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Financial Losses Associated with Bovine Brucellosis (*Brucella abortus*) in Carchi-Ecuador

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Abstract

Brucellosis is an infectious disease of worldwide distribution, which has a great economic impact due to the productive and reproductive losses that it causes, in addition to the serious public health problem. The aim of this study is to estimate the economic losses, through financial analysis, caused by bovine brucellosis in the province of Carchi, over a one-year period. A random sampling was used to determine the prevalence in the study area, where 2976 animals were considered, and the Rose Bengal (RB) test was used as a screening test and the Fluorescence Polarized Assay (FPA) as a confirmatory test, obtaining a prevalence of 8.2% (244/2976). In addition, parameters associated to the losses caused by brucellosis in cattle were determined by literature review. To estimate costs, field information was collected through a survey of a total of 100 randomly selected farmers. The loss estimated due to calves lost as a result of abortions and neonatal death was USD. 79170.00. The loss due to death of 4 cows as a result of metritis was estimated at USD. 5000.00. The cost of examination and treatment of aborted cows was USD. 20100.00. The losses due to reduction in milk production from aborted and non-aborted seropositive cows were estimated at USD. 158114.21. The financial losses due to brucellosis in province of

Carchi were estimated at USD. 262384.21.

Keywords

Bovine Brucellosis, Economic Losses, Carchi-Ecuador

1. Introduction

Brucellosis is an infectious disease of worldwide distribution. While it has been controlled and eradicated in many countries, it remains an endemic disease in some developing countries in Africa, Asia and Latin America [1]. The impact of brucellosis lies in being the most persistent zoonosis worldwide according to the Food and Agriculture Organization and World Health Organization.

In animals, the disease occurs as an infection in the reproductive system of mammals, where abortion in females, and epididymitis and orchitis in males are the most significant symptoms [2]. In female cattle, abortion occurs during the last third of pregnancy, accompanied by placental retention, as well as stillbirths, births of premature calves, birth of weak calves, and decreased lactation [3] [4]. In countries of Africa, there is the peculiarity that in addition to the aforementioned problems there are hygromas and abscesses [5]. There are also reports indicating that after the first abortion, the following pregnancies of bovine females are generally normal and infected animals are asymptomatic, but they are an important source of infection [3].

Brucella species is a group of infectious agents with a high capacity to adapt to new hosts, which is common in mixed cattle, goat, and pig farms, increasing the risk of transmission [6], this group of animals can be infected directly and indirectly [7], by contact with the placenta, fetal fluids, and vaginal discharge from an infected animal; bacteria have also been reported in urine, feces, hygroma fluids, saliva and, nasal and ocular secretions, venereal transmission can also occur in some species of brucella, and the indirect route can occur in calves through the consumption of milk from infected animals [8].

In humans, brucellosis is an accidental disease, caused by direct contact with the causative agent or by the consumption of infected or unpasteurized milk or milk products [1]. The disease in humans presents with different manifestations and even asymptomatically; fever is its main characteristic, but headache, back pain, malaise, osteo-articular manifestations, and fatigue can also occur. Genital complications such as orchitis and epididymitis occur in men [9].

Brucellosis produces significant productive and reproductive conditions that result in economic losses, but one of the most important causes that motivate its study is the public health problem it causes, turning it into a zoonosis [10] [11] [12].

The control and eradication programs of brucellosis at the international level are based on a series of strategies: massive vaccination, diagnosis and slaughter of sero-

positive animals, epidemiological surveillance, and training of farmers [13], in order to reduce the presence of the disease and therefore the economic losses it causes.

The economic losses associated with brucellosis have been estimated worldwide. In the case of Latin America, animal brucellosis causes losses of over 600 million dollars a year [14] [15] [16], and in the case of human brucellosis, Gil and Samartino [17] estimated that treatments of brucellosis range from 340 to 4095 dollars per patient in severe cases.

In the case of Ecuador, which is considered an endemic country for brucellosis, in 1998 the Ministry of Agriculture and Livestock (MAG) through the Ecuadorian Animal Health Service (SESA) [18], estimated the losses caused by bovine brucellosis at USD. 2.5 million per year. For the year 2009 the MAG through the Ecuadorian Agency for Quality Assurance of Agro [19] in the national program of control of bovine brucellosis, estimates that because of brucellosis Ecuador loses over 5 million USD a year, attributed to calves loses due to abortions, milk production losses and cows reposition. With the aforementioned information, the need to carry out focused studies at the regional or provincial level is required, since each area within the country has different epidemiological characteristics. The present study aims to determine a current estimate of the financial losses caused by bovine brucellosis in the province of Carchi, considering parameters such as: prevalence of the province, cost differentiation between male and female calves, dead's due to abortions, abortion treatment costs, subsequent abortions, and neonatal dead's.

2. Methodology

2.1. Area of Study

This study was carried out in the province of Carchi - Ecuador, an agricultural province representing 8.22% of the total Agricultural Productive Units (UPAS) of Ecuador. In addition, it is a province with high potential for dairy farming since it concentrates 8.74% of the total dairy cattle of the Sierra and contributes 5% of the total milk production of Ecuador [20]. From the point of view of brucellosis, the province of Carchi is in an area of high prevalence for brucellosis according to MAG-SESA [18].

2.2. Source of Information

For the estimation of financial losses associated with bovine brucellosis in the province of Carchi, productive and reproductive parameters were considered, as indicated in **Table 1**, supported by literature review. For the determination of the prevalence, 2976 blood samples were collected from female bovine animals older than 2 years. All procedures carried out in the present investigation were in accordance with the guidelines and the approval Governmental Manual of Taking and Sending Samples in Domestic Animals of the Laboratories of the Animal Health Directorate, Animal Resources of the Agency of Regulation and Control of Phyto and Zoosanitario (AGROCALIDAD), Ecuador, under the

Table 1. Bovine population, reproductive fitness and productive and reproductive losses associated with bovine brucellosis.

Parameters	Value	Reference
Mature females bovines in Carchi	87,813	Foot-and-mouth disease vaccination campaign Ecuador 2018
% Cows	70%	Foot-and-mouth disease vaccination campaign Ecuador 2018
% Heifers	30%	Foot-and-mouth disease vaccination campaign Ecuador 2018
% Mortality	5.52%	[37]
% Females suitable for reproduction	50%	[37]
% Abortion at 1st. birth due to brucellosis	16%	[15]
% Abortion at 2nd. and at subsequent birth due to brucellosis	10%	[14]
% Lost milk of aborted cows	20%	
% Lost milk of non aborted cows	10%	[15]
% Neonatal Mortality	10%	[32]
% Mortality due to abortion	1%	[23]
Average milk production per animal * day^{-1}	10.7	[37]
Average lactation days	225.67	[37]

identification: Instructive INT/DA/019. Once the serum was extracted it was analyzed, in the veterinary diagnostic laboratory of the UPEC, using the Rose Bengal Test (RB) following the protocol described by the OIE [13], and the positive results were confirmed with the Polarized Fluorescence test (FPA), which for its execution used the guidelines of the commercial kit "Brucella Antibody Test Kit FPA" of the Ellie house. The cut-off point for the interpretation of results was ≥89.9 mP [21] [22]. The costs were estimated with the collection of field information, taking a sample of 100 randomly selected farmers, using the interview technique through a structured questionnaire (**Parameters fitted in the model**).

With regard to the preparation of the questionnaire, the people who intervened were socialized about the objective of the investigation, as well as about each of the questions, in order to obtain the greatest true answers, the costs related to the intervention of a professional for post-abortion/animal treatment, purchase and sale the values of weaned male and female calves were considered.

2.3. Economic Model

The model used to determine the financial losses due to bovine brucellosis in the

province of Carchi was carried out using as base the studies of Santos *et al.* [23] and Angara, *et al.* [24] due to standardized scheme for it could not be evidenced to carry out this study.

$$TFL = RL + PL \quad (1)$$

where:

TFL = Total Financial Loss.

RL = Reproductive Loss (value of: calves lost due to abortions, neonatal death, death of mature cow and veterinary interventions).

PL = Productive loss (value of milk lost)

$$RL = CL + ND + CD + VI \quad (2)$$

where:

CL (value of Calves Lost due to abortion) = (number of male calves lost × average price of male calf) + (number of female calves lost × average price of weaned female calf) (3)

ND (value of Neonatal Death) = (number of male calves lost due to neonatal death × average price of male calf) + (number of female calves lost due to neonatal death × average price of weaned female calf) (4)

CD (value of death of mature cow) = number of cows dead due to abortion × average price of mature cow (5)

VI (Cost of Veterinary Intervention) = number of seropositive aborted cow's × cost of veterinary intervention/cow (6)

PL (value of milk lost) = (quantity of milk lost by aborted cows at second birth + milk lost by non-aborted cows) × unit price of milk price (7)

2.4. Parameters Fitted in the Model

The parameters and data were collected from the field survey and it fitted as follow:

1) Number of alive mature cows in the province was obtained by multiplying the number of total mature cows (87,813) × the survival percentage registered in the province (94.48%).

2) Number of alive cows suitable for reproduction were obtained by multiplying the number of alive mature cow's × the percentage of cows suitable for reproduction (50%).

3) Number of seropositive cows = number of alive cows suitable for reproduction × the prevalence.

4) Number of seropositive cows at first birth (heifers) = Number of seropositive cow's × percentage of cows at first birth registered in the province.

5) Number of seropositive cows at second birth (cows) = Number of seropositive cow's × percentage of cows at second birth (cows) register in the province.

6) Number of seropositive aborted cows = (number of seropositive cows at first birth × abortion rate at first birth) + (number of seropositive cows at second birth × abortion rate at second birth).

7) Number of male calves lost = 0.5(probability of born males) × number of seropositive aborted cows.

8) Number of female calves lost = 0.5(probability of born females) × number of seropositive aborted cows.

9) Number of calves lost due to neonatal death = number of seropositive non aborted cow's × rate of neonatal death.

10) Number of male calves lost due to neonatal death = 0.5(probability of born males) × number calves lost due to neonatal death.

11) Number of female calves lost due to neonatal death = 0.5(probability of born females) × number calves lost due to neonatal death.

12) Number of cows dead due to abortion = number of seropositive aborted cow's × percentage of mortality risk for aborted cows.

13) Milk lost from aborted cows = number of seropositive aborted cows at second birth × average of milk production cow·day^{-1} × average lactation days' × percentage of milk loss from aborted cows.

14) Milk lost from non-aborted cows = number of seropositive non aborted cow's at second birth × average of milk production cow·day^{-1} × average lactation days × percentage of milk loss from non-aborted cows.

15) Prevalence of brucellosis 8.22% obtained from the field study.

16) Average price of male calf of USD 40.00 obtained from field interviews.

17) Average price of weaned female calf of USD 250.00 obtained from field interviews.

18) Average price of mature cow of USD 1250.00 obtained from field interviews.

19) Cost of veterinary intervention per cow of USD 50.00 obtained from field interviews.

20) Liter milk production cost of USD 0.25 obtained from field interviews.

2.5. Data Analysis

The Excel version 2010 program was used to tabulate the data, through the application of the formulas indicated in section 2.4., with the information showed in Table 1.

3. Results

3.1. The Prevalence Rates of Bovine Brucellosis in Carchi Province

The prevalence in the province was found to be 8.2% based on Rose Bengale (RB) test and confirmed with Fluorescence Polarization Assay (FPA).

3.2. Losses Due to Bovine Brucellosis

3.2.1. Number of Seropositive Reproductive Cows at First and Second Birth

The number of seropositive cows at first and second birth is 3402.

3.2.2. Number of Cows Died Due to Abortions

The number of aborted cows is estimated at 402 of which 4 cows died due to metritis resulting from abortions.

3.2.3. Number of Calves Lost

Calves lost due to brucellosis as a result of abortion and neonatal death are estimated at 702 animals.

3.2.4. Quantity of Milk Lost due to Brucellosis

The quantity of milk lost from seropositive aborted and non-aborted cows is found to be 632456.83 l·year^{-1}.

3.3. Financial Losses Due to Bovine Brucellosis

3.3.1. Losses of Calves Lost (CL)

The loss due to calves' losses resulting from abortions and neonatal death was USD. 79170.00, using Equations (3) and (4).

3.3.2. Losses Due to Mortality

The loss due to death of 4 cows which died as a result of metritis was estimated at USD. 5000.00, using Equation (5).

3.3.3. Cost of Veterinary Intervention (VI)

The cost of examination and treatment of aborted cows was USD. 20100.00, using Equation (6).

3.3.4. Losses Due to Reduction in Milk Production (PL)

The losses due to reduction in milk production from aborted and non-aborted seropositive cows was estimated at USD. 158114.21, using Equation (7).

3.4. Total Financial Losses Due to Bovine Brucellosis

The total financial losses due to brucellosis in province of Carchi were estimated at USD. 262384.21.

4. Discussion

Brucellosis is an infectious-contagious disease that affects mammals with reproductive and productive repercussions, which leads to large economic losses, in addition to public health problems.

In the present study, the prevalence value in the province of Carchi was established with the use of the Rose Bengal (RB) test as a screening diagnosis, due to its high sensitivity 100% [25] and speed, and as a confirmatory diagnosis the test of Polarized Fluorescence, due to its high specificity value of 100% [26].

The prevalence observed in this study is 8.2%, which indicates that the province of Carchi continues to be a high prevalence area for bovine brucellosis, since this value is within the prevalence range determined by the MAG, Ecuadorian Agricultural Health Service [18] which is between 4% to 10.62%. This result complements previous prevalence estimations at the cantonal and parish level in

the province of Carchi: a prevalence of 6.95% in the parish of Santa Martha de Cuba-Canton Tulcán [27], a prevalence of 2.17% in the Canton Espejo [28], and 7.10% in the Canton Montufar [29]. It indicates that the control and eradication plans used are not bearing the expected results and that more effort is needed to achieve this goal.

Brucellosis is an infection well known for its reproductive conditions, where abortion is the main clinical sign, which generally occurs during the second third of pregnancy, accompanied by placental retention and metritis. This clinical sign rarely occurs in 100% of seropositive females, since it depends on: the prevalence of the area, the immunological status of the animal, the source and route of infection, as well as the period of infection [14] [30].

The number of abortions considered in this research represents 16% (164) and 10% (238) in abortions at first birth (heifers) and subsequent abortions (cows) respectively, as mentioned by Matope *et al.* [25] that relates seropositivity with the presence of abortions in Zimbadwe, Africa, and Panama. The abortion at first birth in heifers is associated of a result of primo-infection of brucellosis, trough consumption of colostrum of milk from infected cow, and the subsequent abortions are attributed at latent infectious of brucellosis [31].

Perinatal mortality is also considered a clinical sign of bovine brucellosis but occurs in low percentages (4.8%) as mentioned by Santos R. L. *et al.* [32].

The aforementioned reproductive problems lead to productive problems because of decreased milk production; in this study it was estimated milk losses of around 632456.83 l·year^{-1}, representing USD 158114.21, as a result of the interruption of lactation due to abortion as mentioned [14] where they attribute between 20% to 25% decrease in milk production due to brucellosis. In addition to this percentage of losses, it is necessary to add 10% of losses of milk production not associated with abortions but rather to infection caused by brucella that decreases the productive potential of animals as mentioned by Matope *et al.* [25].

According to MAG-SESA in 1999 [18] the losses associated with bovine brucellosis in Ecuador was USD 2.5 million a year; at the provincial level no investigations have been carried out to determine this value, and with the information raised the costs associated with Bovine brucellosis (*Brucella abortus*) in the province of Carchi was estimated at USD. 262384.21. The losses caused by brucellosis have been determined in other places: USD 7.3 million in the state of Khartoum in Sudan [24], USD 3.4 billion in India [33], USD 448 million in Brazil [32]; while Arenas and Moreno [34] report losses of USD 2176 million in Colombia.

Despite the economic losses, it is important to consider that the real problem of brucellosis lies in the effect on public health, and therefore the importance of directing actions towards the control o brucellosis in animals, since the risk of contagion of animal-human brucellosis is due to contact or interaction between people and seropositive animals [35], as well as the consumption of unpasteurized milk and dairy products, as mentions by Aggad H. and Boukraa L. [36]

In addition, this type of study allows the integration of information regarding an animal diseases and is a framed within the current trends of epidemiological studies in zoonotic diseases, which is the interest in human-animal and environment relations, through the concept of "One Health" in order to join the multidisciplinary work professionals worldwide to guarantee human and animal health and environmental protection.

5. Conclusion

The financial losses associated with bovine brucellosis in the province of Carchi were estimated at USD 262384.21 considering both productive and reproductive parameters. It is important to consider that the financial losses indicated in this study could increase if it is considered within a control and eradication program, since seropositive animals must be slaughtered, and the value of replacements is high. All of this denotes the economic importance of bovine brucellosis, and that the estimate is apparently an underestimation of the true economic losses that this zoonosis causes to livestock in Ecuador, causing not only productive problems in dairy farms, but also could cause impacts on public health, due to brucellosis is a zoonotic disease.

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Non-Applicable.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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