Temporal analysis and costs of ruminant brucellosis control programme in Egypt between 1999 and 2011

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Summary

Data for the prevalence of brucellosis in ruminants in Egypt are scarce; recent studies suggest the disease is endemic, with a high prevalence. The aim of this study was to assess the financial costs and the impact of the current control programme on the pattern of brucellosis among ruminants between 1999 and 2011. A univariate binary logistic regression model was used to compare between seropositive proportions for different years for each species. The proportion of seropositive cattle was significantly increased from 2000 to 2004 then significantly decreased from 2005 to 2011. The proportion of seropositive buffalo fluctuated year to year, however there was a significant increase in 2008 (OR 3.13, 95% CI 2.69-3.66, $p < 0.001$). There was a decrease in the proportion of seropositive sheep during the study period except in 2001 and 2009 in which there was a significant increase. The proportion of seropositive goats increased in 2000 and 2001, and then decreased from 2002 to 2007. In 2008 there was a significant increase in the seropositive proportion of goats (OR 2.53, 95% CI 2.21-2.90, $p<0.001$). The average annual cost for the control programme including testing and compensation was more than US$3 million. The total cost for the control programme including testing and compensation for the period (13 years) between 1999 and 2011 was more than US$40 million, from which more than 56% for cattle. Further studies are required for the effectiveness of the current control strategies and alternative strategies should be considered. The socio-economic impact of brucellosis and its control measures should be investigated.

Introduction

Brucellosis is a highly contagious disease affecting almost all domestic species, leading to severe economic losses due to abortion, infertility and reduced milk production. It is considered one of the most economically important zoonoses globally (Perry and Grace, 2009; WHO 2009). The disease is not only endemic and neglected with high burdens in animals and human in low-income countries but also without effective control (McDermott and Arimi, 2002). Although the burden of brucellosis is greatest in developing countries, most data and evidence on the economic burden of brucellosis and the benefits of its control are from developed countries (McDermott et al., 2013). In Egypt, brucellosis was first reported in 1939 and, although data for the prevalence of brucellosis in ruminants are scarce, recent studies suggest the disease is endemic in all ruminant species. In Monufia Governorate, 5.36%, 3.33% and 3.17% of cattle, buffaloes and goats were seropositive for *Brucella* spp. by Rivanol test and 7.14%, 4.26%, 2.47% and 6.35% of cattle, buffaloes, sheep and goats were seropositive by the Buffered Acidified Plate Antigen (BAPA), respectively (Samaha et al., 2008). In another study, in which samples were collected from 126 herds from all over Egypt, 26.66%, 18.88% and 17.22% of sheep flocks, goat flocks and cattle herds were seropositive for *Brucella* spp. respectively (Kaoud et al., 2010). In Kafrelsheikh Governorate, blood samples from sheep and goats and milk samples from cattle and buffalo were tested for *Brucella* spp, the seroprevalence in cattle, buffaloes, sheep and goats was 12.2%, 12%, 12.2% and 11.3%, respectively (Hegazy et al., 2011). In one of the Nile Delta villages, Monufia Governorate, the individual and household seroprevalence of *Brucella* spp. in cattle and buffaloes was 11.0% (95% CI: 3.06%-18.4%) and 15.5% (95% CI: 6.61%-24.7%), respectively (Holt et al., 2011). More recently, the seroprevalence of *Brucella* was 18.09% in blood samples from sheep and goat flocks from five governorates in the Nile Delta (Mahboub et al., 2013).

Brucellosis not only affects animals but humans can be infected via many potential routes such as consumption of raw milk and non-heat treated dairy products from infected animals or via contact with infected animals or contaminated materials from infected animals (Jennings et al., 2007; Glynn and Lynn, 2008). Although the disease in humans is rarely fatal, it can be severely debilitating and requires a long period of treatment. In addition to the cost of treatment, the inability to work increases economic losses caused by the disease (Pappas and Memish, 2007). In Egypt, data for prevalence or incidence of human brucellosis are scarce and almost all studies are based on hospital surveys. A study conducted in 2007 found that 3% and 11% of patient with acute febrile illness were positive for *Brucella* spp. by culture and serology, respectively (Afifi et al., 2007). In 2000, the incidence was estimated to be 18/100,000 person-year in Bilbeis district (Crump et al., 2003). In Fayoum governorate, it was estimated to be 64/100,000 person-year and 70/100,000 person-year in 2002 and 2003, respectively (Jennings et al., 2007); However, data from the Ministry of Health provide an incidence of 0.3/100,000 person-year (Pappas et al., 2006). The incidence rate in 2007, 2008 and 2009 was 6.4, 6.61 and 4.62/100,000 person-year, respectively. However these figures are not reliable because hospitals are required to notify the cases of brucellosis to the Ministry of Health. In practice notifications only come from governmental hospitals but not from private health centres, private clinics and private hospitals, so the incidence in human populations is likely to be underestimated.

Since 1981, the national programme for brucellosis in ruminants in Egypt involves testing all female ruminants older than six months and slaughtering serological positives, with voluntary vaccination of calves using *Brucella abortus* S19 vaccine and lambs and kids using *B. melitensis* Rev.1 vaccine (Refai, 2002). According to the General Organization of Veterinary

Services (GOVS), in 2012, 360,000 animals were tested costing about one million US$[1] and 50,000 cattle and 50,000 sheep were vaccinated, costing about US$ 90,000 for the vaccine. However the previous findings in both ruminants and human indicate that the disease is endemic in the country and affecting both animals and humans. There has been no economic evaluation conducted for the current programme of brucellosis in Egypt. The aim of this study was to assess the financial costs and the impact of the current programme on the temporal pattern of brucellosis among cattle, buffalo, sheep and goats using data from the active surveillance programme between 1999 and 2011.

Materials and methods

Study area and ruminant population

Egypt is located in the north-eastern corner of Africa and south-western Asia (27,00º N, 30,00º E). It is bounded on the north by the Mediterranean Sea, on the east by Palestine, on the south by Sudan, and on the west by Libya. The total area is about one million square meters and composed of 27 administrative governorates, while the populated area is about 78990 km^2 (7.8% of the total area). The human population according to the most recent survey is about 94 million, both at home and abroad[2]. In Egypt, the majority of cattle are owned by individual households, and kept in groups of one to five and moved daily between the house yard and grazing lands. Sheep and goat are also kept in small flocks that are often composed of animals from various households managed by a single shepherd. Some larger mobile flocks are also kept, and there are a small number of government and privately-owned commercial dairy farms (Aidaros 2005; Holt et al., 2011). The Nile Delta, is the most densely populated area, while upper Egypt, and especially the desert regions, are less populated. Livestock demographic data (Figure 1) and the number of animals tested for brucellosis,

[1] Current exchange rate; 1 US$=6.06 LE (Egyptian pound) according to the world bank exchange rate for 2012 http://data.worldbank.org/indicator/PA.NUS.FCRF

[2] http://www.sis.gov.eg/En/Default.aspx

together with the results of the tests for each species, were obtained from the GOVS and are reported by Wareth et al. (2014).

Description of the national brucellosis control programme

Data on the numbers of animals tested for brucellosis were provided by the GOVS based on the active surveillance programme for brucellosis. Within this programme, the GOVS' veterinarians collect blood samples from all female ruminants nationally. Serum samples are serologically tested for *Brucella* spp. antibodies using Rose Bengal Plate Test (RBPT), positive samples are then confirmed by the Complement Fixation Test (CFT) at the Department of Brucellosis Research, Animal Health Research Institute (AHRI) according to the OIE guidelines. Brucellosis confirmed cases are slaughtered under the supervision of GOVS' veterinarians at the government abattoirs and owners are compensated according to the compensation scheme (Refai, 2002).

Costs of brucellosis control programme

Surveillance and testing of animals

According to the programme, GOVS' veterinarians are responsible for collecting blood samples from animals all over the country. The Egyptian Ministry of Agriculture is responsible for logistics and for supplying all material needed such as vehicles, needles, blood tubes, and ice boxes. The cost of sampling an individual animal is US$ 1.93 for labour, and US$ 1 for consumables (needles, tubes, syringes and ear tags) and administration (planning, implementing and transporting samples from sites of collection to the laboratory). The cost of the serological tests, RBPT and CFT, is US$ 1.93 each, including reagents, consumables and labour. The previous costs were based on the actual prices and expert opinions.

Compensation for animals slaughtered

According to the programme, the slaughter of seropositive animals by both RBPT and CFT under the supervision of GOVS is compulsory and livestock owners compensated. The amount of compensation varied according to the species, age and breed of seropositive animals, Table 1. As there were no detailed data for the species, breed and age of compensated cattle and buffalo an average of US$ 747 was used to calculate the compensation of a cattle or buffalo.

Vaccination

Vaccination against brucellosis is voluntary. The cost of a single dose of vaccine is about one US$ which is administered by a GOVS' veterinarian. The cost of transporting, cold chain, syringes, needles, ear tags and labour for a single animal is one US$ (Expert opinion). By law, animals must be tested before being vaccinated; therefore the cost of sampling and testing (as detailed before) was added to the cost of vaccination. Accurate figures for the total number or the proportion of animals vaccinated annually were not available. Based on personal communication with veterinarians from GOVS, it seems that about 100,000 animals are vaccinated every year.

Data management and analysis

Data were stored in a Microsoft Office Excel 2007. Frequency tables were used to calculate the proportions of animals tested and proportions seropositive for *Brucella* spp. per year for each ruminant species. Statistical analyses were conducted to allow comparison between different years and ruminant species using IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp. Univariable logistic regression was used to compare the proportion of seropositive animals in each species for different years, with seropositive as the response variable and 1999 as the reference year.

Results

A total number of 4,331,154 animals were tested between 1999 and 2011. The results (Figure 2) showed that, the frequency of testing cattle was higher than other species with a maximum of 4.34% in 2006. The proportion of tested buffalo and sheep was below 2% except in 2001 (2.3% in buffalo). The proportion of tested goat was less than 1% apart from 2008 and 2009 in which 1.04% and 1.06% were tested, respectively. The results of serological tests (Figure 3) showed that, the highest proportion of seropositive was in sheep, followed by goat, cattle and buffalo with an average of 1.68%, 1.18%, 0.73% and 0.48%, respectively.

The highest proportions of seropositive cattle (1.27%), buffalo (1.08%), sheep (3.65%) and goat (3.22%) were observed in 2002, 2008, 2009 and 2008, respectively. The proportion of seropositive cattle was significantly increased from 2000 to 2004 then significantly decreased from 2005 to 2011, Table 2. The proportion of seropositive buffalo fluctuated year to year, however there was a significant increase in 2008 (OR 3.13, 95% CI 2.69-3.66, $p < 0.001$), Table 3. There was a decrease in the proportion of tested sheep that were seropositive during the study period except in 2001 and 2009 in which there was a significant increase, Table 4. The proportion of seropositive goats increased in 2000 and 2001, and then decreased from 2002 to 2007. In 2008 there was a significant increase in the seropositive proportion of goats (OR 2.53, 95% CI 2.21-2.90, $p<0.001$), Table 5. The seropositive proportion of ruminants showed a slight increase from 1999 to 2004 then decreased a part from 2008 and 2009 in which there was an increase, Table 6.

The average annual cost for sampling and testing cattle was about US$ 800,000 followed by sheep, less than US$ 400,000 then buffalo and goat, Figure 4. The average annual cost for testing all ruminants was about US$ 1,658,000. The total costs for sampling and testing ruminants in the study period was US$ 21,554,630 with more than 50% for cattle. The average compensation for cattle, US$ 927,733, was higher than other species, Figure 5. The average annual compensation cost for all ruminants was about US$ 1,428,000. The total compensation in the study period was US$ 18 million with cattle about 65%. The average annual total cost for the control programme including testing and compensation was more than US$ 3 million. The highest costs were for cattle particularly in year 2002 and 2003, Figure 6. The total cost for the control programme including testing and compensation in the study period was US$ 40,112,726, from which more than 56% for cattle. According to experts from GOVS, the annual cost for voluntary vaccination was about US$ 700,000.

Discussion

Since 1981, several control measures have been implemented with the aim to eradicate brucellosis however it is still endemic in the country. The official brucellosis disease control strategy stipulates that all female ruminants and valuable males aged ≥ 6 months are serologically tested for brucellosis every 6 months. The results indicated that in any given year between 1999 and 2011, the proportion of tested ruminants never exceeded 2.15%. This low proportion of testing could be due to many reasons such as lack of funds, shortage in laboratory facilities and trained staff (Refai, 2002). It was found that, livestock owners were unwilling to test their animals, fearing that positive ones will be culled with unsatisfactory compensation (Holt et al., 2011). Studies have also found farmers and veterinarians lack motivation, with insufficient funding to sustain the control programme (Hegazy et al., 2009). Our results showed that there were huge variations in the intensity of testing across species and from year to another, although the proportion of testing cattle was consistently higher than other species all over the study period. This is likely to affect the efficacy of the control programme and allow the persistence of the disease in the population. It suggests that a formal sampling strategy is not adhered to and consequently the paucity of reliable estimates for the disease in the country. It might also reflect that, policy makers wrongly believed that large cattle are the main source of brucellosis in Egypt. The high intensity of sampling cattle might also be due to the characteristics of the production system stated above and that it might be easy for GOVS' veterinarians to collect samples from cattle compared to other species.

The proportion of seropositive cattle and buffalo was quite low over the study period and rarely exceeded 1%. However, results from other regional or sub-regional studies indicated that the seroprevalence of brucellosis in cattle and buffalo was ranged from about 3% to 17% (Samaha et al., 2008; Hegazy et al., 2011; Holt et al., 2011; Mahboub et al., 2013). The proportion of seropositive sheep was around 2% except in 2009 (3.7%), which is quite lower than findings by other regional studies (3% to 26%) (Samaha et al., 2008; Hegazy et al., 2011; Holt et al., 2011; Mahboub et al., 2013). However, poor implementation of random sampling strategies increases the unreliability of the outcomes (Hegazy et al., 2009). To the authors' knowledge, veterinarians always used convenient sampling rather than random sampling such as sampling households near veterinary clinics, near the main roads and those they have a business relationship with. Therefore these figures should be interpreted carefully, and it is not possible to extrapolate these results to the national livestock population in Egypt. There were no clear temporal variations in the proportion of seropositive animals in any species across the study period. Due to the small proportion of animals tested or vaccinated the programme, as currently implemented, is very unlikely to neither eradicate brucellosis nor control it effectively.

For assessing the socioeconomic impact of brucellosis, data of the direct and indirect impact of the disease on animals and human are required eg; production data and the losses due to brucellosis in animals and the losses and costs of brucellosis in humans. Also valid animal disease incidence and loss data, both within infected herds and in the national population of herds, is extremely important for sound epidemiological and cost-benefit studies of animal disease programs. In Egypt, most of these data were lacking, further studies are required to conduct a socio-economic impact of brucellosis and a benefit-cost analysis for the control programme. However, it was possible to estimate the monetary costs for the control programme. About US$ 1,658,000 were spent annually for sampling and testing of all ruminants; of which more than 50% were spent on cattle. This money could be used more effectively by using a strategic sampling frame with epidemiologically sound study design. As a part of the programme, serologically positive animals are slaughtered and owners are compensated. About US$ 1,428,000 were spent as compensation per year with about 65% for cattle. However, it is unlikely that farmers would be satisfied with the level of compensation as it represents less than 50% of the market value. This could be one of the main factors hindering the success of the control programme (Hegazy et al., 2009; Hegazy et al., 2011; Holt et al., 2011). Farmers may be more willing to comply with serological testing requirements if compensation was given at the market value of the positive animals and the process of compensation was easier and faster than it is currently. The average cost for the control programme including testing and compensation was more than US$ 3 million per year and the total cost in the study period was more than US$ 40 million. This amount of money, will only be justified if the disease is well led. With complete control of brucellosis, money would be used for the improvement of livestock production, food security and public health (Bamaiyi et al., 2012). Apparently, control of brucellosis seems expensive but it was estimated that for each US$1 expenditure on control, US$ 7 were saved (Acha and Szyfres, 1987). A simulation study of the effective strategies for brucellosis in small ruminants in one of the Nile Delta Governorates indicated that vaccination of 50% of young replacements and 25% of adult sheep every year would reduce the seroprevalence of brucellosis by 75% after 10 years (Hegazy et al., 2009). In Mongolia, it has been estimated that the annual mass vaccination of livestock against brucellosis for 10 years would reduce the prevalence of brucellosis by 52% (Zinsstag et al., 2005; Zinsstag et al., 2007). Therefore, an economic analysis would be required to determine whether these technically more effective strategies would be more cost-effective as well.

Despite more than 30 years of implementation of control and compensation scheme for brucellosis with voluntary vaccination, brucellosis is still endemic in Egypt. To develop a national strategy for control or eradication of brucellosis, the veterinary authorities should select an approach compatible with the prevailing socioeconomic status and the prevalence of the disease. As part of the strategy, the impact of brucellosis on the livestock economy and human health and the costs of the potential control or eradication strategies must be evaluated before implementation. Knowledge and attitudes of different stakeholders, which may vary between different regions of the country, and the availability of resources to carry out the strategy should also be considered (Blasco and Molina-Flores, 2011).

In designing an effective policy for controlling brucellosis the following critical factors should be considered, the prevalence of infection, species of *Brucella* prevalent, animal species involved and the temporal pattern of the prevalence or incidence in animals and humans (Robinson, 2003). To achieve that, well designed studies for collecting data about, risk factors, prevalence and economic impact of the disease and its control measures should be conducted. Alternative or complementary control strategies could include vaccination of small and large ruminants, biosecurity measures and movement control (Blasco and Molina-Flores, 2011). Any control programme must be accompanied by strong surveillance systems to monitor the progress of the programme and detect any new infections in both people and livestock herds or flocks. Simulation studies for assessing the efficacy of different control strategies should be carried out. The simulation study previously conducted in Egypt (Hegazy et al., 2009) was for small ruminants only, it has not simulated the disease in large ruminants and other production characteristics. To our knowledge, there were no simulation studies for the economic impacts of the disease and its control measures in Egypt. This type of studies is very important especially when there are no enough resources to frequently test large number of animals to evaluate the actual status of the disease in the population. So, simulations could predict the situation of the disease in the population and the outcomes could be confirmed with a small sample every year. Also simulation studies would be helpful for assessing the efficacy of alternative disease control strategies and their economic impacts. Outcomes of these studies would help policymakers applying the appropriate control programme and efficient allocation of resources.

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References

Acha, P.N., Szyfres, B., 1987. Zoonoses and communicable diseases common to man and animals. Pan American Health Organization.

Afifi, S., Wasfy, M., Azab, M., Youssef, F., Pimentel, G., Graham, T., Mansour, H., Elsayed, N., Earhart, K., Hajjeh, R., 2007. Laboratory-based surveillance of patients with bacterial meningitis in Egypt (1998–2004). European Journal of Clinical Microbiology & Infectious Diseases 26, 331-340.

Aidaros, H., 2005. Global perspectives-the Middle East: Egypt. Revue Scientifique et Technique de l'Office International des Epizooties. 24, 589–96.

Bamaiyi, P.H., Abd-Razak, N.S., Zainal, M.A., 2012. Seroprevalence and economic impact of eradicating zoonotic brucellosis in Malaysia: A case study of Melaka state of Malaysia. Veterinary World 5, 398-404.

Blasco, J.M. and Molina-Flores, B., 2011. Control and eradication of Brucella melitensis infection in sheep and goats. Veterinary Clinics of North America: Food Animal Practice, 27, 95-104.

Crump, J.A., Youssef, F.G., Luby, S.P., Wasfy, M.O., Rangel, J.M., Taalat, M., Oun, S.A., Mahoney, F.J., 2003. Estimating the incidence of typhoid fever and other febrile illnesses in developing countries. Emerging infectious diseases 9, 539.

Glynn, M.K., Lynn, T.V., 2008. Zoonosis Update. AVMA 233, 900-908.

Hegazy, Y., Ridler, A., Guitian, F., 2009. Assessment and simulation of the implementation of brucellosis control programme in an endemic area of the Middle East. Epidemiology and infection 137, 1436-1448.

Hegazy, Y.M., Moawad, A., Osman, S., Ridler, A., Guitian, J., 2011. Ruminant brucellosis in the Kafr El Sheikh Governorate of the Nile Delta, Egypt: prevalence of a neglected zoonosis. PLoS neglected tropical diseases 5, e944.

Holt, H.R., Eltholth, M.M., Hegazy, Y.M., El-Tras, W.F., Tayel, A.A., Guitian, J., 2011. *Brucella* spp. infection in large ruminants in an endemic area of Egypt: cross-sectional study investigating seroprevalence, risk factors and livestock owner's knowledge, attitudes and practices (KAPs). BMC public health 11, 341.

Jennings, G.J., Hajjeh, R.A., Girgis, F.Y., Fadeel, M.A., Maksoud, M.A., Wasfy, M.O., El Sayed, N., Srikantiah, P., Luby, S.P., Earhart, K., 2007. Brucellosis as a cause of acute febrile illness in Egypt. Transactions of the Royal Society of Tropical Medicine and Hygiene 101, 707-713.

Kaoud, H., Zaki, M.M., Shimaa, A., Nasr, A., 2010. Epidemiology of brucellosis among farm animals. Nature and Science 8, 190-197.

Mahboub, H.D., Helal, M.A., Eldaim, A., Attia, M., El-Razek, A., Mahmoud, E., Elsify, A.M., 2013. Seroprevalence of Abortion Causing Agents in Egyptian Sheep and Goat Breeds and Their Effects on the Animal's Performance. Journal of Agricultural Science 5, 1916-9752.

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

McDermott, J. J., and Arimi, S. M., 2002. Brucellosis in sub- Saharan Africa: epidemiology, control and economic impact. Vet. Microbiol., 90, 111–134.

Pappas, G., Memish, Z., 2007. Brucellosis in the Middle East: a persistent medical, socioeconomic and political issue. Journal of Chemotherapy 19, 243-248.

Pappas, G., Papadimitriou, P., Akritidis, N., Christou, L., Tsianos, E.V., 2006. The new global map of human brucellosis. The Lancet infectious diseases 6, 91-99.

Perry, B., and Grace, D., 2009. The impacts of livestock diseases and their control on growth and development processes that are pro-poor. Philos. Trans. roy. Soc. Lond., B, biol. Sci. 364, 2643–2655.

Refai, M., 2002. Incidence and control of brucellosis in the Near East region. Veterinary microbiology 90, 81-110.

Robinson, A., 2003. Guidelines for coordinated human and animal brucellosis surveillance. FAO.

Samaha, H., Al-Rowaily, M., Khoudair, R.M., Ashour, H.M., 2008. Multicenter study of brucellosis in Egypt. Emerging infectious diseases 14, 1916.

Wareth, G., Hikal, A., Refai, M., Melzer, F., Roesler, U., Neubauer, H., 2014. Animal brucellosis in Egypt. J Infect Dev Ctries 8, 1365–1373.

World Health Organization (WHO) 2009. Global health risks: mortality and burden of disease attributable to selected major risks. WHO, Geneva. Available at: www.who.int/healthinfo/global_burden_disease/global_health_risks/en/index.html "Accessed on 01-10-2015"

Zinsstag, J., Roth, F., Orkhon, D., Chimed-Ochir, G., Nansalmaa, M., Kolar, J., Vounatsou, P., 2005. A model of animal–human brucellosis transmission in Mongolia. Preventive veterinary medicine 69, 77-95.

Zinsstag, J., Schelling, E., Roth, F., Bonfoh, B., De Savigny, D., Tanner, M., 2007. Human benefits of animal interventions for zoonosis control. Emerging infectious diseases 13, 527.

Tables

Table 1: Compensation for animals slaughtered by brucellosis control programme in Egypt (source: GOVS)

Species/breeds	Age	Compensation/US$
Cattle and buffalo	< 6 months	325
Foreign breeds cattle, buffalo and bulls	From 6 months to 2 years	616
	From 2 to 5 years	1387
	>5 years	971
Mixed breeds	From 6 months to 2 years	462
	From 2 to 5 years	1156
	>5 years	701
Baladi cattle and buffalo (native breeds)	From 6 months to 2 years	385
	From 2 to 5 years	925
	>5 years	539
Sheep	All ages	162
Goat	All ages	115

Table 2: Proportions of seropositive cattle for *Brucella* spp. Based on the brucellosis control programme in Egypt, 1999-2011

Year	Tested	Seropositive	Seropositive (%)	OR	95% CI	*P* value
1999	108,622	824	0.76	Ref.	-	-
2000	145,750	1,305	0.90	1.18	1.08-1.29	<0.001
2001	152,436	1,378	0.90	1.19	1.09-1.29	<0.001
2002	162,309	2,067	1.27	1.68	1.55-1.82	<0.001
2003	168,281	2,009	1.19	1.57	1.45-1.71	<0.001
2004	154,984	1,406	0.91	1.19	1.09-1.30	<0.001
2005	174,673	1,291	0.74	0.97	0.89-1.06	0.56
2006	199,954	982	0.49	0.65	0.59-0.71	<0.001
2007	161,206	843	0.52	0.69	0.63-0.76	<0.001
2008	182,248	1,186	0.65	0.86	0.78-0.93	<0.001
2009	175,750	871	0.50	0.65	0.59-0.72	<0.001
2010	183,490	640	0.35	0.46	0.41-0.51	<0.001
2011	167,188	592	0.35	0.47	0.42-0.52	<0.001

Table 3: Proportions of seropositive buffalo for *Brucella* spp. Based on the brucellosis control programme in Egypt, 1999-2011

Year	Tested	Seropositive	Seropositive (%)	OR	95% CI	*P* value
1999	62,900	218	0.35	Ref.	-	-
2000	66,109	391	0.59	1.71	1.45-2.02	<0.001
2001	81,302	288	0.35	1.02	0.86-1.22	0.80
2002	67,802	331	0.49	1.41	1.19-1.67	<0.001
2003	67,588	471	0.70	2.02	1.72-2.37	<0.001
2004	56,041	373	0.67	1.93	1.63-2.28	<0.001
2005	69,931	266	0.38	1.10	0.92-1.31	0.30
2006	61,595	165	0.27	0.77	0.63-0.95	0.012
2007	68,548	334	0.49	1.41	1.19-1.67	<0.001
2008	59,080	637	1.08	3.13	2.69-3.66	<0.001
2009	51,924	196	0.38	1.09	0.89-1.32	0.384
2010	53,783	162	0.30	0.87	0.71-1.06	0.17
2011	55,986	112	0.20	0.58	0.46-0.72	<0.001

Table 4: Proportions of seropositive sheep for *Brucella* spp. Based on the brucellosis control programme in Egypt, 1999-2011

Year	Tested	Seropositive	Seropositive (%)	OR	95% CI	*P* value
1999	62,151	1,437	2.31	Ref.	-	-
2000	68,342	1,303	1.91	0.82	0.76-0.89	<0.001
2001	78,310	1,967	2.51	1.09	1.02-1.17	0.01
2002	99,466	1,111	1.12	0.48	0.44-0.52	0.0001
2003	79,565	1,755	2.21	0.95	0.89-1.02	0.18
2004	68,122	1,081	1.59	0.68	0.63-0.74	<0.001
2005	69,571	1,203	1.73	0.74	0.69-0.80	<0.001
2006	71,929	905	1.26	0.54	0.50-0.59	<0.001
2007	68,171	924	1.36	0.58	0.53-0.63	<0.001
2008	106,215	968	0.91	0.39	0.36-0.42	<0.001
2009	84,798	3,095	3.65	1.60	1.50-1.71	<0.001
2010	66,412	525	0.79	0.34	0.30-0.37	<0.001
2011	65,849	292	0.44	0.19	0.17-0.21	<0.001

Table 5: Proportions of seropositive goat for *Brucella* spp. Based on the brucellosis control programme in Egypt, 1999-2011

Year	Tested	Seropositive	Seropositive (%)	OR	95% CI	*P* value
1999	17,875	232	1.30	Ref.	-	-
2000	16,685	294	1.76	1.36	1.15-1.62	<0.001
2001	21,912	331	1.51	1,17	0.99-1.38	0.07
2002	23,560	307	1.30	1.00	0.85-1.19	0.96
2003	29,576	314	1.06	0.85	0.69-0.97	0.01
2004	25,719	329	1.28	0.99	0.83-1.17	0.86
2005	25,325	257	1.01	0.78	0.65-0.93	0.006
2006	26,689	237	0.89	0.68	0.57-0.82	<0.001
2007	33,791	163	0.48	0.37	0.30-0.45	<0.001
2008	46,703	1,502	3.22	2.53	2.21-2.90	<0.001
2009	44,023	322	0.73	0.56	0.47-0.66	<0.001
2010	39,143	233	0.60	0.46	0.38-0.55	<0.001
2011	31,772	83	0.26	0.21	0.15-0.26	<0.001

Table 6: Proportions of seropositive ruminants for *Brucella* spp. Based on the brucellosis control programme in Egypt, 1999-2011

Year	Tested	Seropositive	Seropositive (%)	OR	95% CI	*P* value
1999	251,548	2,711	1.08	Ref	-	-
2000	296,886	3,293	1.11	1.03	0.98-1.08	0.264
2001	333,960	3,964	1.19	1.10	1.05-1.16	<0.001
2002	353,137	3,816	1.08	1.00	0.95-1.05	0.92
2003	345,010	4,549	1.32	1.23	1.17-1.29	<0.001
2004	304,866	3,189	1.05	0.97	0.92-1.02	0.25
2005	339,500	3,017	0.89	0.82	0.78-0.87	<0.001
2006	360,167	2,289	0.64	0.59	0.56-0.62	<0.001
2007	331,716	2,264	0.68	0.63	0.59-0.67	<0.001
2008	394,246	4,293	1.09	1.01	0.96-1.06	0.672
2009	356,495	4,484	1.26	1.17	1.11-1.23	<0.001
2010	342,828	1,560	0.46	0.42	0.39-0.45	<0.001
2011	320,795	1,079	0.34	0.31	0.29-0.33	<0.001

Figures

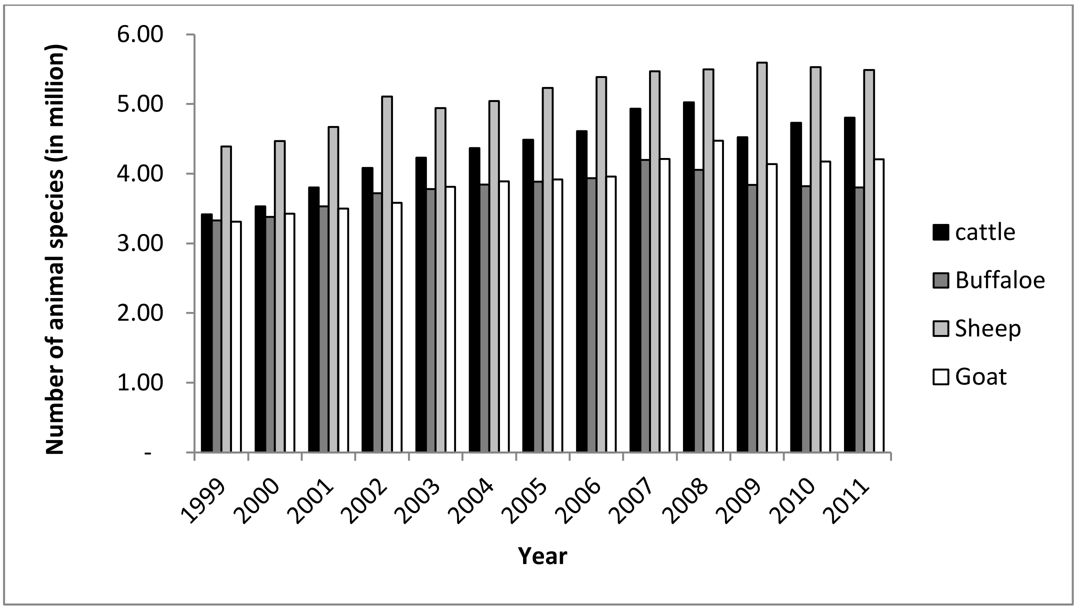

Figure 1: Number of cattle, buffalo, sheep and goat per/year in Egypt from 1999 to 2011

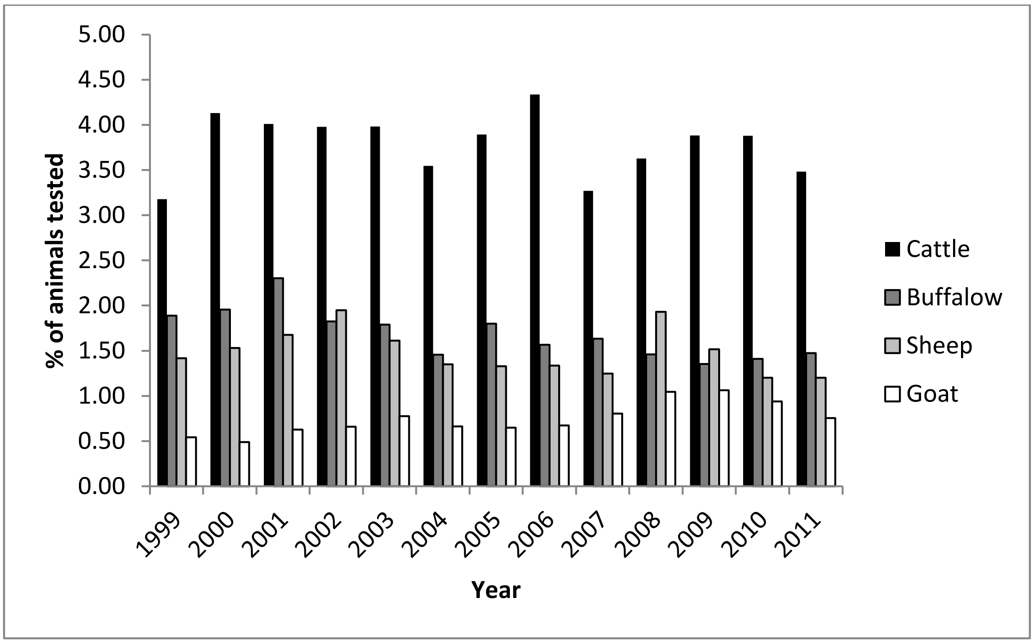

Figure 2: Proportions of serologically tested ruminants for brucellosis control programme in Egypt, 1999-2011

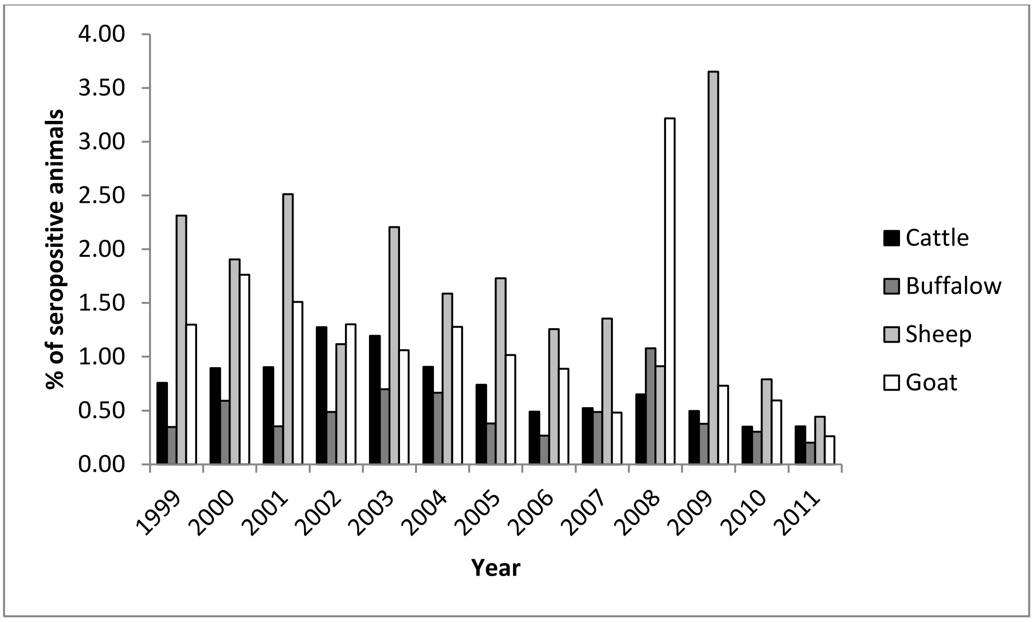

Figure 3: Proportions of seropositive ruminants for *Brucella* spp. based on the brucellosis control programme in Egypt, 1999-2011

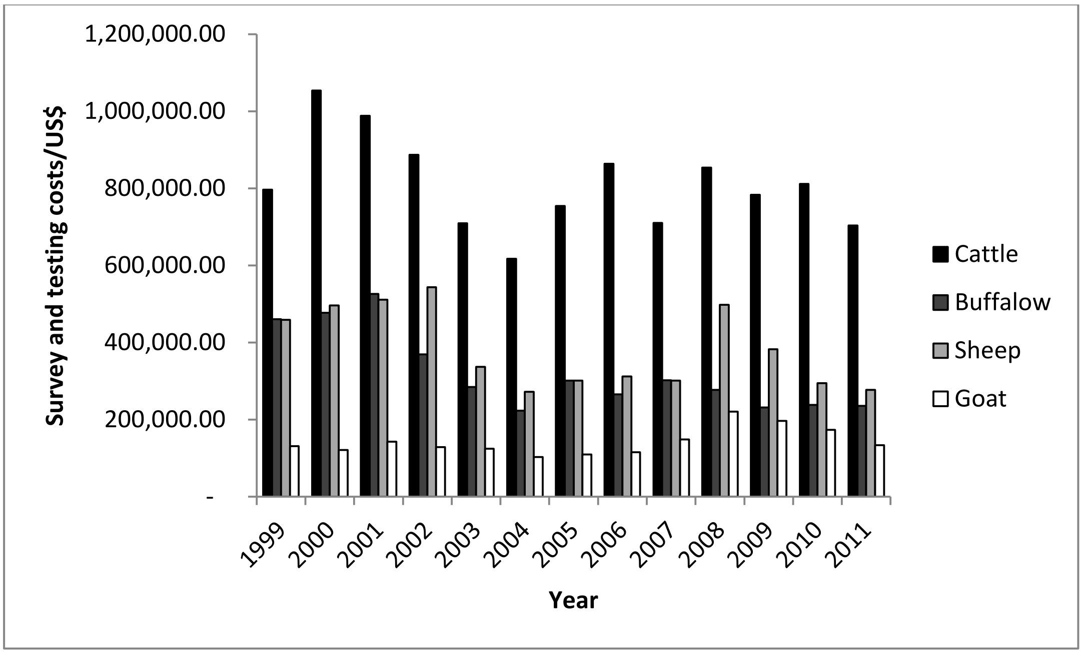

Figure 4: The annual costs (USD) for sampling and testing for brucellosis control programme in Egypt, 1999-2011

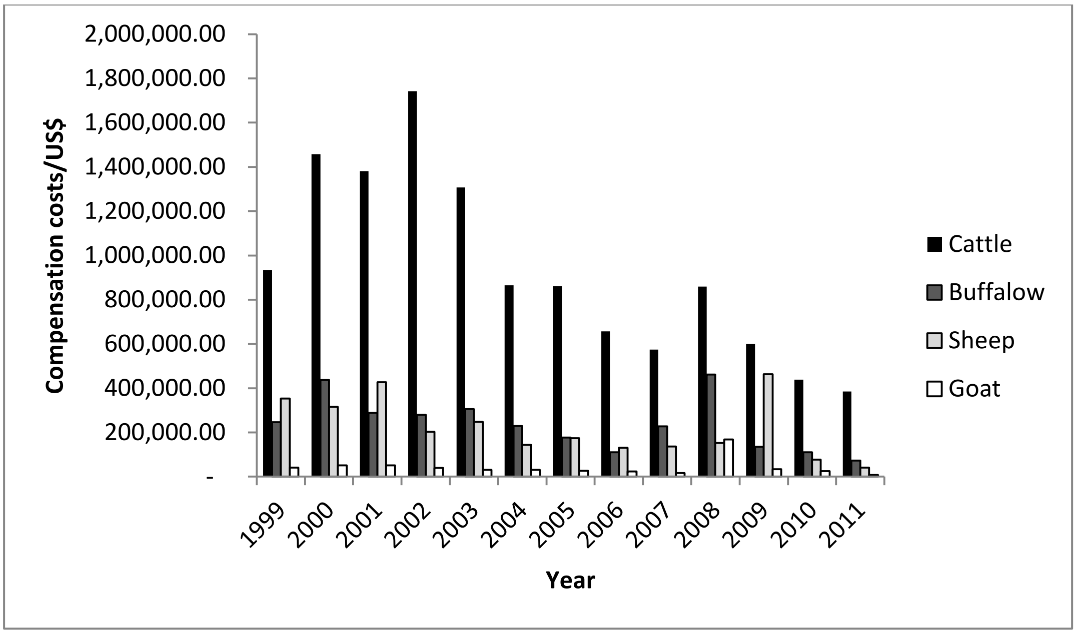

Figure 5: The annual compensation (USD) for brucellosis control programme in Egypt, 1999-2011

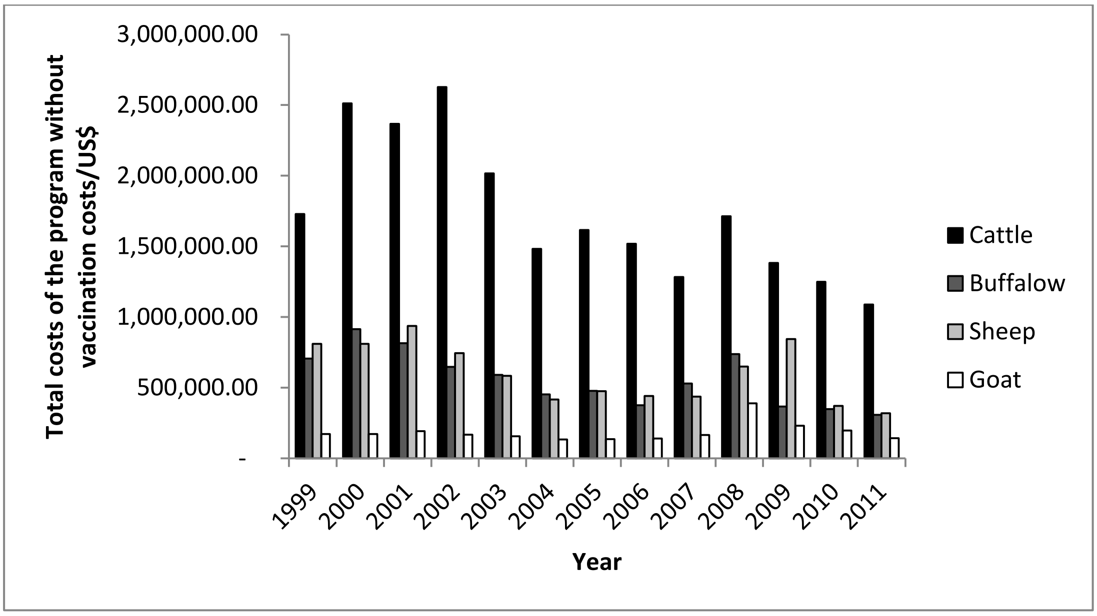

Figure 6: Total annual costs (USD) for the brucellosis control programme in Egypt