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RESEARCH ARTICLE

The Cost-Benefit Analysis of Alternative Brucellosis Control Strategies in Turkey [1]

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[1] *This study was summarized a part of PhD thesis entitled "Estimation of the financial losses resulted from Brucella abortus and Brucella melitensis infections and cost-benefit analysis of alternative brucellosis control strategies in Turkey"*

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Summary

Brucellosis is a zoonotic disease and leads to serious financial losses in infected species. The aim of this study is to determine the most financially rational brucellosis control strategy for Turkey by means of cost-benefit analyses. In this study, four different infection control strategies were designed under three different scenarios named optimistic, expected and pessimistic scenarios. The most financially rational infection control option for Turkey was found to be the second strategy, which is "only young animals, three to six month old female bovine and three to six month old male and female ovine, have been vaccinated and after reaching the target prevalence for each species, vaccinations will be terminated and in the same year test and compulsory slaughter methods will be implemented throughout the country". For the optimistic, expected and pessimistic scenarios according to second strategy the net present value was estimated as -$3.1 million, $29.2 million and $41.9 million respectively, the benefit-cost ratio was estimated 0.86, 2.26 and 2.84 respectively. The results of this study indicated that fighting with brucellosis is financially rational for expected and pessimistic scenarios. However, it should not be forgotten that a financially rational control strategy doesn't means that it is always suitable technically or it is rational in respect to public health.

Keywords: *Brucellosis, Bovine, Control, Cost, Financial, Prevalence*

Türkiye'de Alternatif Bruselloz Kontrol Stratejilerinin Maliyet-Fayda Analizi

Özet

Bruselloz zoonotik bir hastalıktır ve enfekte türlerde ciddi mali kayıplara yol açmaktadır. Bu çalışmanın amacı Türkiye için mali açıdan en rasyonel bruselloz kontrol stratejisinin maliyet-fayda analizleriyle belirlenmesidir. Çalışma kapsamında dört farklı enfeksiyon kontrol stratejisi iyimser, beklenen ve kötümser olmak üzere üç farklı senaryo altında dizayn edilmiştir. Türkiye için mali açıdan en rasyonel enfeksiyon kontrol seçeneğinin ikinci strateji olan "büyükbaş hayvanlar için üç-altı aylık dişilerin, küçükbaş hayvanlar için üç-altı aylık dişi ve erkek genç hayvanların aşılanması ve her bir türde hedef prevalans düzeyine ulaşıldıktan sonra aşılamanın sonlandırılarak aynı yıl test ve zorunlu kesim yöntemlerinin ülke genelinde uygulanması" olduğu belirlenmiştir. İkinci strateji kapsamında iyimser, beklenen ve kötümser senaryolar için net bugünkü değer sırasıyla -$3.1, $29.2 ve $41.9 milyon; fayda-maliyet oranı ise sırasıyla 0.86, 2.26 ve 2.84 olarak tahmin edilmiştir. Bu çalışmanın sonuçları brusellozla mücadelenin beklenen ve kötümser senaryolar için mali açıdan rasyonel olduğunu göstermiştir. Bununla beraber, mali açıdan rasyonel bir kontrol stratejisinin, her zaman için teknik olarak da uygun veya halk sağlığı açısından da rasyonel anlamı taşımayacağı unutulmamalıdır.

Anahtar sözcükler: *Bruselloz, Büyükbaş, Kontrol, Maliyet, Mali, Prevalans*

INTRODUCTION

Brucellosis is a zoonotic disease that causes serious health problems in animals and humans. The disease leads to serious financial losses as it causes reductions in the performance of infected animals and humans, leads to

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yield and labor losses, and entails diagnosis and treatment expenditures. Country-wide total financial losses for 2009 in Turkey caused by brucellosis, respectively in optimistic, expected and pessimistic scenarios, were calculated as $20.066.875, $41.337.446 and $61.711.571 [1].

Disease reports and serosurveys on brucellosis in Turkey indicated that, despite country-wide infection control efforts over many years, the disease is still prevalent [2-7]. In 2010, the numbers of *B.abortus* and *B. melitensis* outbreaks in livestock enterprises for cattle and small ruminants were reported as 412 and 199 respectively; also brucellosis infected human cases were reported as 7703 [8,9]. This situation clearly indicates that the disease causes large country-wide financial losses.

For the assignment of resources needed in the fight against the infection, the submission of proper reasons to public authorities is required. For this reason, it is necessary to perform economical and/or financial analysis to clearly present the costs and benefits of infection control strategies. In this study, alternative infection control strategies were designed under three different scenarios and cost-benefit analyses were performed to determine the most financially rational brucellosis control strategy for Turkey.

MATERIAL and METHODS

Data Collection

The required data was provided by Delphi Expert Opinion Surveys (DEOS) conducted in two rounds with 32 specialist veterinarians, Republic of Turkey Ministry of Food, Agriculture and Livestock (TMFAL) and the TURKVET veterinary-information system. The DEOS were conducted over two sessions in Ankara, Sinop, Igdir, Hatay and Balikesir provinces, which are located in five different geographical regions of Turkey. Data collection started in July 2008 and continued until the end of September 2009.

Designed Alternative Infection Control Strategies

It is indicated that the theoretical base for the control of brucellosis exist over fifty years and comprehensive elimination schemes have been successfully operated in many countries [10]. Considering the technical and financial resources of TMFAL and legal regulations in Turkey, four separate brucellosis control strategies were designed as follows:

According to 1st strategy, all of the young and adult animals have been vaccinated. After reaching/achieving the target prevalence (0.1%) for each species, vaccinations will be terminated and in the same year test and compulsory slaughter methods will be implemented throughout the country. In accordance with test and compulsory slaughter methods, positive detected animals will be sent to slaughterhouse. Payments are only made to positive cattle according to compensation policy of TMFAL and there is no any compensation payment for positive ovine in Turkey.

According to 2nd strategy, only young animals, three to six month old female bovine and three to six month old male and female ovine have been vaccinated. After reaching the target prevalence for each species, 0.1%, vaccinations will be terminated and in the same year test and compulsory slaughter methods will be implemented throughout the country. In accordance with test and slaughter methods, positive detected animals will be sent to slaughterhouse.

According to 3rd strategy, only young animals, three to six month old female bovine and three to six month old male and female ovine, have been vaccinated throughout the country. Test and compulsory slaughter methods have been implemented simultaneously in only infection/outbreak zones. In other words, vaccination, test and compulsory slaughter practices have been combined and started from the first year, without reaching target prevalence. These practices will continue to until reaching the target prevalence. This strategy has put into practice after 2008 by TMFAL.

According to 4th strategy, all of the young and adult female animals have been vaccinated in provinces where 1% or more prevalence is observed and also in infection/outbreak zones. Test and compulsory slaughter methods have been implemented simultaneously in only infection zones. In other words, vaccination, test and compulsory slaughter practices have been combined and started from the first year, without reaching target prevalence. These practices will continue to until reaching the target prevalence. This strategy was being implemented before 2008 by TMFAL.

Cost-Benefit Analysis for Different Control Strategies

In this study, the costs incurred by brucellosis control strategies consist of vaccinations, testing, diagnosis, compulsory slaughter, transport and workforce expenditure in application; while the benefit of these strategies is reduction of disease originated losses by the reduction of the prevalence of brucellosis. The study is taken as reference for the Turkey-wide, brucellosis-originated financial losses [1]. We also taking into account last 10-year average inflation and interest rates for choosing the appropriate discount rate is 10%. Unit values of the some of the important parameters are given in *Table 1*.

Due to the unreliability and/or lack of the some required data, an advanced model could not be generated. In this study, simple mathematical equations were used in order to make a prediction for the future prevalence of

Table 1. *Some of the important parameters considered in financial analysis*
Tablo 1. *Mali analizlerde dikkate alınan bazı önemli parametreler*

Parameters	Value	Source
The total number of bovines in Turkey	10 859 942	TSI[1]
The total number of ovines in Turkey	29 568 152	
The total number of three to six month old female bovine in Turkey	434 398	TSI[1] and TVIS[2]
The total number of three to six month old male and female ovine in Turkey	1 478 407	
The total number of annually vaccinated bovines	434 397	TVIS[2]
The total number of annually vaccinated ovines	1 478 407	
Total number of compulsory slaughter cattle	3840	
The number of outbreaks resulted from *B. abortus,* in 2009	865	
The number of outbreaks resulted from *B. melitensis,* in 2009	131	
The number of villages in Turkey	35 000	TSI[1]
Average number of samples sent from an enterprise in which infection was observed	10	Survey
Average number of visits to livestock enterprises infection is detected, until the eradication of the infection	9	
Average time spent for bureaucratic procedures like data entry (hour)	4	
Average time spent in a laboratory to analyze one sample (hour)	4	
Average time spent in the field for vaccinations (hour)	8	
Target prevalence values for bovine and ovines	0.1%	Assumption
Initial prevalence of brucellosis in bovine	1.43%	TMFAL[3]
Initial prevalence of brucellosis in ovine	1.97%	
Expected immunization rate after the vaccination	75%	VCRI[4]
Discount rate chosen for the financial analysis	10%	TSI[1]
The cost of one dose of vaccine for young cattle	$0.73	TMFAL[3]
The cost of one dose of vaccine for adult cattle	$0.47	
The cost of one dose of vaccine for ovines	$0.14	
Average compensation paid by the state for an infected bovines	$617	
Average compensation paid by the state for an infected ovines	$89	
Average daily workforce costs for veterinarians	$9	Survey and Calculation
Average daily workforce costs for medical technicians	$6	
Average daily workforce costs for drivers	$5	
Average daily workforce costs for laboratory specialist	$11	
Average costs of analysis of suspected samples in a laboratory	$24	
Average cost of medical tools and equipment (Blood collecting tube, injection syringe, cannula, etc.) used in a village	$11	
Average cost of transportation to go to the village	$28	

[1] Turkish Statistical Institute, [2] TURKVET Veterinary Information Systems, [3] The Ministry of Food, Agriculture and Livestock, [4] Veterinary Control and Research Institutes

brucellosis. Prevalence models were used to determine the benefits obtained by applying the strategies. The fundamental factors of these models were based on the calculation of the effects on prevalence of the number of animals immunized through vaccination and brucellosis positive animals are sent to compulsory slaughter.

For every strategy, initial prevalence values were taken as 1.43% for cattle and 1.96% for ovines; these values were taken from the most extensive country-wide sero-survey results conducted by the TMFAL [2]. Sensitivity and specificity of the Complement Fixation Test are taken into account 89.0% and 83.5%, respectively [11]. The period required to reach 0.1% prevalence was used to determine the application period for each strategy. In other words, time period was determined by prevalence values of the different strategies. Detailed explanations related to models were given below;

1st model

For bovines

End of the 1st year value, $P_{B1} = [((B \times P_B) - (V_B \times I_B)) + C_s)]/B$

End of the 2nd year value, $P_{B2} = [((B \times P_{B1}) - (V_B \times I_B)) + (C_s \times (PB_1/PB_0))]/B$

End of the 3rd year value, $P_{B3} = [((B \times P_{B2}) - (V_B \times I_B)) + (C_s \times (PB_2/PB_1))]/B$

For ovines

End of the 1st year value, $P_{O1} = [(O \times PO_0) - (V_O \times I_O)]/O$

End of the 2nd year value, $P_{O2} = [(O \times PO_1) - (V_O \times I_O)]/O$

End of the 3rd year value, $P_{O3} = [(O \times PO_2) - (V_O \times I_O)]/O$

Note: For bovines and ovines, similar formulas were used for following years until the prevalence value reach targeted value.

Where;

B = The total number of bovines in Turkey

O = The total number of ovines in Turkey

V_B = The total number of annually vaccinated bovines

V_O = The total number of annually vaccinated ovines

P_B = Initial prevalence of brucellosis in bovine

P_O = Initial prevalence of brucellosis in ovine

P_{B1} = End of the 1st year prevalence in bovine

P_{O1} = End of the 1st year prevalence in ovine

P_{B2} = End of the 2nd year prevalence in bovine

P_{O2} = End of the 2nd year prevalence in ovine

I_B = Expected immunization rate after the vaccination in bovines

I_O = Expected immunization rate after the vaccination in ovines

C_s = Total number of compulsory slaughter cattle

2nd model: The differences of the second strategy from first one are as follows,

$B_{3\text{-}6}$ = The total number of three to six month old female bovine in Turkey

$O_{3\text{-}6}$ = The total number of three to six month old male and female ovine in Turkey

There is no another change in the formula.

For bovines and ovines:

End of the 1st year value, $P_{B1} = [((B_{3\text{-}6} \times P_B) - (V_B \times I_B)) + C_s)]/B$

End of the 1st year value, $P_{O1} = [(O_{3\text{-}6} \times PO_0) - (V_O \times I_O)]/O$

3rd model: The differences of the third strategy from second one are as follows,

In this strategy, vaccination, test and compulsory slaughter practices have been combined and started from the first year, without reaching target prevalence. Therefore, "C_s" should be removed from the total number of infected bovines. In another words, it is contributes to decreasing of prevalence. There is no another change in the formula.

For bovines

End of the 1st year value, $P_{B1} = [((B \times P_B) - (V_B \times I_B)) - C_s)]/B$

4th model: The differences of the fourth strategy from third one are as follows,

B = The total number of young and adult female bovines have been vaccinated in provinces where 1% or more prevalence is observed and also in infection zones.

O = The total number of young and adult ovines have been vaccinated in provinces 1% or more prevalence is observed and also in infection zones.

There is no another change in the formula.

RESULTS

The costs and benefits of the application of four different brucellosis control strategies and the Net Present Value (NPV) and Benefit-Cost Ratio (BCR) were summarized in *Table 2, Table 3,* and *Fig. 1* below.

Table 2. *Costs of the alternative brucellosis control strategies (U.S. Dollar)*
Tablo 2. *Alternatif bruselloz kontrol stratejilerinin maliyetleri (Amerikan Doları)*

Cost Components	1st Strategy	2nd Strategy	3rd Strategy	4th Strategy
I. Total vaccination expenses	6.062.151	324.878	818.822	430.791
I. a. Vaccination of bovines	3.940.398	201.424	327.529	185.240
I. b. Vaccination of ovines	2.121.753	123.454	491.293	245.551
II. Transport and workforce	5.442.500	3.211.250	3.211.250	1.948.549
II. a. Transportation	979.650	995.487	995.487	350.738
II. b. Workforce	4.462.850	2.215.763	2.215.763	1.597.811
III. Test, diagnosis and compulsory slaughtering	2.922.550	2.922.550	4.662.033	4.662.033
III. a. Laboratory analyses of samples	1.519.726	1.519.726	1.538.471	1.538.470
III. b. Medical tools used in screening tests	350.706	350.706	-	-
III. c. Compensation payment	29.225	29.225	2.377.637	2.377.637
III. d. Workforce and bureaucratic procedures	1.022.893	1.022.893	745.925	745.926
Total Costs by the end of projected period	$60.445.805	$38.283.830	$52.152.630	$42.248.238

Table 3. Results of the financial analysis for the different strategies and scenarios.
Tablo 3. Farklı strateji ve senaryolar için mali analizlerin sonuçları

Financial Appraisal	Scenarios	1st Strategy	2nd Strategy	3rd Strategy	4th Strategy
NPV [1]	Optimistic	- 16.6	- 3.1	- 16.0	- 5.9
	Expected	25.5	29.2	25.0	32.3
	Pessimistic	49.2	41.9	35.8	50.8
BCR [2]	Optimistic	0.63	0.86	0.58	0.80
	Expected	1.56	2.26	1.66	2.06
	Pessimistic	2.08	2.84	1.95	2.67

[1] Net Present Value (million US Dollar, [2] Benefit-Cost Ratio

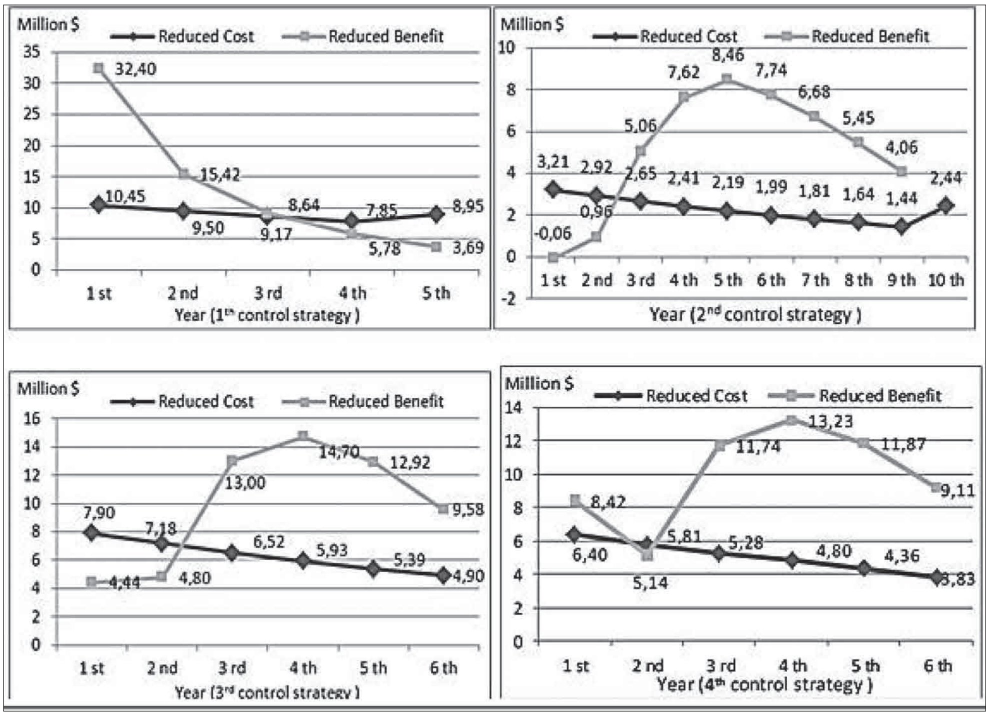

Fig 1. Reduced costs and benefits for different control strategies by years

Şekil 1. Farklı stratejiler için yıllar itibariyle indirgenmiş maliyet ve faydalar

For the first strategy, the highest expenditures are 50% for "country-wide vaccination costs" and 45% for "transport/arrival and workforce originated expenditures". It is presumed that this strategy will be sustained for five years for both bovines and ovines. *Fig. 1* demonstrates that the benefits of the first strategy are high for the first two years, but for the following years, the benefits obtained from this strategy are reduced. Accordingly, for the first four years, expenditures decreased steadily but costs for additional tests and compulsory slaughter in the last year caused a rise in expenditures.

For the second strategy, the highest costs will be 84% for "transport and workforce originated expenditures", and the biggest portion of this consists of workforce costs. Although with the estimated sustained period of ten years for bovines and eight years for ovines this strategy has less expenditure than the first, it is important to notice that it takes more time to reach the target prevalence value. *Fig. 1* demonstrates that the benefits of the second strategy will show a remarkable increase by the third year and peak in fifth year before beginning to decrease steadily. While in the first nine years the expenditures are decreased, in the last year, the costs for additional tests and compulsory slaughter will rise.

For the third strategy, the highest costs will be 54% for "test and compulsory slaughter costs in the disease outbreak zone". It is estimated that the strategy will be suspended for six years for both cattle and small ruminants. *Fig. 1* shows that benefits of the third strategy will show a remarkable increase by the third year and peak in the fourth year, but will then begin to decrease steadily. For expenditures, a steady decrease is estimated over six years.

The highest costs for the fourth strategy will be "test and compulsory slaughter costs in the disease outbreak zone" at 66%. It is estimated that for bovines, it will continue for six years and for ovines it will continue for five years. The benefits of this strategy are similar to the benefits of the third.

Calculated NPV and BCR values for four separate brucellosis control strategies under three different scenarios were demonstrated in *Table 3*. For all strategies in the scope of the expected scenario, BCR was found to be higher than 1 and the highest BCR value observed in the second strategy was 2.26. For both strategies in the scope of optimistic scenario, NPV negative was observed and the highest BCR value all among the strategies is determined as 0.86 for the second strategy. For both strategies in the scope of the pessimistic scenario, the NPV positive was observed and the highest BCR value all among the strategies is determined as 2.84 for the second strategy.

Finally, the second strategy was determined to be the most financially advantageous of all the scenarios in conclusion of the financial analysis.

DISCUSSION

One of the most important factors in determining which strategy to use in the fight against brucellosis is evaluating the strategies not only from technical aspects but the strategies should also be applicable and rational from an economical aspect. Therefore, it was the aim of this study to determine the costs and benefits of different strategies planned for the control of brucellosis in Turkey.

A value of BCR 2.96 which was determined for a vaccination program for 30 years, is close to the value of the expected scenario of the second strategy, and for the pessimistic scenario it is close to second and fourth strategies in of our study. BCR 5.04 which was determined for test and slaughtering strategies is higher than all strategies BCR values in this study. The main reason for this is probably that they did not take the effects on public health and exportation potential into account [12]. BCR 1.13 which is determined for a vaccination based bovine brucellosis control program is close to the ratios in second and fourth strategies in the optimistic scenario in this study [13]. The total net benefits from the application of different bovine brucellosis control programs for 19 years is calculated as $296 million to $768 million [14]. This result is much higher than our findings and the probable reason was the program applied for a longer period and the cattle population in the United States is proportionally much higher than Turkey. A study was conducted for a cattle brucellosis control program based on a test and slaughtering which begins with a brucellosis prevalence value of 11% and continues over 14 years shows 0.59 BCR and negative for NPV [15]. This ratio is much lower than our findings except for the optimistic scenario. The reasons for this difference could be that they did not take the effects on public health into account; and did not make any attempt to reduce the high initial prevalence with any vaccination program, before the application of testing and slaughtering was initiated. An accelerated bovine brucellosis eradication strategy based on the testing-slaughtering method with 0.6% initial prevalence was studied [16]. The results of this study indicated that the BCR value was higher than 1 after the fourth year, a total benefit of $236 million while a total cost of $43 million for the tenth year. A comparison with our study could not be made as the strategy planned in our study was not the same as Kouba [16]. The reason for Kouba's observation that the financial benefit of eradication is high is that he considered not only losses in the animal production system but also the benefits obtained by brucellosis eradication which is the status acquired by free from brucellosis. By the application of a mass vaccination program for cattle and small ruminants for ten years, 51.856 human beings could be protected from brucellosis. For this program, a figure of 3.2 BCR and $18.3 million NPV was determined. Despite the fact that we took not only human health but also animal production losses into consideration, the BCR for all scenarios and strategies in this study is lower than Zinstag et al.[17].

By considering cattle brucellosis in Turkey for a period of 20 years, Yurtalan performed the economical analysis of different control strategies [18]. The most rational strategy determined in this study financially was "vaccination of whole population for every year". The 6.77 BCR and $175.102.324 NPV achieved in his study are much higher values than any strategy in any scenario in our study. The main reasons for this inconsistency could be differences between initial prevalence and the periods of the application of these strategies. Yurtalan [18], determined 0.62 BCR and $136.423.313 NPV for another strategy in which test and slaughtering methods were applied for four years; also, he determined 0.77 BCR and $-70.171.774 NPV for a different strategy in which test and slaughtering methods were combined with vaccination and applied for a period of three years. Due to there being no similarities between any strategies in our study, no comparison could be made.

It is a well-known fact that testing, culling, vaccination and notification are most effective control methods for brucellosis. It is indicated that reducing the level of testing would have a major effect on the rate of spread of infection, should it be important [19]. Abortion notification is a very important additional means of surveillance. It may be feasible to eradicate *B. ovis* from flocks with moderate to high (10% to 38%) prevalence of infection by culling on the basis of 2 sequential tests. Vaccination was found to be more effective as a control strategy when the prevalence of flock infection was high (greater than 15%); however, it did not substantially reduce *B. ovis* transmission when the prevalence of flock infection was low, less than 10% [20].

It is suggested that to make a good economic assessment of a disease the problem should be approach as a system, if relevant epidemiological, medical and economic variables are not taken into consideration to evaluate the impact the result will not be reliable and the benefits for producers and consumer of animal products will not be as good as expected [21].

The results of these studies indicated that fighting with infection is financially rational for expected and pessimistic scenarios, and BCR is bigger than one in all of the strategies for the mentioned scenarios. Also, the second strategy in which it was designed to continue for ten years with cattle and eight years with small ruminants is more advantageous than the presently applied strategy (3rd strategy). Nevertheless, it is very important to consider a strategy that is optimal financially, but may not be suitable technically or in respect to public health.

Different control strategies, periods, resources and methods could be planned for the financial and/or economical analysis of brucellosis and infection like it in further studies. It is also of great importance to know the incidence and prevalence of the disease, social-economical structure of livestock enterprises, legal regulations, and technical and financial resources of authorized ministries in the relevant countries. However, use of current and reliable data in the estimation of benefits and costs of infection control strategies should not be forgotten.

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