (Table 2). A pre-tested semi-structured questionnaire was utilized for the field survey to gather data on body weight (cow and heifer), milk production/cow/day, price of a calf, a cow, price of milk/liter, price of beef/kg, treatment cost of a suspected *Campylobacter* infected animal (infertility/abortion/repeat breeding), restocking cost if required, where infertility, repeat breeding, or abortion in cow/heifers are present.

Further, the cost of different parameters of livestock goods (milk and meat), cost of different categories of animal (cow and calf) were validated through discussions with the relevant stakeholders [milk sellers (n=10),

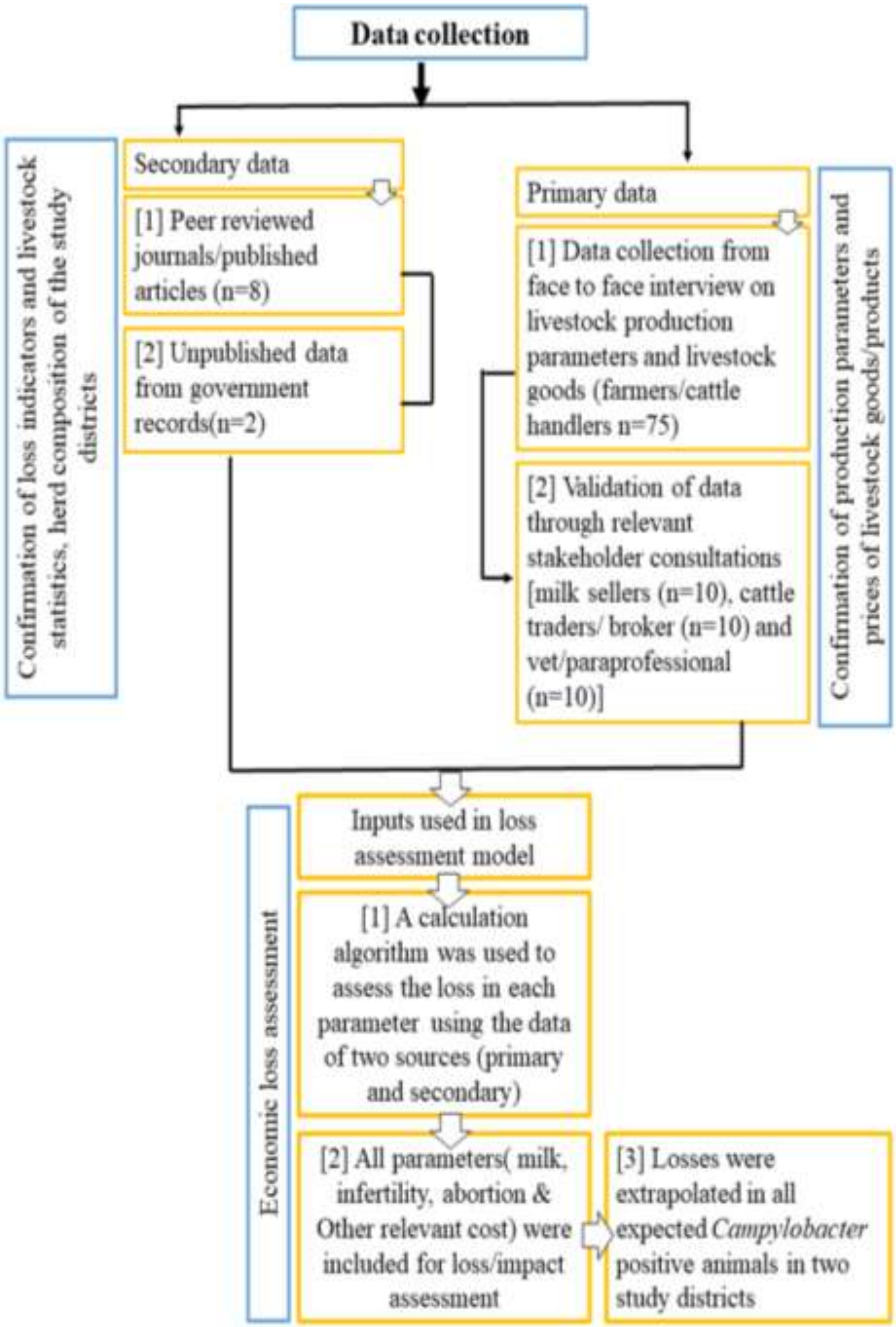

Figure 2. Layout of methodology that entails collection of data from different sources/stakeholders used in economic impact assessment model under this study**.**

cattle traders/broker (n=10), veterinarians and paraprofessionals (n=10)]. A verbal consent was obtained from each of the participant interviewed under this field survey.

Economic impact assessment model

At present, there are an estimated 24.2 million cattle in Bangladesh (DLS, 2020b), of which 15% of crossbred cattle are being kept predominantly in farming condition (Hamid et al., 2017). A prevalence study was conducted by Hoque et al. (2021) on 540 heads of dairy cattle in two study districts during April 2018 to May 2020. The data on prevalence rate generated through this study has been utilized in economic loss assessment model. A beta probability distribution was performed in this assessment to interpret the uncertainty level in expected number of *Campylobacter* spp. infected crossbred farmed cattle including financial loss at different parameters using Analysis ToolPak in Excel (Brown

Table 1. Secondary data used in the assessment of economic loss in farming cattle in two study districts.

Parameter	Data included in this study	Reference
Cattle population (heads)		
District: Dhaka:	226, 000	DLS (2020a)
Mymensingh:	923, 000	
Percentage of crossbred cattle in the national herd	15%	Hamid et al. (2017)
Percentage of crossbred cattle in DCC area	100%	DLS (2020a)
Prevalence of bovine *Campylobacter* in Dhaka and Mymensingh districts		
Dairy cows/heifers	30.9 (27-35)	Hoque et al. (2021)
Herd composition in two districts		
Proportion of milking cows in total female cattle	70%	Islam et al. (2020)
Proportion of pregnant cows/heifer in total crossbred cattle	50%	
Average lactation (days) length of a crossbred cow?	250 days	Hamid et al. (2017) and Das et al. (2003)
Type of losses		
Reduction of milk production in dairy cows	7%	Akhtar et al. (1993)
Gestation losses/abortion	20%	Silveira et al. (2018)
Reduction of pregnancy/infertility	20%	Silveira et al. (2018) and Michi et al. (2016]

Table 2. Factors used in the economic impact assessment. The data were collected and validated through field survey semi-structure interview with cattle traders/brokers, milk sellers, government and private veterinarians and paraprofessionals.

Parameter	Data collection method
Body weight a mature cow (average age ≥4 years): carcass weight approximately 60% of live weight	Field survey
Average milk production liter/cow	Field survey
Price of a 1 month old cow/bull calf	Field survey
Price of a mature cow (≥4 years)	Field survey
Price of 1 kg beef	Field survey
Price of 1 L milk	Field survey
Treatment cost due to *Campylobacter* infection (abortion, infertility)	Field survey
Restocking cost if an animal with infertility or abortion	Field survey

et al., 2001).

In this study, we calculated the losses relating to *Campylobacter* in farmed crossbred cattle for the study districts (Dhaka and Mymensingh) during July - December 2020. The study did not cover the indigenous cattle (Zebu) as these are reared mostly in the households. Fifteen percent (15%) crossbred animal displayed in the national herd (Hamid et al., 2017) was used for estimation numbers of crossbred cattle in two studied districts. However, 100% crossbred cattle being reared in the Dhaka city corporation area (DLS, 2020a) was taken under this study. In summary, 51,402 heads of crossbred cattle in Dhaka district, and 138,540 heads of crossbred cattle in Mymensingh district were confirmed (Table 3). The proportion of different categories of cattle, viz; milking cows, pregnant cows/ heifers was confirmed from a previous study (Islam et al., 2020) (Table 1). The data on prevalence rate of *Campylobacter* spp. with its probability distribution of an earlier research (Hoque et al., 2021) was generalized in the estimated whole crossbred cattle population of two districts. Thus, a total number of infected animals was obtained (Table 4). The losses reported in published articles in production parameters were used in the estimated infected animals of two study districts (Table 1). Finally, losses in livestock goods and the relevant costs were then converted into monetary figures (BDT: Bangladesh Taka) considering the market price for a single year.

The areas considered for economic loss assessment, includes: decrease milk production, infertility, and neonatal deaths including other pertinent costs (treatment, cleaning and sanitation, and restocking cost (if required). The study has evaluated the economic loss of *Campylobacter* as per the method described earlier (Zeng et al., 2019) with a minor adjustment stated in the following formula.

$$\text{Economic loss} = \boldsymbol{Dmip} + \boldsymbol{Dpg} + \boldsymbol{Ab} + \boldsymbol{Oth} \quad (1)$$

Where

Dmip: Cost for decreased milk production, [*Dmi*=number *Campylobacter* positive cows/heifers (Dhaka: 7942, Mymensingh: 21391) × 70% milking cows x milk production (most likely: 20 L)/cow x 250 days (average lactation length) x 7% reduction of milk production in infected cows x cost of 1-L milk (BDT 55)].

Table 3. Calculation of number of crossbred (farmed) cattle used in this study**.**

District/Upazila/municipality area	Number of cattle (indigenous and crossbred)	Number of crossbred cattle	Proportion of crossbred cattle	Data source
District: Dhaka	226,000			DLS (2020a)
Dhaka metropolitan area	-	20,590	100%	
Subdistricts/upazila: Dhamrai, Dohar, Keraniganj, Nowabganj and Savar		30,812	15%	Hamid et al. (2017)
Total crossbred cattle in Dhaka district		51,402		
Mymensingh (subdistricts/upazia: Bhaluka, Dhobaura, Fullbaria, Gaffargaon, Gauripur, Haluaghat, Iswarganj, Muktagacha, Sadar, Nandail, Phulpur, Trisal and Tarakanda)	923,000			DLS (2020a)
Total crossbred cattle in Mymensingh district		138,450	15%	Hamid et al. [2017)
Total number of crossbred farmed cattle in two districts		189, 852		

Table 4. List of the variable inputs captured through field interview data collection: prices of live animals and livestock goods (milk and meat) used for the estimation economic impact (amount in BDT) (n=75).

Parameters	Pert distribution		
	Most likely	Minimum	Maximum
Body weight of a mature cow (≥ 4 years): meat-60% of live weight(Kg)	200	180	380
Average milk production (liter/cow)	20	6	28
Price of a 1 month old cow/bull calf (BDT)	30,000	20,000	70,000
Price of a mature cow (≥4 years) in BDT	200,000	120,000	300,000
Price of 1 l milk in BDT	55	45	80
Price of 1 kg beef in BDT	600	550	620
Treatment cost/ infected animal (BDT)	500	200	1,000
Cleaning or disinfection cost/ infected animal (for abortion)	200	200	1,000
Price of new animal: heifer/cow (BDT)	180,000	120,000	300,000
Restocking cost of a new animal after adjustment with the carcass value of an infected animals	60,000	10,000	102,000

Dprg: the cost for decreased pregnancy, [*Dpg*= Number of positive mature cows/heifers (Dhaka: 7,942, Mymensingh: 21,391) x 50% non-pregnant cows/heifers x 20% infertility x cost for 1 month old calf (BDT 30,000)].

Ab: Cost for abortion in dairy cows, [*Ab*= Number of positive cows/heifers (Dhaka: 7,942, Mymensingh: 21,391) x 50% pregnant cows/ heifers x 20% gestation loss x cost for 1 month old calf (BDT 30,000)].

Oth**:** other costs, [*Oth*= applicable cost for veterinary health care in infected animals + cleaning/sanitation cost + restocking cost after adjustment with the carcass value (if needed)]. here, cost for veterinary health care = BDT 500/animal × 40% infected animal (total infected cows/heifers-Dhaka:7,942, Mymensingh:21,391) (20% decrease pregnancy + 20% abortion); Cleaning and sanitation cost: BDT 200/animal × 20% abortion (total infected cows/heifers-Dhaka: 7,942, Mymensingh: 21,391); Restocking cost = 40% (20% abortion and 20% infertility) cases (buying value of a new cow/heifer BDT 180,000 - carcass value of the present stock, 200 kg meat x BDT 600 =120,000)= BDT 60,000.

Data management and statistical analysis

Data collected via stakeholder interview from farms (n=75), include weight of a mature cow/heifer (≥ 3 years, average milk production (liter/cow/day), price of an one-month-old cow/bull calf, price of a mature cow/heifer (≥3 years), price of a 1 L of milk, treatment cost of a *Campylobacter* infected cattle, restocking cost of a cow/heifer with infertility or abortion produced in the probability distribution functions (most likely, lowest value, highest value) using ModelRisk (VOSE, 2019) and presented in Table 4. The data were obtained and recorded in a Microsoft Excel® worksheet. Proportion, percentage, and 95% confidence interval (CI) were calculated using an Excel data analysis tool pack for estimating the financial impact of different parameters (decreased milk production, infertility/ decreased pregnancy, abortion in dairy cows and other pertinent costs).

RESULTS

Number of *Campylobacter* infected animals

Connected to the total number of crossbred farmed cattle, the number of mature cows/heifers (≥3 years old) were calculated as 94,926 (50% of total crossbred cattle population) of which 29,332 (95% CI: 25,630-33,324) cows and heifers were predicted to be positive with

Table 5. Expected number of *Campylobacter* positive animal in study districts (Dhaka and Mymensingh).

District/ animal category	Expected number positive animal	95% CI		Basis of calculation
		LL	UL	
Dhaka				
Cows and heifers (≥3 years old)	7942	6939	8995	
Mymensingh				Table 1 and 3 with beta distribution
Cows and heifers (≥3 years old)	21,390	18691	24229	
Total cows and heifers	29,332	25,630	33,224	

LL: Lower limit, UL: Upper limit.

Campylobacter spp. (Table 5). The list of the variable inputs captured through field interview data collection includes prices of live animals and livestock products used in economic loss estimation is shown in Table 4.

Decreased milk production

An amount of BDT 395.25 million (95% CI: 345.36-446.34) was estimated to be financial loss due to decreased milk production in two study districts. However, among the two districts, Mymensingh emerged as the top position with a financial loss of BDT 288.25 million (Table 6).

Decreased pregnancy and abortion in dairy cows

These two parameters were measured as an equal economic loss (BDT 87.99 million in each parameter) in two studied districts. However, Mymensingh district was captured with higher economic loss (BDT 64.17 million in each parameter) than Dhaka district (BDT 23.82 million in each parameter) (Table 6).

Other relevant costs

In this category, the restocking cost was captured as the highest loss parameter (BDT 703.89 million, 95% CI: 615.12-794.98) in two study districts. Considering the number of cattle population, Mymensigh district was weighed with the greater economic burden (BDT 513.38 million) than Dhaka district (BDT 190.61 million). Other parameters like veterinary health care (BDT 5.87 million) and cleaning disinfection cost (BDT 1.18 million) were evaluated as substantial loss parameters under the other relevant costs category.

The annual economic loss due to decreased milk production, infertility as a result of decreased pregnancy, abortion in dairy cows with other relevant costs (veterinary health care, cleaning and, disinfection and restocking cost (if applicable) is presented in Table 6. The total financial loss from this disease was assessed as BDT 1282.3 million (95% CI: 1120.4-1448.0 million) (Equiv. USD 14.1 million, 95% CI: 13.2-17.0 million) in farmed crossbred cattle of two study districts.

The pivotal economic loss was estimated in other cost categories (BDT 711.03 million, 95% CI: 621.27 -802.92 million), of which restocking cost is the key contributor in this category (BDT 703.9 million, 95% CI: 615.1-794.9 million) followed by decreased milk production, and abortion in dairy cows or infertility respectively (Figure 3). However, decreased milk production was established to be the second position with an annual financial loss of BDT 395.3 million (95% CI: 345.4- 446.3 million) followed by infertility due to decreased pregnancy or abortion in dairy cows (Table 6 and Figure 3). The financial impact of *Campylobacter* in farmed cattle was found to be higher in each loss parameter at Mymensingh than Dhaka district (Figure 4).

DISCUSSION

The livestock sector has contributed 1.43% to the national economy of Bangladesh in the year 2019-20 with a growth rate of 3.04%. About 70% (20% directly and 50% indirectly) of rural people of Bangladesh depend on livestock (DLS, 2020b). Since a number of economic impact studies on bovine campylobacteriosis have been conducted marginally in different geographical locations in the world, emphasizing the potential losses for livestock keepers (Silveira et al., 2018; Jimenez et al., 2027; Hum et al., 1994), no research has been conducted in Bangladesh. The study has estimated that substantial economic losses of BDT 1,282.26 million (95% CI: 1120.41-1448.00) in farming cattle of two districts was reasonably found to be higher due to the presence of highly positive *Campylobacter* spp. in farmed cattle. A major change in livestock rearing system has been taking place from extensive indigenous to semi-intensive/intensive crossbred exotic cattle in urban and periurban settings of Bangladesh since the 1980s (Mshelia et al., 2010), and facilitates the incursion of cattle-adapted *Campylobacter* strains (Mourkas et al., 2020). Therefore, a greater spectrum of economic loss has been perceived in this current study.

Table 6. Annual economic losses (in million BDT) due to decreased milk production, infertility/decreased pregnancy, along with other relevant losses (veterinary health care, cleaning, and disinfection cost and restocking (if applicable) with 95% CI (Confidence Interval) in the studied districts.

Parameters/Districts	Estimated	Confidence interval (CI)	
		Lower Limit (UL)	Upper Limit (UL)
Decreased milk production			
Dhaka	107.01	93.5	119.86
Mymensingh	288.24	251.86	326.48
Total in Category Parameter A	395.25	345.36	446.34
Infertility due to decreased pregnancy			
Dhaka	23.82	20.82	26.68
Mymensingh	64.17	56.07	72.69
Total in parameter B	87.99	76.89	99.37
Abortion in dairy cows			
Dhaka	23.82	20.82	26.68
Mymensingh	64.17	56.07	72.69
Total in Parameter C	87.99	76.89	99.37
Other costs			
Dhaka			
Vet. health care	1.59	1.39	1.78
Cleaning and dis	0.32	0.28	0.36
Restocking	190.61	166.54	213.48
Total other costs in Dhaka	192.51	168.2	215.61
Mymensingh			
Vet. health care facilities	4.28	3.74	4.85
Cleaning and disinfection	0.86	0.75	0.97
Restocking	513.38	448.58	581.5
Total other cost in Mymensingh	518.52	453.07	587.31
Total in parameter D	711.03	621.27	802.92
Total (A+B+C+D): Dhaka	347.16	303.34	388.83
:Mymensingh	935.10	817.07	1059.17
Grand total in two districts (in BDT Million)	1282.26	1120.41	1,448.00
Grand total in two districts (in USD Million) (1 USD=85 BDT approx.)	15.09	13.18	17.04

The study has investigated highest *Campylobacter* loss associated with restocking cost for farming cattle followed by decrease milk production, abortion/infertility in dairy heifers/cows. This finding is apparently coherent with another research was conducted in Argentina as the disease accounts for a 10% decrease in the calving rate in the infected herds with an annual financial loss of USD 165 million (Jimenez et al., 2011). Another study in the United States confirmed the cost of abortion in dairy cattle that was evaluated yearly at around USD 555 per animal (De Vries, 2006), and a theoretical lessening of 20% for abortion in a farm composed of 1,000 pregnant cows that measured an economic loss of USD 111,000 (Silveira et al., 2018). A few studies have confirmed the distribution of repeat breeding of around 11% (Asaduzzaman et al., 2016; Hasib et al., 2020), and abortion of < 10% in crossbred cows (Parvez et al., 2020; Alam et al., 2014) in different locations of Bangladesh. These reproductive problems are associated with substantial economic cost due to treatment (veterinary health care facilities) and replacement of the diseased animals that have had a direct impact to the livelihoods of marginal dairy farmers in Bangladesh (Talukder et al., 2005). The restocking cost was found as a paramount financial loss as farmers' attempt to overcome the productivity loss related to infertility as a result of repeat

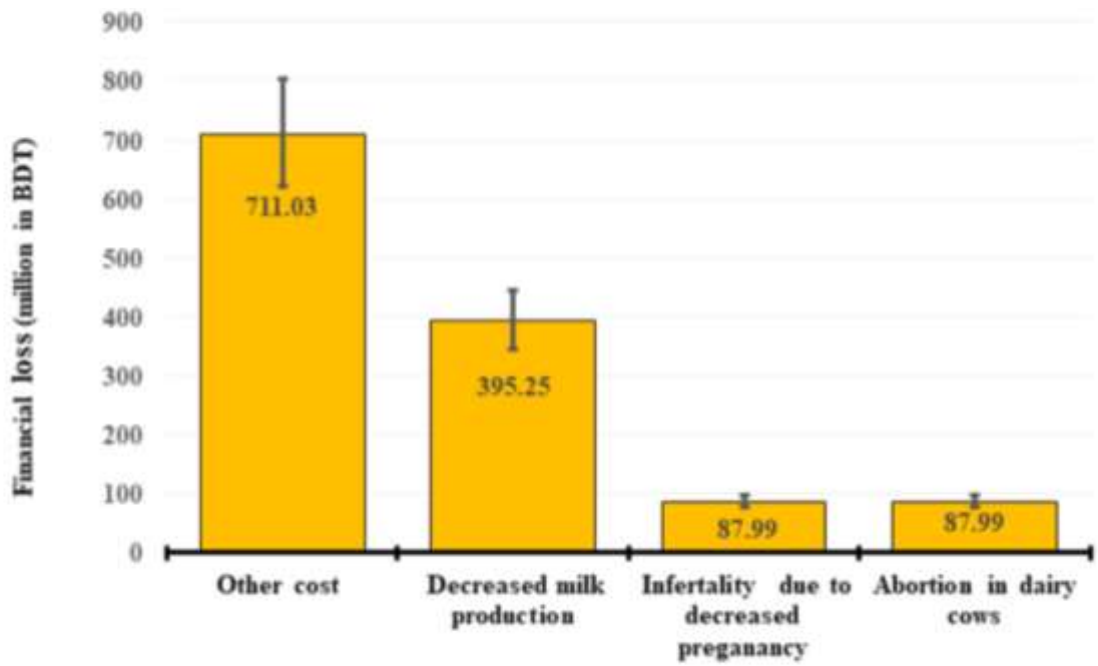

Figure 3. Estimated annual economic losses with 95% CI (Confidence Interval) (BDT in million) due to other costs (loss for veterinary health care, cleaning and disinfection, and restocking cost if applicable), decreased milk production, infertility/decreased pregnancy and abortion losses.

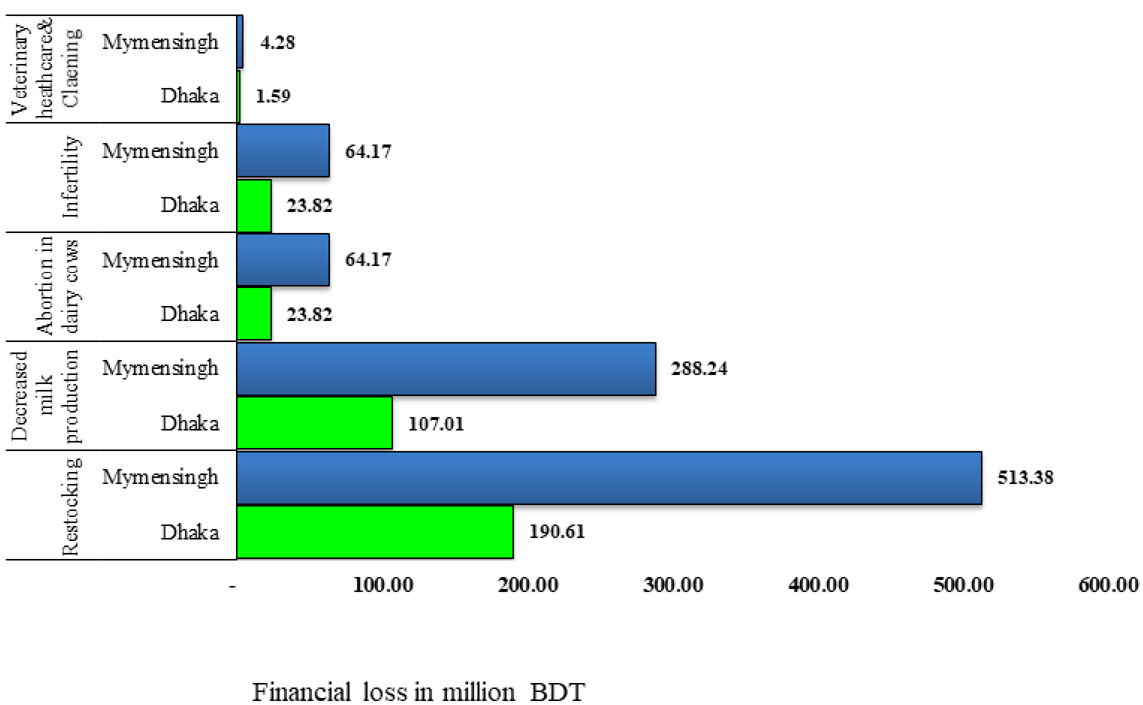

Figure 4. Comparison of financial loss in different parameters among two study districts (in million BDT).

breeding or abortion by selling their current stocks and purchasing of new reproductive animals.

According to the Department of Livestock Services (DLS), Bangladesh, the country's total milk production was 9.40 million metric tonnes in 2018 against 15.02 million metric tonnes that has demonstrated that 63% of demand was satisfied through its own production (DLS, 2018). However, in the same year, Bangladesh imported 0.11 million tonnes of powdered milk to lessen the production gap (BBS, 2018). Bangladesh is now self-reliant in meat production after various measures were taken by the government to boost the country's livestock sector (BBS, 2018). The impact of bovine campylobacteriosis will reduce milk production directly and indirectly, will widen the gap between demand and supply of animal origin food, and ensure further dependency on imported powdered milk. It is imperative to recognize this in the dairy industry of Bangladesh for mitigating this shortfall that has a positive impact on income of the marginalized dairy farmers. Nevertheless, the diseases, like bovine campylobacteriosis, may impede this possibility via decreased production including their zoonotic transmission.

Bovine campylobacteriosis are not the diseases that get more attention in LMICs like many other economically important infectious diseases such as foot and mouth disease (FMD) and peste des pettits ruminants (PPR); however, the burden of bovine campylobacteriosis has not yet been appraised in most countries. The key stakeholders are not conscious of the actual burden of this disease in cattle including its significant public health implications. Highlighting key dairy health impacts through production loss, risk of zoonotic transmission, international trade embargo, and animal welfare issues should be important to assist the researchers and planners in considering the priority options (Wells et al., 1998). Undoubtedly, the most important change to the natural host position of *C. jejuni* has taken place in recent times resulting in cattle-specific pathogen found to have originated through intensive livestock farming (Thépault et al., 2017; Sheppard et al., 2013; Morley et al., 2015).

Bovine campylobacteriosis, notably *C. jejuni* has been recognized for decades, as they are estimated to be the primary reproductive diseases of cattle. To improve livestock production in terms of keeping sustainable economic output, a collective action between cattle farmers, government bodies, dairy industry, and academia needs to focus on further exploration of this disease in the area of diagnosis, treatment, prevention and control measurements (Michi et al., 2016). The highest prevalence of BCG has been confirmed in the LMICs where natural breeding program in cattle is mostly practiced (Mshelia et al., 2010).

To lessen the above financial burden of bovine campylobacteriosis, it is commendable to bring about all farmed female reproductive cattle under artificial insemination (AI) program to prevent venereal transmission of *Campylobacter*. However, breeding bulls under the AI program should be periodically tested on presence of *Campylobacter* through government support and culling of the positive animal to be ensured (Seid, 2019; Bondurant, 2005; Truyers et al., 2014; Cobo et al., 2004) along with vaccination of all bulls, cows, and heifers (Seid, 2019) is also needed. However, breeding bulls carrying *Campylobacter* can be treated using frequent antimicrobial preputial washes and may need additional injectable antimicrobials (Revell, 1998; Taylor, 2002) where scarcity of resources is an advent. Regular screening and segregation of infected animal from the herd is needed at primary stage, and test and culling would be implemented in the final stage after adjustment of adequate financing under farmers' compensation scheme.

Good farm management is the prerequisite for fecal transmission of *C. coli* and *C. jejuni* that includes good cleanliness and hygienic practices in cattle farms, along with proper slurry management through composting or biogas plants (Hoque et al., 2021). Good practice of composting will reduce *Campylobacter* (and other important zoonotic pathogens such as *Salmonella* and *Escherichia coli*) within 5 days due to the high-temperature generation (>50°C) (Hutchison et al., 2005) would be beneficial to reduce the load of *Campylobacter* in the farm environment and to minimize the reinfection in cattle.

The study has few limitations as it did not cover indirect losses incurred by bovine campylobacteriosis, including all categories of animals at the farm level; also, this study focused only on two districts of Bangladesh that failed to capture the actual burden. The model that has been established in this study is comparatively simple, including all potential direct losses associated with the reproduction of crossbred farming cattle for the first time in Bangladesh. Additionally, the outputs of this study could be utilized for other cattle-dominant districts of Bangladesh. Therefore, a future greater survey including all direct and indirect losses of *Campylobacter* considering animal situation (behavior, physical conditions, etc.) during the follow-up of the illness is intended and recommended.

Conclusion

The study confirms a variety of financial losses on livestock productivity related to bovine campylobacteriosis infection in crossbred farmed cattle based on the animal level prevalence and recommends an urgent need for resorting to control approaches that is fit-for-purpose in low resource settings in supporting and sustaining the livelihoods and food security for marginal dairy farmers.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors are grateful to dairy farmers/farm attendants, animal traders/broker, veterinarians/paraprofessionals for their assistance during field survey data collection. The authors are indebted to Mr. Syful Islam, Scientific Officer, Agricultural Economics Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh for reviewing the manuscript. The study was funded by Krishi Gobeshona Foundation (KGF Project ID: TF-45-L/17), Bangladesh.

REFERENCES

Akhtar S, Riemann HP, Thurmond MC, Franti CE (1993). The association between antibody titres against *Campylobacter fetus* and milk production efficiency in dairy cattle. Veterinary Research Communications 17(3):183-191.

Alam MA, Uddin MM, Parvin MS, Rahman MM, Bari FY (2014). Prevalence of reproductive diseases and its associated risk factors in crossbred dairy cows. Research in Agriculture Livestock and Fisheries1(1):71-79.

Asaduzzaman K, Bhuiyan M, Rahman M, Bhattacharjee J (2016). Prevalence of repeat breeding and its effective treatment in cows at selected areas of Bangladesh. Journal of Veterinary Medicine 14(2):183-190.

Azami HY, Zinsstag J (2018). Economics of bovine tuberculosis: a one health issue. In Bovine tuberculosis. Chambers M, Gordon S, Olea-Popelka F, Barrow P. eds.), Chapter 3, 31–42. 2018. Available online: https://www.cabi.org/animalscience/ebook/20183117960

Bangaldesh Buraue of Statistics(BBS) (2018). Statistical Year Book of Bangladesh, Statistics Division, Ministry of Planning, The Government of Peoples Republic of Bangladesh.

Bier P, Hall C, Duncan J, Winter A (1977). Experimental infections with Campylobacter fetus in bulls of different ages. Veterinary Microbiology 2(1):13-27.

Bondurant RH(2005). Venereal diseases of cattle: natural history, diagnosis, and the role of vaccines in their control. Veterinary Clinics of North America: Food Animal Practice 21(2):383-408.

Brown LD, Cai TT, DasGupta A (2001). Interval estimation for a binomial proportion. Statical Science 16(2):101-117.

Clark B (1971). Review of bovine vibriosis. Australian Veterinary Journal 47(3):103-107.

Cobo ER, Morsella C, Cano D, Cipolla A, Campero C M (2004). Immunization in heifers with dual vaccines containing *Tritrichomonas foetus* and *Campylobacter fetus* antigens using systemic and mucosal routes. Theriogenology 62(8):1367-1382.

Das PK, Ali SZ, Islam ABMM, Roy BKA (2003). A comparative study of productive and reproductive performance and estimates of heritability for economic traits in different genetic groups of cattle available at Baghabarighat milk pocket area of Bangladesh. Journal of Biological Science 3(8):726-740.

De Vries A (2006). Economic value of pregnancy in dairy cattle. Journal of Dairy Science 89(10):3876 3885.

DLS (2018). Livestock Econonoy at a Glance 2017-18. Department of Livestock Services, Minstery of Fisheies and Livestock. Government of the People's Republic of Bangladesh. 2018. Available online: https://dls.portal.gov.bd/sites/default/files/files/dls.portal.gov.bd/page/ee5f4621_fa3a_40ac_8bd9_898fb8ee4700/Livestock%20Economy%20at%20a%20glance%20%20%282017-2018%29.pdf. Last accessed on: 10 Jan 2021

DLS (2020a). District-wise animal data base. Department of Livestock Services, Ministry of Fisheries and Livestock. Avialable online: Available online: http://old.dls.gov.bd/ Last accessed on: 19 January 2021.

DLS (2020b). Livestock economy at a glance, 2019-20. Department of Livestock Services, Ministry of Fisheries and Livestock, Government of the People's Republic of Bangladesh. Avialable online: https://dls.portal.gov.bd/sites/default/files/files/dls.portal.gov.bd/page/ee5f4621_fa3a_40ac_8bd9_898fb8ee4700/2020-07-22-19-34-e4cd5ed65f45419ee038e00b8939c1a0.pdf. Last accessed on: 19 Jan 2021

EFSA and ECDC (2018). The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2017. EFSA Journal 16(12):5500.

Hamid MA, Rahman A, Zaman MA, Hossain KM (2017). Cattle Genetic Resources and their Conservation in Bangladesh. Asian Journal of Animal Science 11(2):54-64.

Hasib FMY, Reza MMB, Alam MMU, Azizunnesa TH, Azizunnesa (2020). Occurrence and risk factors of repeat breeding on household dairy cows of Hathazari in Chattogram. Bangladesh Journal of Veterinary and Animal Sciences 8(1):102-111.

Hoque N, Islam SS, Uddin MN, Arif M, Haque, AKMZ, Neogi SB, Hossain MM, Yamasaki S, Kabir SML (2021). Prevalence, risk factors, and molecular detection of *Campylobacter* in farmed cattle of selected districts in Bangladesh. Pathogens 10(3):313.

Hum S, Brunner J, McInnes A, Mendoza G, Stephens J (1994). Evaluation of cultural methods and selective media for the isolation of *Campylobacter fetus* subsp *venerealis* from cattle. Australian Veterinary Journal 71(6):184-186.

Hutchison M, Walters L, Moore A, Avery S (2005). Declines of zoonotic agents in liquid livestock wastes stored in batches on-farm. Journal of applied Microbiology 99(1):58-65

Irons PC, Schutte AP, Van Der Walt ML, Bishop GC (2020). In: Infectious Diseases of Livestock. 2. Coetzer JAW, Tustin RC, editor. Cape Town: Oxford University Press. Genital Campylobacteriosis in cattle pp. 1459-1468.

Islam SS, Rumi TB, Kabir SML, van der Zanden AG, Kapur V, Rahman AKMA, Ward MP, Bakker D, Ross AG, Rahim Z (2020). Bovine tuberculosis prevalence and risk factors in selected districts of Bangladesh. PLoS One 15(11):e0241717.

Jimenez DF, Perez AM, Carpenter TE, Martinez A (2011) Factors associated with infection by *Campylobacter fetus* in beef herds in the Province of Buenos Aires, Argentina. Preventive Veterinary Medecine 101(3-4):157-162.

McDermott J, Grace D, Zinsstag J (2013). Economics of brucellosis impact and control in low-income countries. Revue scientifique et technique 32(1):249-261.

Michi AN, Favetto PH., Kastelic J, Cobo ER (2016) A review of sexually transmitted bovine trichomoniasis and campylobacteriosis affecting cattle reproductive health. Theriogenology 85(5):781-791.

Modolo J, Lopes C, Genari T (2000). Occurrence of *Campylobacter* in the genitals of teaser bulls maintained at an embryo transfer center. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 52(2):96-97.

More S, Bøtner A, Butterworth A, Calistri P, Depner K, Edwards S (2017). EFSA Panel on Animal Health and Welfare (AHAW)(2017). Assessment of listing and categorisation of animal diseases within the framework of the Animal Health Law (Regulation (EU) No 2016/429): Trichomonosis. EFSA Journal 15(10):e04992

Morley L, McNally A, Paszkiewicz K, Corander J, Méric G, Sheppard SK, Blom J, Manning G (2015). Gene loss and lineage-specific restriction-modification systems associated with niche differentiation in the *Campylobacter jejuni* sequence type 403 clonal complex. Applied Environmental Microbiology 81(11):3641-3647.

Mourkas E, Taylor AJ, Méric G, Bayliss SC, Pascoe B, Mageiros L, Calland JK, Hitchings MD, Ridley A, Vidal A (2020). Agricultural intensification and the evolution of host specialism in the enteric pathogen *Campylobacter jejuni*. Proceedings of the National Academy of Sciences of the United States of America 117(20):11018-11028.

Mshelia GD, Amin JD, Woldehiwet Z, Murray RD, Egwu GO(2010). Epidemiology of bovine venereal campylobacteriosis: geographic distribution and recent advances in molecular diagnostic techniques. Reproduction in Domestic Animals 45(5):e221-30

NDDP(2016). National Dairy Development Policy. (Final draft) Bangladesh. Available from: https://mofl.gov.bd/site/notices/7e9183bf-8da5-4292-b92f-ab2116661b3d/National-Dairy-Development-Policy-2016-Draft-for-Opinion.

OIE (2021a). OIE-Listed diseases, infections and infestations in force in 2020. In OIE-Listed diseases 2021. Avaialble online: https://www.oie.int/animal-health-in-the-world/oie-listed-diseases-2021. Last accessed on 19 Jan 2021.

OIE (2021b). WAHIS ionterface: Country inforamtion: Bangladesh yearly current notifiaable diseases 2019. Available online:

https://www.oie.int/wahis_2/public/wahid.php/Countryinformation/Animalsituation.

Parvez M, Faruque M, Khatun R (2020). Prevalence of abortion, calf mortality and proportion of cattle population in commercial dairy farms of Bangladesh. Research Journal of Veterinary Practitioners 8(1):51-55.

Revell S (1998). The bull as a potential vector of disease. Cattle Practice (United Kingdom)

Roux F, Sproston E, Rotariu O, MacRae M, Sheppard SK, Bessell P, Smith-Palmer A, Cowden J, Maiden, MC, Forbes KJ (2013). Elucidating the aetiology of human *Campylobacter coli* infections. PLoS One 8(5):e64504

Seid A (2019). Bovine Campylobacteriosis and its Economic Importance: A Review. Dairy and Veterinary Science Journal 11(2): 555807.

Sheppard SK, Dallas JF, Strachan NJ, MacRae M, McCarthy ND, Wilson DJ, Gormley FJ, Falush D, Ogden ID, Maiden MC (2009). *Campylobacter* genotyping to determine the source of human infection. Clinical Infectious Disease 48(8):1072-1078.

Sheppard SK, Didelot X, Meric G, Torralbo A, Jolley KA, Kelly DJ, Bentley SD, Maiden MC, Parkhill J, Falush D (2013). Genome-wide association study identifies vitamin B5 biosynthesis as a host specificity factor in *Campylobacter*. Proceedings of the National Academy of Sciences of the United States of America 110(29):11923-11927.

Silveira CdS, Fraga M, Giannitti F, Macías-Rioseco M, Riet-Correa F (2018). Diagnosis of Bovine Genital Campylobacteriosis in South America. Frontier Veterinary Science 14(5):321.

Skirrow MB (1994). Diseases due to *Campylobacter*, *Helicobacter* and related bacteria. The Journal of Comparative Pathology 111(2):113-149.

Talukder MAS, Khandoker MAMY, Rahman MGM, Islam MR, Khan MAA (2005). Reproductive problems of cow at Bangladesh Agricultural University Dairy Farm and possible remedies. Pakistan Journal of Biological Science 8(11):1561-1567.

Taylor A (2002) Venereal *Campylobacter* infections in cattle. Cattle Practice 10(1):35-42.

The World Bank (WB) (2018). Combined Project Information Documents /Integrated Safeguards Datasheet (PID/ISDS). Livestock Development-based Dairy Revolution and Meat Production Project (P161246). http://documents1.worldbank.org/curated/fr/795391522032371954/pdf/Project-Information-Document-Integrated-Safeguards-Data-Sheet-Livestock-Development-based-Dairy-Revolution-and-Meat-Production-Project-P161246.pdf.

Thépault A, Méric G, Rivoal K, Pascoe B, Mageiros L, Touzain F, Rose V, Béven V, Chemaly M, Sheppard SK (2017). Genome-wide identification of host-segregating epidemiological markers for source attribution in *Campylobacter jejuni*. Applied Environmental Microbiology 83(7):e03085-16.

Truyers I, Luke T, Wilson D, Sargison N (2014). Diagnosis and management of venereal campylobacteriosis in beef cattle. BMC Veterinary Research 27(10):280.

van Bergen MAP, Linnane S, van Putten JPM, Wagenaar JA (2005). Global detection and identification of *Campylobacter fetus* subsp. *venerealis*. Revue scientifique et technique 24(3):1017-26.

VOSE (2019). Installation, Activation, De-activation, Upgrade. Model Risk Installtion Guide 2019. Avialable online: https://www.vosesoftware.com/includes/content/ModelRisk_installation_guide.pdf

Wells SJ, Ott SL, Seitzinger AH (1998). Key health issues for dairy cattle—new and old. Journal of Dairy Science 81(11):3029-3035.

Zeng JY, Robertson ID, Ji QM, Dawa YL, Bruce M (2019). Evaluation of the economic impact of brucellosis in domestic yaks of Tibet. Transboundary Emerging Disease 66(1):476-487.