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Full Research Article

ECONOMIC EVALUATION OF A PROGRAM FOR MONITORING AND CONTROLLING TRICHINELLA IN PIGS

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Abstract

Introduction. Trichinellosis is a cosmopolitan anthropozoonosis, and is a group of systemic diseases caused by larval forms of *Trichinella*. This is one of the oldest and most controversial parasitic zoonoses that has been in the forefront of veterinary, medical and biological research for many years. Parasites from the genus *Trichinella* were diagnosed in more than one hundred species of domestic and wild mammals and birds. The aim of this study was economic evaluation of a program for monitoring and controlling *Trichinella* in pigs.

Materials and Methods. A systematic pest rodent control program deemed suitable for monitoring and controlling *Trichinella* in pigs was implemented in a representative test zone. The results of the pest rodent control program were analyzed using cost-benefit analysis to determine if a similar program would be suitable for a larger land area.

Results and Conclusions. Prior to pest control, the incidence of *Trichinella* in pigs living in the test zone increased annually, while after systematic pest rodent control, the incidence of

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Trichinella-positive pigs decreased. These results, as well as relevant economic indicators, enabled us to design two mathematical models describing the control and monitoring of *Trichinella* in a larger land area. In this area, Srem Region, Serbia, a suitable *Trichinella* control program in pigs is clearly justified because the profit to cost ratio was positive for both models.

Key words: pest rodent control, profit and cost analysis, trend, trichinellosis

INTRODUCTION

Trichinellosis is a zooparasitosis, a disease that, according to the International Zoosanitary Codex, falls in the list of "C" infectious diseases. On the basis of international regulations and codices, the measures a country should conduct on its territory in order to be declared free of trichinellosis are precisely determined. Based on the law in Serbia (Official Gazette of RS, no. 12/2019), it is mandatory to report the infection of animals and any disease found in humans. There are several other legal protocols in Serbia that closely regulate the necessary actions and procedures that must be undertaken in order to detect, monitor, control and eradicate *Trichinella* in pigs (Mirilović, 2006; Teodorović et al., 2007).

Preliminary studies that have been conducted indicate that trichinellosis is a very serious health and economic problem in Serbia (Mirilović et al., 1997; Teodorović et al., 1997). To assist in the eradication of this disease in humans, the animal health protection measures in Serbia provide for the examination of all slaughtered pig carcasses for the presence of *Trichinella*, and for implementation of systematic pest rodent control in pig farms and smallholdings. In developing a program for the control of *Trichinella* in pigs in a specific geographical area, it is necessary to undertake a whole range of measures and to determine the exact dynamics of their implementation. One of the most important links in the spread and maintenance of trichinellosis in a given territory, not only in Serbia, is the rat. Therefore, one of the most important factors is the implementation of systematic pest rodent control, although valorization of all other indicators is also conducted (Stojčević et al., 2004; Mirilović et al., 2006; 2009). One of the most important aspects in the development of such a pest control program is to identify and quantify all the costs necessary for the proper and continuous execution of the program.

Official animal health protection measures in Serbia include diagnostic examinations of all slaughtered pig carcasses for *Trichinella* and implementation of systematic pest rodent control. This is necessary in order to detect, monitor and prevent the spread of infection with *Trichinella spp.* by pigs. Before developing a program for the control of *Trichinella* in pigs in a specified area, a wide range of measures and the exact dynamics of their implementation must be determined. Creating a trichinellosis eradication program is a complex, delicate, and very extensive task. The aim of this study was to design and implement a suitable *Trichinella* control program for pigs in a test zone, to detect, monitor, and prevent the spread of infection of pigs with *Trichinella*, and finally, to determine whether a similar, suitable *Trichinella* control program would be cost-effective over a larger geographical area.

MATERIALS AND METHODS

The research was carried out in one settled area, hereafter called the test zone, with 1,121 households and around 3,000 residents within the epidemiological area of Srem. The designated area is flat land, with a large livestock output that is pig-oriented. This includes a large number of fattening pigs as well as pigs raised for household consumption. The research spanned a 10-year period. The slaughtered pigs from the test zone were analyzed in two groups, one encompassing pigs slaughtered in households and the other covering pigs slaughtered in industrial slaughterhouses. Trichinelloscopic examination was also conducted in two ways: trichinelloscopy and digestive testing of aggregate samples (Teodorović et al., 2000; Mirilović, 2006; Marucci et al., 2016).

To determine the approximate number of rats in the household yards within the studied area, we used a scale to estimate the number of rodents in a given area (Hrgović et al., 1991). According to this scale:

- If no rats are seen but pawprints and feces are found, as well as any minor damage caused, 0 – 100 are present.
- If rats are seen occasionally at dusk or at night, then 100 – 500 are present.
- If rats are seen regularly at night and occasionally during the day, 500 – 1000 are present.
- If a large number of rats are seen throughout the night, and some are apparent during the day, along with visibly large damage, >1,000 are present.

Systematic pest rodent control was carried out in the test zone using the preparation Brodisan, a liquid concentrate with 0.25% bromadiolone (3- (3- (4-bromobiphenyl-4-yl) -3-hydroxy-1-phenylpropyl) -4-hydroxycoumarin) to prepare poisoned bait to reduce the number of rodents. The bait was prepared according to the following recipe: 92.80% ground corn, 5.00% sugar and 2.20% Brodisan (Backhans and Fellstrom, 2012; Moran, 2012; Sayer, 2017). To carry out this method of systematic pest control, a specific amount of bait (based on yard size) is necessary. Bait was laid down on the rodents' runways and also next to any visible holes in the houses within the test zone. In addition to pest control in the households, grave pits, garbage landfills, agricultural cooperatives and schools and sports grounds were also submitted to pest control. Pest control was initially carried out in October, when rodents move from the fields to the animal environs (livestock facilities, silos, barns, etc.) where food for livestock is stored or in the barns where the cattle are housed (Mirilović, 2006).

Systematic pest rodent control in the test zone was conducted after five years. Thus, the first five-year period covered the years prior to systematic pest control, while the second five-year period covered the years after the pest control.

Following the implemented measures, two models for analyzing the cost-benefits of tracking and controlling *Trichinella* were developed. Cost-benefit analysis determined the economic effects of applying the pest rodent control program that would reduce/eliminate *Trichinella* in pigs and trichinellosis in humans. When implementing the program it is necessary to valorize all costs and profits. After the analysis and determination of the present value of future costs and profits, economic evaluation of the program was carried out on the basis of the following criteria: Net Present Value (NPV), Cost and Benefit Ratio (CBR) and Internal Return Rates (IRR). As a criterion of eligibility regarding the economic justification for implementing a *Trichinella* control program, a positive evaluation of the program occurred when NPV >0 and CBR ≥1. Economic evaluation of the acquired model was carried out using the Cost-benefit analysis tool (Tešić et al., 2002; Mirilović, 2006; Tešić et al., 2011).

For statistical analysis, descriptive statistical indicators (measures of central tendency and measures of variation) were used. Further analysis was dependent on whether or not the analyzed data was normally distributed. The normality of the analyzed data was tested by the Kolmogorov-Smirnov test. In the case of normally distributed data, parametric statistical indicators were used to compare significant differences between groups. When data was not normally distributed, nonparametric statistical indicators were used. The best customized line was also displayed, while the criterion for accepting the best custom line was the correlation coefficient. The significance of the differences was established at the significance levels of 5 and 1%. Statistical analysis of data was conducted using GraphPad Prism version 6.00 for Windows (GraphPad Software, San Diego, California USA), www.graphpad.com and Microsoft Excel.

RESULTS

In the designated test zone over the course of the investigated 10-year period, 95,500 pigs were slaughtered, whether by slaughterhouses or in any given household. Of this number, 1,224 (1.28%) of the pigs tested positive for *Trichinella*. The largest number of pigs diagnosed with *Trichinella* in any one year was in the fourth year of observation. There were 272 infected pigs, which accounted for 3% of the number of slaughtered pigs that year (9,057), or 0.28% of the total number (95,500). Of all the years studied, the largest number of infected pigs was diagnosed from the fourth to sixth year of observation when a total of 727 pigs were diagnosed, i.e. 59.39% of all infected pigs during the 10-year period. The smallest number came from the first year with only 6 (0.49%) pigs infected during that time (Table 1).

Table 1. Numbers of slaughtered and *Trichinella*-infected pigs in the test zone over a ten-year period

Year	No. of pigs slaughtered	No. of pigs that tested positive for *Trichinella*	% of *Trichinella*-positive pigs per year
1	8,334	6	0.07
2	9,524	53	0.58
3	9,489	112	1.18
4	9,057	272	3.00
5	8,652	243	2.81
6	10,783	212	1.97
7	9,776	133	1.36
8	9,791	75	0.77
9	10,489	69	0.66
10	9,605	49	0.51
Total	95,500	1,224	1.28

Systematic pest rodent control of the examined settlement

We estimated the number of rats in the household yards based on a survey that encompassed a subsample of 50 households. The households surveyed had all been registered with trichinellosis two or more times. The survey was conducted in February, and among all households surveyed, only three of them had noted pest rats in the five years prior to the study. The remaining households had never noted pest rats at any point. The results from the survey, however, showed that 72% of households had between 500 and 1,000 rats, 18% had 100 to 500 rats, and 10% hosted over 1,000 rats. (Figure 1)

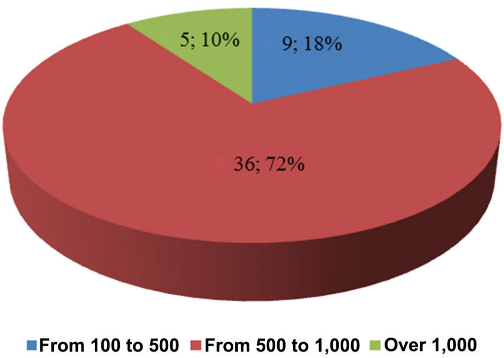

Figure 1. Number of rats per household

After collecting data about the probable number of rats per household, and based on the already present and increasingly frequent occurrence of *Trichinella* in pigs, (in a four-year period (Table 1), 443 pigs were found to be *Trichinella*-positive), we began with preparations for systematic pest rodent control. Systematic pest rodent control included the following elements:

Determination of the surface of the ground and the buildings to be treated: On the basis of land registry data and records located in the cadastral records office, we established the size of the land holdings in the test zone. The total land area of each household where systematic pest control was carried out is the area covered by a house with a garden, and the animal environs including the auxiliary facilities for storing animal feed and machinery and the livestock facilities. By summing all these elements, we found the total area of all households was 12,779.40 acres, and the average household size for performing systematic pest rodent control was 11.40 acres or 1,140 m^2.

Determination of nutrient and rodenticide requirements for bait preparation: Based on expert opinion and our own experience, second-generation anticoagulants were chosen as the means for implementing systematic pest rodent control. After only one consumption event, these poisons prevent the rodent's blood from coagulating, increase permeability and lead to spraying of blood vessels, thereby resulting in hemorrhages of different sizes forming in organs and organ systems. Systematic pest rodent control in the test zone was carried out with the Brodisan preparation.

On the basis of our previous experience and literature data, we determined the optimal amount for the first placement of bait is about 200 g per acre. Based on this figure, we calculated the total amount of bait required in the average yard is 3.65 kg. Of this amount, 2.28 kg was first placed on the rat movement paths, in livestock storage facilities, attics, landfills, silos and animal feeding facilities, as well as visible holes. The remaining amount (average 1.37 kg per household) was left with the host to supplement anywhere it was missing, or where the rodents had consumed the bait. The total amount required for all households was 4,100 kg of bait. According to the pest rodent control plan, bait was also divided among these sites: grave pits (250 kg of bait), three garbage dumps (70 + 50 + 40 kg), agricultural cooperatives (180 kg), and schools with sports facilities (150 kg). A total of 740 kg of bait was used for these areas. The total required amount of bait for one systematic pest rodent control event in the test zone was 4,840 kg.

Determining the labor force necessary for the timely and proper implementation of systematic pest rodent control: Based on technological norms and expert opinion, we found that one pest controller during normal working hours can install, bait and monitor traps for about 50 households. Additionally, one supplier with a vehicle can serve a maximum of six pest controllers. Based on the number of households in the test zone and the average household land area, we found that for the systematic pest rodent control of this settlement, which would last for two working days, 12 pest controllers, 2 suppliers with delivery vehicles, and one coordinator were needed.

Calculation of auxiliary materials for implementing systematic pest rodent control in the test zone (cardboard pads for trap placement, plastic buckets and blades, plastic bags, protective equipment). Based on the amount of bait, the number of traps and the average household land area, we calculated 28,000 cardboard pads for placing traps, 15 x 10 kg plastic buckets, 15 plastic spoons with a capacity of 100 grams, and 1,500 plastic bags were needed. Plastic bags were used to contain the bait which was added to the bait stations at certain time intervals. Plastic bags (100) were used to collect and innocuously remove dead rats. To protect against possible direct contact with toxic substances or dead rats, each pest controller used protective equipment consisting of work clothes, raincoats, rubber aprons, gloves, boots and protective masks.

Personnel training, population education and information for residents: Permanently employed staff from the Department for Disinfection and Pest Control, Sava Veterinary Station, Sremska Mitrovica, conducted the pest control operation. In addition to these experts for the implementation of pest control, six workers were also employed *via* the Employment Bureau. To prepare residents for pest control, at a time when farmers do not have too much field work, an educational lecture entitled *Stop Trichinellosis* was organized in the local Culture Center, which was attended by around 550 residents. This was alongside occasional lectures on the mode of transmission and control of trichinellosis and a screening of the film *Trihinellosis* by Dr. Radovan Pavlović. In the lectures, the systematic pest rodent control plan was described in detail to the audience, giving their duties in collecting corpses of dead rats and preventing other animals from coming into contact with the set traps. Also, the local authority printed posters that contained information about the period and required activities for the systematic pest control. The local hunt club was involved in capturing stray dogs at ten days before the pest rodent control was conducted and two months after placing the traps, thus removing stray dogs that are potential *Trichinella* transmitters.

Implementation of pest control, replenishing traps and innocuous removal of dead rats: Systematic pest rodent control of the test zone was initially carried out in the first half of October. The pest control was organized so that trap placement took the equivalent of two work days by two teams each with six pest controllers and one supplier who delivered the necessary quantities of bait to each team. After laying out the traps on the third and eighth days, control was carried out and the traps and other areas were supplemented with the specified quantities of bait. After that, the pest controllers collected the dead rats, placing them into nylon bags specifically made for grabbing rats and safely incinerating them.

Control of pest rodent control conducted and processing of results: After the first systematic pest control carried out in October, systematic pest control was performed over the next three years between the months of March and October. At all times between two pest controls, prepared bait was available at the local veterinary clinic and provided received free of charge to residents if needed. The result of these systematic pest controls, in addition to reducing the population of rats and the lesser economic damage they caused, was a fall in the number of *Trichinella*-positive pigs.

Effects of systematic pest control carried out in the test zone: Systematic pest rodent control of the test zone was performed in October after five years of observation. Five days after the pest control was carried out, the pest controllers added baits to those bait stations where they had been eaten and, in cooperation with the residents, collected all 6,000 dead rodents into impermeable bags. Rat corpses were transported by special vehicle a tomb located in the south-eastern part of the village and incinerated. Ten days before the systematic pest control took place, the local hunt club caught 11 stray dogs at first, and then another 6 on the second attempt.

In the first five-year period before the systematic pest control, 45,296 slaughtered pigs originating in the test zone were examined for *Trichinella*. *Trichinella* was found in 686 (1.51%) of these pigs. Trend lines showing the number of infected pigs in this five-year period are shown in Figure 2. The increase in infected pigs over time is satisfactorily described by the two trend lines, because for both lines, the correlation coefficients were $r_{xy} = 0.88$. Analyzing the number of infected pigs in this first five-year period, we concluded the average annual increase in the number of *Trichinella*-infected pigs in the test zone was about 70 (69.30; Y = -70.7 + 69.3xi).

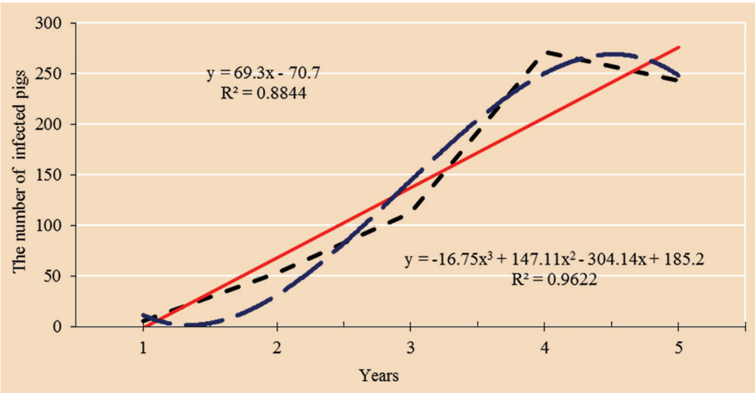

Figure 2. Numbers and trends of *Trichinella*-infected pigs in the test zone before systematic pest control

In the second five-year period, 50,444 slaughtered pigs originating in the test zone were examined. *Trichinella* was detection in 538 (1.07%) of these pigs. Trend lines showing the number of infected pigs in this five-year period are shown in Figure 3. Analyzing the trend of the number of infected pigs in the second five-year period after the systematic pest rodent control in the test zone, and based on the negative parameter b from the straight line trend, the average annual decrease in the number of infected pigs was about 40 (39.80; (Y = 226.2 - 39.8x), i.e. 37% fewer infected pigs than in the previous year. The trend is better described by the 2nd degree polynomial, because its correlation coefficient was $r_{xy} = 0.99$.

The difference in the numbers of *Trichinella*-infected pigs in the test zone during the five years before and the five years after the systematic pest control was significant ($p<0.01$).

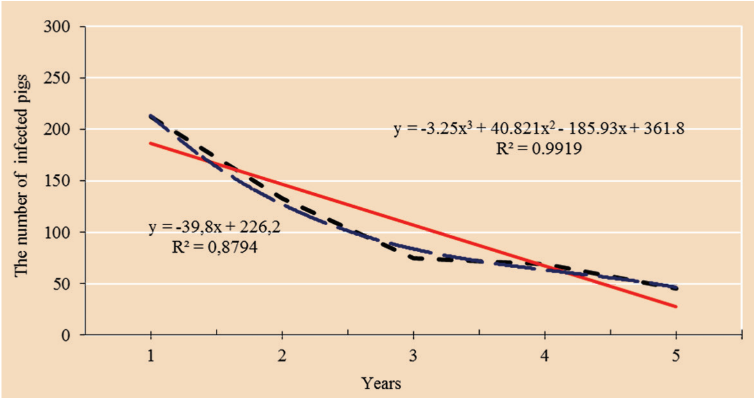

Figure 3. Numbers and trends of *Trichinella*-infected pigs in the test zone after systematic pest rodent control

Determination of factors and development of a program for monitoring and control of *Trichinella*

During development of our program, we used the following costs, obtained *via* previous research and technical and technological standards:

- The cost of marking pigs in the first year was planned on the basis of the average number of pigs, and it was reduced annually by 20% after the pest control was implemented.
- The costs of serological examination were planned on the basis of the number of pig samples that would be necessary to ensure detection of *Trichinella* larvae in the pig carcasses with 95% accuracy. Since the pig population is not a uniform population, but rather consists of a large number of categories, it was necessary to stratify the sample obtained so that all categories of pigs were satisfactorily represented.
- The planned costs of pest control were based on the costs of the pest control conducted. The total cost of pest control included cost of materials (based on the required amount of bait per landholding) and labor. The pest control was carried out twice annually (in March and October), and consisted of a large number of visits (3-5) to place and replenish baits, and remove and incinerate dead rats and any material remains.
- The planned costs for trichinelloscopic examinations were determined based on the number of slaughtered pigs in the test zone.

All listed costs were calculated on the basis of the list price list provided by the Veterinary Chamber (pest control, pig marking, serological analysis, trichinelloscopic examination) or on the basis of market prices (cereals for pest control and other necessary materials).

The primary cost benefit expected comes from the smaller number of pigs with *Trichinella*. Savings will also come in reducing costs for trichinelloscopic examinations and finally, a reduced number of hospitalized patients suffering from trichinellosis. On the basis of this, the projected profit is expected from:

- reduced number of pigs infected with *Trichinella* (37% reduction annually);
- reduced number of trichinelloscopic examinations during program implementation (10% reduction annually);
- reduced number of hospitalized patients during program implementation (15% reduction annually).

In addition to these savings, which are a positive result of the implementation of the *Trichinella* control program in pigs, the numerous other benefits include unhindered and increased export of pork and meat products, drop in disease risk to humans, and reduced economic losses caused by animal feed contamination with rodent scat and hair. Increased production of pork and other meats can result too, but since this is not easily quantified, it was not taken into account when developing this *Trichinella* control program.

In determining the optimal duration for the development of a *Trichinella* control program, we were guided by literature data, the results of other authors and our own research. Based on all these factors, and taking into account the epizootiology and epidemiology in Serbia, the biological characteristics of the parasite and the organizational and economic characteristics of the economic milieu of the country, we determined the duration of the program should be ten years. Based on our knowledge, this is the optimal deadline for such a complex and comprehensive program to deliver relevant results.

Implementation of the *Trichinella* control program in pigs was modeled in a limited epidemiological area of Srem bounded by two rivers. In this geographically large area, which covers 3,486 km^2, seven municipalities housed 335,901 inhabitants. In these seven municipalities, there are 120 organized settlements, with an average of 96 inhabitants per square kilometer. In this area, over a ten-year period, the calculated cost for future implementation of the *Trichinella* control program was €2,901,682.35 (Table 2). Out of this total planned cost, pig marking was estimated to cost €809,152.94 (27.84% of the total planned costs) and serological diagnostics cost €505,058.82 (17.41%). The planned costs of systematic pest control were €666,458.82 (22.97%). The cost of procurement and preparation of rat baits amounted to 17.55%, and the invested work was 5.42% of the total planned cost. Costs planned for trichinelloscopic examination in the ten-year period of the *Trichinella* control program were €921,011.76 (31.73%).

Expected profit that was calculated to result from future implementation of a planned program for *Trichinella* reduction in Srem was €5,101,247.06 (Table 3). The lion's share of the profit, €2,686,070.59 (52.66% of the estimated profit) would be from reducing the incidence of pigs carrying *Trichinella*. The profit from the savings from a reduced number of trichinelloscopic examinations was estimated as €1,313,929.41 (25.76%). The savings resulting from a reduced number of human cases of trichinellosis were estimated at €1,101,247.06 (21.58%).

Table 2. Structure of planned costs (€) for the future *Trichinella* control program in the epidemiological area of Srem

Year	Pig Marking	Serological Diagnosis	Systematic Pest Rodent Control		Trihinelloscopic Examination	Yearly Total
			Material	Work		
1	98,682.35	50,505.88	117,152.94	37,788.24	221,917.65	526,047.06
2	78,941.18	50,505.88	117,152.94	37,788.24	221,917.65	506,305.88
3	78,941.18	50,505.88	58,576.47	18,894.12	166,447.06	373,364.71
4	78,941.18	50,505.88	58,576.47	18,894.12	110,964.71	317,882.35
5	78,941.18	50,505.88	47,705.88	11,341.18	66,576.47	255,070.59
6	78,941.18	50,505.88	28,388.24	9,070.59	44,388.24	211,294.12
7	78,941.18	50,505.88	20,388.24	5,894.12	22,200.00	177,929.41
8	78,941.18	50,505.88	20,388.24	5,894.12	22,200.00	177,929.41
9	78,941.18	50,505.88	20,388.24	5,894.12	22,200.00	177,929.41
10	78,941.18	50,505.88	20,388.24	5,894.12	22,200.00	177,929.41
Total	809,152.94	505,058.82	509,105.88	157,352.94	921,011.76	2,901,682.35

Table 3. Structure of planned profit (€) on implementing a future *Trichinella* control program in pigs in the epidemiological area of Srem

Year	Reduction of *Trichinella*-positive Pigs	Trichinelloscopic Screening Savings	Savings from the Reduced Number of Diseases Cases	Yearly Total
1	89,811.76	88,764.71	61,141.18	239,717.65
2	89,811.76	97,635.29	70,317.65	257,764.71
3	119,870.59	107,411.76	80,917.65	308,200.00
4	164,223.53	118,152.94	93,011.76	375,388.24
5	224,988.24	129,964.71	106,964.71	461,917.65
6	308,235.29	142,964.71	123,011.76	574,211.76
7	422,282.35	157,258.82	141,470.59	721,011.76
8	422,282.35	157,258.82	141,470.59	721,011.76
9	422,282.35	157,258.82	141,470.59	721,011.76
10	422,282,35	157,258.82	141,470.59	721,011.76
Total	2,686,070.59	1,313,929.41	1,101,247.06	5,101,247.06

Cost-benefit analysis: After establishing all the costs necessary for implementing a future *Trichinella* control program in pigs in Srem and the profits resulting from the reduction in numbers of *Trichinella*-positive pigs, i.e., a reduced number of trichinelloscopic examinations and a reduced number of human trichinellosis cases, we arrived at the economic evaluation of the projected program. The economic evaluation, i.e. the social justification of the *Trichinella* control program, was carried out using cost-benefit analysis. Since it is a dynamic method, it was necessary to discount all the monetary values that would be used in this program in order to get them to the present value. This was done using an appropriate discount factor. Based on current inflationary trends, bank interest rates and interest rate assessments for the future, we calculated that all discounts should be based on a discount rate of 3%. Using this discounting process, we determined the present value of costs and profit, and based on this analysis we determined the basic criteria for assessing the economic justification of implementing a *Trichinella* control program in the wider geographical area of Srem. The economic feasibility of the program is estimated based on the NPV, CBR and IRR. When calculating these parameters, we set up two models: model A, which includes all the costs foreseen by the *Trichinella* control program and model B that did not take into account the cost of marking pigs, since this is, in any case, carried out independently of *Trichinella* control programs.

Based on our cost-benefit analysis, both models (model A and model B) prove the economic justification of our *Trichinella* control plan, i.e. both models show that implementing a future *Trichinella* control program in pigs within the epizootic Srem region would have a positive economic effect (Tables 4 and 5). In both cost-benefit models, NPVs were positive (model A NPV = €1,652,182.14 and model B NPV = €2,334,732.57). The profit:cost ratios calculated using both models were >1 (model A CBR = 1.64, model B CBR = 1.25), indicating the projected *Trichinella* control program for Srem would be economically justified and cost-effective. The IRRs calculated by both models are shown in Table 5.

Table 4. Analysis of profit and expenses (€): cost:benefit analysis on implementation of a future *Trichinella* control program in pigs in Srem

Year	Model A		Model B	
	Cost	Profit	Cost	Profit
1	526,047.06	239,717.65	427,364.71	239,717.65
2	506,305.88	257,764.71	427,364.71	257,764.71
3	373,364.71	308,200.00	294,423.53	308,200.00
4	317,882.35	375,388.24	238,941.18	375,388.24
5	255,070.59	461,917.65	176,129.41	461,917.65
6	211,294.12	574,211.76	132,352.94	574,211.76
7	177,929.41	721,011.76	98,988.24	721,011.76
8	177,929.41	721,011.76	98,988.24	721,011.76
9	177,929.41	721,011.76	98,988.24	721,011.76
10	177,929.41	721,011.76	98,988.24	721,011.76
Total	2,901,682.35	5,101,247.06	2,092,529.41	5,101,247.06

Table 5. Analysis of profit and expenses (€): calculated present value on implementation of a future *Trichinella* control program in pigs in Srem

Year	Discount factor*	Model A		Model B	
		Cost	Profit	Cost	Profit
1	0.97	526,047.06	239,717.65	427,364.71	239,717.65
2	0.94	506,305.88	257,764.71	427,364.71	257,764.71
3	0.92	373,364.71	308,200.00	294,423.53	308,200.00
4	0.89	317,882.35	375,388.24	238,941.18	375,388.24
5	0.86	255,070.59	461,917.65	176,129.41	461,917.65
6	0.84	211,294.12	574,211.76	132,352.94	574,211.76
7	0.81	177,929.41	721,011.76	98,988.24	721,011.76
8	0.79	177,929.41	721,011.76	98,988.24	721,011.76
9	0.77	177,929.41	721,011.76	98,988.24	721,011.76
10	0.74	177,929.41	721,011.76	98,988.24	721,011.76
Total		2,901,682.35	5,101,247.06	2,092,529.41	5,101,247.06

*interest rate % 3

	Model A	Model B
NPV	1,652,182.14	2,344,732.57
CBR	1.64	2.25
IRR	29.80	49.20

calculated present value

DISCUSSION

One of the most important links in the spread and maintenance of human trichinellosis in a given territory, not only in Serbia, is the rat. In the large rodent group (Rodentia), comprising over 3,000 species, the gray rat (*Rattus norvegicus*) and the domestic black rat (*Rattus ratttus*) are the most significant in our climate. Infection of domestic pigs, as the most important factor in the transmission of disease to humans, is caused by the consumption of corpses or live rats, as well as by eating uncooked swill containing infectious larvae. The course of the infection in pigs is free of visible symptoms, so diagnosis is only at slaughter when pig carcasses can be examined (Venturiello et al., 1998). Humans are most commonly infected *via* consumption of pork and non-heat-treated or insufficiently heat-treated meat products. Human disease can commonly occur after game or horse meat consumption. *Trichinella* infections have been reported worldwide after consumption of meat from bears, walruses, foxes, sheep, cougars and dogs (Dupoy-Camet et al., 2000).

On the basis of preliminary research we have carried out, as well as on the basis of literature data (Cuperlovic et al., 2001), we found that trichinellosis is very intensely present in the epizootiological area of Srem. Mirilović (2006) and Teodorović (2007) established that in Serbia, there are endemic areas where trichinellosis occurs regularly. These areas are Srem, part of Bačka, the Mačva region and Negotin Krajina.

The number of rats in populated places varies throughout the year and has a seasonal character. During the spring and summer they move into the fields, and in the fall they return back to more populated areas. This is an important note when considering and planning the timing of systematic pest rodent control, although continuous preventive measures against rodents should be maintained. As the main vehicle in the spread of *Trichinella*, this is the best way to safely control their population.

In the first five-year period of this study, we found the number of *Trichinella*-infected pigs in the examined area, on average, increased annually by about 70. However, in the second five-year period after the systematic pest rodent control in the test zone, the number of *Trichinella*-infected pigs, on average, decreased annually by about 40.

In both cost-benefit models, monetary indicators (NPV, CBR and IRR) confirmed that if a similar, suitable *Trichinella* control program was implemented in the epizootic Srem region, the financial benefits would outweigh the monetary costs.

CONCLUSION

On the basis of examined epizootiological and epidemiological characteristics and economic significance of *Trichinella* and trichinellosis in the examined geographic area, the program developed for pest rodent control and suppression, and the calculated economic evaluations of the projected program for the wider Srem region, we conclude:

- In the test zone, the incidence of *Trichinella* in pigs over the 10-year period was 0.157%.
- Experimental data collected from pigs within the test zone showed the number of *Trichinella*-infected pigs prior to systematic pest control steadily increased by about 70 pigs annually. However, after the systematic pest rodent control, the number of *Trichinella*-infected pigs reduced by about 40 pigs annually. In the test zone, a significantly higher number of *Trichinella*-infected pigs was determined before the systematic pest control than was determined after the pest control was implemented.
- Expected profits from implementing a suitable *Trichinella* control program in Srem in the future amount to €5,101,247.06, 52.66% of which would be from the reduced number of *Trichinella*-infected pigs, 25.76% would be from the reduced number of trichinelloscopic examinations conducted, while 21.58% of the savings would result from the reduced number of disease cases in humans.
- Economic evaluation of two models developed to show the impact of the proposed *Trichinella* control program in the Srem region proved there would be a positive economic effect. Positive NPVs were established (model A NPV = €1,652,182.14; model B NPV = €2,334,732.57). CBRs showing the profit:cost ratios were >1 for both models.

- On the basis of the results obtained in the test zone, the economic evaluation we conducted and the calculated coefficients produced, we found that there is significant economic justification for implementing a similar, suitable program for the control of *Trichinella* in domestic pigs in the Srem epizootiological region.

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Authors contributions

MM was responsible for all aspects of the work in ensuring that questions related to the accuracy and integrity of the work are appropriately investigated; **ZK contributed to acquisition of data;** VB gave contribution to data analysis and statistical interpretation of data; ĐS was involved in revision of the article for intellectual content; PB was responsible for critical evaluation and approval of the final version to be published; FN was responsible for feeding strategy and for the final revision of the article; TV has made substantial contribution to conception and design, and drafting the article.

Competing interests

The authors declare that they have no competing interest

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EKONOMSKA EVALUACIJA MODELA PROGRAMA ZA PRAĆENJE I ERADIKACIJU TRIHINELOZE

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Kratak sadržaj

Uvod. Trihineloza je kosmopolitska antropozoonoza, koja se ubraja u grupu sistemskih bolesti, a prouzrokovana je larvenim oblicima valjkastog crva *Trichinella species*. Ona je jedna od najstarijih i najupornijih parazitskih zoonoza koja se već duži niz godina nalazi u žiži interesovanja veterinarskih, medicinskih i bioloških naučno-istraživačkih radnika. Paraziti iz roda *Trichinella* dijagnostikovani su u više od sto vrsta domaćih i divljih sisara i ptica. Postavljeni cilj ovog istraživanja je procena efikasnosti programa za praćenje i iskorenjivanje trihineloze pomoću analize dobiti i troškova.

Materijal i metode. Procena efikasnosti programa za praćenje i iskorenjivanje trihineloze urađena je kroz analizu dobiti i troškova U jednom naseljenom mestu izvedena je kontrolisana sistemska deratizacija.

Rezultati i zaključak. Pre deratizacije pojava trihineloze u naseljenom mestu imala je pravolinijsku uzlaznu tendenciju, dok je nakon sistematske deratizacije tendencija pojave pozitivnih slučajeva bila negativna. Rezultati dobijeni na ovaj način, kao i relevantni ekonomski pokazatelji, omogućili su nam da dizajniramo dva programska modela za kontrolu, praćenje i iskorenjivanje ove parazitoze na ovom području. Na osnovu analize dobiti i troškova dizajniranih modela utvrđena je opravdanost programa, jer je koeficijent odnosa dobiti i troškova bio pozitivan za oba modela.

Ključne teči: deratizacija, analiza dobiti i troškova, trend, trihineloza