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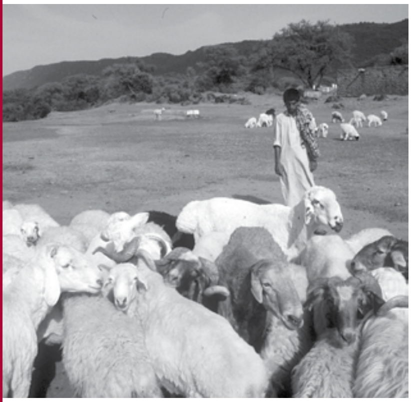

proceedings

BRUCELLA MELITENSIS IN EURASIA AND THE MIDDLE EAST

FAO technical meeting in collaboration with
WHO and OIE
Rome, May 2009

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Contents

Acronyms and abbreviations

CD-ROM	Compact Disc - Read Only Memory
CFT	Complement Fixation Test
cELISA	Competitive ELISA
CFU	Colony Forming Units
CMI	Cell Mediated Immunity
DALY[1]	Disability Adjusted Life Year
ELISA	Enzyme Linked Immuno-sorbent Assay
EU	European Union
FAO	Food and Agriculture Organization
FMD	Foot and Mouth Disease
FPA	Fluorecence Polarisation Assays
GLEWS	Global Early Warning System
IAEA	International Atomic Energy Agency
iELISA	Indirect ELISA
KAP	Knowledge, Attitudes and Practices
MZCP	Mediterranean Zoonoses Control Programme
NGO	Non-governmental Organization
NH	Native Hapten
OIE	World Organisation for Animal Health
PAHO	Pan-American Health Organization
PBCP	Palestinian Brucellosis Control Programme
PCR	Polymerase Chain Reaction
PPR	Peste des Petits Ruminants
QALY[2]	Quality Adjusted Life Year
RADISCON	Regional Animal Disease Surveillance and Control Network
RBT	Rose Bengal Test
SAT	Serum Agglutination Test
S-LPS	S-Lipopolysaccharides

[1] A measure of overall disease burden and defined as one year of healthy life lost

[2] A measure of disease burden and is based on the years of life added by an intervention

SPS	Sanitary and Phytosanitary Agreement
TAD	Trans-boundary Animal Diseases
TCP	Technical Cooperation Programme
TR-FRET	Time-resolved fluorescence energy transfer
VPH	Veterinary Public Health
WAHID	World Animal Health Information Database
WAHIS	World Animal Health Information System
WHO	World Health Organization
WTO	World Trade Organization

1. Introduction

A technical meeting of brucellosis experts was convened in Rome from 11 to 14 May 2009 by the Food and Agriculture Organization (FAO) in collaboration with the World Health Organization (WHO) and the World Organisation for Animal Health (OIE), in order to develop guidance to support and improve surveillance and control of *Brucella melitensis* infection in affected countries. The meeting was opened by Dr J. Domenech, Chief of FAO's Animal Health Service, Animal Production and Health Division. Since the creation of the Joint FAO/WHO Expert Committee on Brucellosis in 1986, there have been a number of meetings and publications relating to brucellosis in general and some specifically addressing the problems of *B.melitensis* infections (see Appendix 3). Over the last two decades, a number of developed countries have eradicated, or significantly reduced, the prevalence of *B.abortus* infections. However, with the exception of some Western European countries, few countries have successfully eradicated *B.melitensis* infections.

While speciation of *Brucella sp.* is a fairly routine procedure for modern and safe laboratories, unfortunately many smaller and less economically developed countries do not have these resources and therefore reliable information as to the actual *Brucella* species infecting their flocks and herds is lacking. However, from what is currently known, *B.melitensis* is much more common than *B.abortus* in many countries in Eastern Europe, Central Asia and the Middle East. The meeting therefore focused on *B.melitensis,* while recognizing that *B.abortus* might occur concurrently.

Progress in the control of *B.melitensis* infections has been uneven, especially in Eurasia and the Middle East where ovine and caprine infections are still widespread. This has resulted in very significant human illness, primarily from consumption of contaminated dairy products or from occupational exposure to infected livestock. In small ruminants (sheep and goats), abortion, reduced fertility, reduced milk production and lowered newborn viability are the major impacts. Management systems for small ruminants vary markedly in these areas and food hygiene practices also are deficient. There are major gaps in the knowledge of many livestock producers, and their practices are not adequately focused on preventive measures.

Currently, efforts in some countries in these two regions are focused on vaccination of breeding age animals to raise herd/flock immunity and reduce abortion rates. When herd or flock prevalence levels are significantly lowered, application of test-and-slaughter programmes could become feasible if adequate compensation is provided, in addition to the implementation of movement control within and between countries. This is essentially the methodology used by developed countries to eradicate *B.abortus* infections following long-term vaccination programmes. However, it is evident that there is considerable variation between countries in their attempts to control *B.melitensis* infections and this meeting was held to address both technical and non-technical constraints.

2. Objectives and expected outcomes

The main purpose of the meeting was to seek views and reach consensus among invited experts that would form the basis of guidance for countries to either commence or improve their *B.melitensis* surveillance and control programmes. Specifically, it was perceived that there was a need for a better understanding of the technical issues related to diagnosis and surveillance, so that veterinary administrators and, ultimately, politicians could assess the economic and human health impact in their countries.

Thereafter, appropriate prevention and control strategies could be selected or modified, including not only the technical support services, but also estimations of cost-benefits of interventions. The importance of intersectoral collaboration between both veterinary and public health authorities was also to be addressed as an essential component. The potential for regional control programmes was also seen as a priority, given that cross-border movement of animals was likely in some situations. The meeting was expected to identify any gaps in the current knowledge of *B.melitensis* epidemiology or diagnosis and suggest funding options to ensure sustainability. Finally a "toolbox" of practical techniques was to be assembled as a guide for those involved in control programmes.

3. Summaries of presentations

3.1 OVERVIEW OF THE EPIDEMIOLOGY AND CONTROL OF *BRUCELLA MELITENSIS* IN THE MIDDLE EAST AND EURASIA *(A. EL IDRISSI)*

Brucella melitensis infection is recognized as a significant public health challenge, with a major economic and financial burden in countries where the disease remains endemic. The disease is still common in the Mediterranean region, the Middle East, Central Asia and parts of Latin America. Over the last ten years, the infection has re-emerged, with high prevalence in sheep and goats in other countries and, in particular, in Eastern Europe, the Balkans, and Eurasia. Of the three biovars of *B.melitensis*, biovar 3 seems to be the most common in these regions.

Economic losses from *B.melitensis* infections are very significant and include decreased productivity as a result of abortion, weak offspring and decreased milk production, as well as lost trade opportunities. *B.melitensis* is very contagious for humans and the disease, unless diagnosed and treated both promptly and effectively, can become chronic, affecting multiple body systems. The infection is acquired by humans following ingestion of contaminated dairy foods and from occupational exposure to infected live animals or carcasses during slaughter. While sheep and goats are the major reservoir of *B.melitensis* infection, there is increasing evidence of emergence in cattle and camels.

FAO has been responsible for advancing practical knowledge and experience on brucellosis in various countries and assisting in the development of sound strategies and policies for sustainable control programmes. Technical support has been provided to selected countries where brucellosis impacts significantly on both human health and livestock, on which households depend for income and food security. Countries in the Middle East and Central Asia benefited from support under the Regional Animal Disease Surveillance and Control Network (RADISCON) from 1996 to 2003, or directly through FAO's Technical Cooperation Programme (TCP). The latter includes Morocco, Syria, Kyrgyzstan and, more recently, Oman and Bosnia and Herzegovina. Donor funded projects have been supported in many countries in the region, including Kosovo, Tajikistan, Iraq, Armenia and Palestine.

The control strategies promoted by FAO in these endemically infected countries have been aimed at reducing prevalence and disease (i.e. abortion) in susceptible species (primarily sheep and goats) and therefore limiting spread within and between flocks and herds, using long term vaccination as the main tool. The FAO programme for brucellosis control calls for the implementation of an action plan comprising five components including:

- a baseline seroprevalence survey of animals using statistical methods to ensure results are representative of both susceptible livestock and regions of the country;
- development and implementation of a risk-based vaccination control strategy, based on survey findings;
- development of a surveillance system to ensure early warning against spread of disease/infection to new areas;

- monitoring results for progress and changes in infection/disease incidence; and
- reviewing and updating control strategies, to reflect the results obtained, as mentioned above.

In addition, public awareness and targeted education, as well as intersectoral collaboration, have been promoted for the effective prevention of disease in humans and its control in livestock.

Some of the major constraints of many control programmes have been:

- weak veterinary administrations, often insufficiently funded;
- absence of a clearly defined legal framework for a control programme;
- lack of accurate and reliable information on the disease in both humans and animals;
- ill-defined control strategy and un-monitored programmes;
- lack of intersectoral and interregional collaboration;
- poorly controlled movement of animals across borders and within countries.

3.2 FIELD EXPERIENCE WITH THE CONTROL OF *BRUCELLA MELITENSIS* FROM SELECTED COUNTRIES

Israel *(M. Banai)*

Brucella abortus was eradicated from cattle in the 1980s, based on vaccination of female calves with strain 19 vaccine and the implementation of a test-and-slaughter programme. Young (2-6 month old) female calf vaccination continues to be mandatory. In 1988, *B.melitensis* emerged as a national problem and a test-and-slaughter programme combined with Rev.1 vaccination (Elberg strain by ocular route) of young animals was conducted from 1993-97. Over 40 000 sheep and goats were culled, but the programme ceased because of budgetary constraints. This programme resulted in a significant reduction in the incidence of human brucellosis, as well as improved control of the spread of the disease among dairy cattle. Moreover, no human Rev.1 cases have been documented since the beginning of use of the ocular vaccination using the Elberg strain.

Vaccination of replacement female ewe-lambs and kid-goats with full dose Rev.1 given by conjunctival route has been carried out since then. In 1999, whole flock vaccination was instigated in several flocks, resulting in abortion storms in some intensively managed herds, and Rev.1 isolates were recovered. Rev.1 was also isolated from milk. In some cases the vaccine failed to protect flocks, despite virtually 100 percent coverage. Because of this experience, whole flock vaccination was banned in Israel. Moreover, ending the eradication programme has led to an increase in human cases and sporadic *B.melitensis* infections in dairy cattle herds have also been documented, presumably originating from small ruminant sources. The reported incidence of human brucellosis has been fairly static over the last decade. All cases were due to *B.melitensis, biovar* 1 mostly in southern Israel, and biovar 2 in northern Israel.

Tajikistan *(R. Jackson et al.)*

In a survey of 37 districts in Tajikistan in 2003, 5.8 percent of sheep and 5.47 percent of goat samples had serological evidence of infection by Rose Bengal Test (RBT) and competitive ELISA (cELISA) tests. Approximately 70 percent of 172 villages had seropositive animals and in some villages up to 40 percent of sheep and 45 percent of goats were seropositive. Evidence of animal infection was found in 14.4 percent of 3 513 households.

A pilot vaccination programme for small ruminants was initiated in 2004 in nine rayons. It used mass vaccination of young and adult non-pregnant female animals in 2004 and 2007, with vaccination of three to eight month old replacement females in autumn and spring in all years. Random checks of vaccination titres three to four weeks after vaccination were also carried out. The seroprevalence of infection in small ruminants in sentinel and randomly selected villages, as determined by RBT screening and confirmatory cELISA, was 8.9 percent in 2003 and 1.6 percent in 2009. Vaccination coverage currently ranges between 75 and 80 percent.

Armenia *(R. Jackson et al.)*

Armenia currently has a human population of about 3 million people and 600 000 cattle, sheep and goats. The median size of herds and flocks is three cattle of breeding age, eight sheep and three goats. Communal grazing and migration to summer pastures is common. A test–and-slaughter programme for brucellosis has been operating for a number of years.

A seroprevalence survey in 2006/07 established that the prevalence was 1.2 percent in cattle, 1.5 percent in sheep, and 2.7 percent in goats. Overall, 27 percent and 19 percent of 913 communities recorded infected cattle and small ruminants respectively. The household seropositivity rate was 2.3 percent. Infection in cattle was statistically associated with agricultural land size, presence of infection in small ruminants and size of cattle population. Large communities and large herds and flocks were generally at greater risk of infection than small communities.

While not knowing the actual species of *Brucella* involved at that stage, the data showed a widespread and uneven distribution of *Brucella* infection throughout Armenia. A comparison of findings for cattle and small ruminants showed sufficient differences to suggest that a number of epidemiological forces might have been operating for these two groups of livestock and the analyses did identify priority areas for the implementation of targeted risk-based surveillance and control measures.

Mongolia *(F. Roth)*

Mongolia has one of the highest reported human incidence rates of brucellosis - greater than 60/100 000 people. A test-and-slaughter programme commenced in the 1960s. This programme resulted in a reduction in individual animal prevalence but not in herd/flock prevalences. In addition, it was impossible to depopulate entire herds because of costs and no *Brucella*-free replacement animals were available. During the 1970-80s, a vaccination programme was introduced using both strain 19 and Rev.1. This also was unsuccessful because of discrepancies (up to 40 percent) between the actual and the required vaccination levels. During the 1990s there was an increase in prevalence following extensive privatization of veterinary services and inadequate surveillance of brucellosis. In 2000 a new vaccination programme was introduced with the aim of eradicating the disease by 2010. This vaccination programme has not been monitored or assessed as yet, but there is mounting evidence that the current programme is failing to meet its targets. Ultimately, a well-designed and robust test-and-slaughter campaign will be needed to achieve complete eradication.

A new action plan has been prepared, including enforcing and assuring the immunization campaign, education on preventive measures, assuring access to diagnosis and treatment of the most vulnerable high risk groups, i.e. herders, and implementing data analysis. This new plan will be pilot tested in two areas and, based on experience, epidemiological surveillance and action plans will be revised. Intersectoral collaboration between the Ministry of Health and the Ministry of Food, Agriculture and Light Industry will be strengthened.

Kyrgyzstan *(E. Schelling)*

A test-and-slaughter plus vaccination programme was operated up to 1990. Following privatization of the veterinary services, there was a collapse of surveillance activities and, from then on, both animal and human brucellosis increased, until in 2007 the reported human cases reached 74/100 000. A decision was made by the public health and veterinary authorities to cooperate in assessing the impact of brucellosis. Workshops were held with stakeholders from health and livestock sectors, donors, service providers and livestock organizations to review the veterinary strategy, perceptions of services, and market opportunities of transhumant livestock systems. Laboratory capacity was improved through training, including training in quantitative epidemiology. Field teams of veterinarians/technicians and physicians/nurses were introduced.

Multistage cluster sampling frames based on oblast (province), rayon (district) village, and proportional to size of village, were developed. Human (n=1800) and animal (sheep, goats and cattle) sera were collected (n=5369). The field study was complemented by a socio-economic household questionnaire on livestock production and a patient-based survey on the cost of brucellosis. Apparent seroprevalence rates were 15.6 percent in humans 2.8 percent in cattle, 3.3 percent in sheep and 2.4 percent in goats. The highest variances were at the district level. Seropositivity of goats was associated with human seropositivity at the district level.

Macedonia - Former Yugoslavian Republic of *(T. Kirandziski)*

The Macedonian Veterinary Directorate had been implementing a test-and-slaughter strategy for some years, but despite this the “village” prevalence remained at approximately 20 percent and the individual animal prevalence at about 2.5 percent. While brucellosis was widespread, the absolute number of infected animals was highly localized. Test-and-slaughter had also become too expensive. Therefore a decision was made to change this strategy, based on village prevalence levels in three geographical regions of the country, i.e. a region where the disease was traditionally not present or was at very low levels (<5 percent), a second region where the infection rate was 5-20 percent, and a third region where the infection rate was high i.e. >20 percent. It was decided to test-and-slaughter in the “free” region, vaccinate replacement animals and test-and-slaughter adult animals in the “moderately” infected region, and to carry out mass vaccination in the third region in the first year and vaccinate replacement animals in subsequent years. At the same time, identification and registration of small ruminants commenced. It will be necessary for several years of implementation of the revised programme before evaluation of results and before making any necessary modifications.

Palestine *(S. Alfuqaha)*

The Palestinian Brucellosis Control Programme started in 1998, adopting the strategy of mass vaccination of sheep and goats (all ages and both sexes) via the conjunctival route using full dose Rev.1 vaccine. A survey estimated the overall initial animal prevalence at 18.6 percent, with 72.9 percent of the flocks infected. The total sheep population was estimated at 530 822 and the goat population at 341 017.

The vaccination campaign started with mass vaccinations in 1999 and was repeated every two years until 2008, with vaccination coverage ranging between 25 to 95 percent depending on the year. From 2000 to 2005, vaccination of replacement animals only was carried out every two years with coverage at around 35 percent. Infrastructure weakness, limited resources, political and security crises, poor vaccine quality, deficient farmer awareness and uncontrolled animal movements were the major limitations. Despite these problems, the sheep and goat prevalence was reduced to 4.8 percent and the flock/herd prevalence to 46.3 percent as of 2005. There was also a significant decrease in human infections over this period.

Egypt *(B. Molina-Flores)*

Brucellosis, particularly *B.melitensis*, is endemic in Egypt, presumably affecting large numbers of animals as well as humans. It appears to be of particular risk in rural communities, especially in Upper Egypt. Several attempts have been made to control the disease by the national veterinary services, with assistance from development agencies and international organizations. A new Spanish-Egyptian cooperation project for the control of ruminant brucellosis in the Upper Egypt area was funded by a Spanish Cooperation project from 2005-09. This project included seven governorates, and involved primarily smallholders. The project also sought to strengthen the Egyptian veterinary services' capabilities to control brucellosis by improving surveillance at both field and laboratory levels and by implementing a massive vaccination campaign, training veterinary personnel, implementing brucellosis public awareness campaigns and enforcing brucellosis control legislation.

3.3 EVALUATION OF OLD AND NEW TOOLS FOR DIAGNOSIS AND CONTROL OF *BRUCELLA MELITENSIS* INFECTIONS

Latest developments in sheep and goat brucellosis diagnostic and surveillance tools *(B. Garin-Bastuji)*

The primary sources of infection for sheep and goats are foetal fluids and vaginal discharges after abortion, or full term parturition by infected females. Excretion of *B.melitensis* occurs also in milk and in semen and, therefore, infection can be transmitted through colostrum/milk consumption or mating. Congenital infections concern a limited rate of animals born from infected dams and are likely to result in latent infections. These animals may seroconvert at their first parturition only.

Historically, detection of *B.melitensis* infected animals is carried out either by direct visualization (Stamp's staining), isolation and identification of the causative agent, or by indirect measurement of either humoral (antibodies) or cell-mediated immune (CMI) responses.

Bacteriological and molecular diagnosis

Vaginal swabs, placentas or aborted foetuses are preferred for microscopy and culture, while primarily lymph nodes (especially head and mammary), but also spleen, udder, uterus, epididymes and testes, are recommended from necropsied animals. Vaginal swabs and milk are the most useful from live animals. Selective media are recommended for bacteriological isolation and better results are obtained when two different media are included - Farrell and modified Thayer-Martin. Differentiation of *Brucella* at species, biovar, and strain level by bacteriological and/or by molecular techniques, is usually carried out in reference laboratories.

Polymerase Chain Reaction (PCR) assays (including real-time format) are useful additional techniques for direct detection of an organism, but have not been adequately tested under field conditions and still need validation. In summary, while bacteriological isolation and identification provides a definitive diagnosis, it is time-consuming, expensive and requires well-equipped, safe laboratory facilities. However, before a country commences a control/eradication programme, it is useful to know exactly which species of *Brucella* is in cause and which animal species are infected.

Indirect (serological and allergic) diagnosis

Congenitally infected animals generally show no detectable antibodies before their first gestation. Young animals, when infected, usually show a low and transitory response, while adult animals develop antibodies at one to two months that usually persist for six months or more and may fluctuate during lambing/kidding or abortion. It is important to note that considerable variation in individual responses is to be expected.

For practical, large-scale surveillance and eradication purposes, the detection of antibodies against the relevant *Brucella* epitopes (S-LPS mainly) is still the most widely used technology. However, antigens and tests standardized according to OIE requirements have to be used for both efficacy and reliability. Specificity, i.e. the likelihood of false positive reactions, is important since antibodies against *Brucella sp.* may be present in a population due to either prior vaccination with, for example, Rev.1 vaccine, or other natural infection by cross-reactive gram negative bacteria such as *Yersinia enterocolitica* O:9.

Despite the scanty and sometimes conflicting available information, the RBT and Complement fixation tests(CFT) are the most widely used for small ruminants and remain the only OIE prescribed tests for international trade in these species.

RBT is recommended for the screening of sheep and goats for *B.melitensis* infection. This test is useful for early detection of infected flocks but, at individual level, it lacks specificity in low prevalence areas and also lacks sensitivity, especially in sheep. The sensitivity of the test can be improved by a simple modification, increasing the amount serum from 25 µl to 75 µl while maintaining the volume of antigen at 25 µl.

The complement fixation test (CFT) is the confirmatory test most widely used for small ruminants, despite its complexity and the heterogeneity of techniques used. Testing of sera from *B.melitensis* culture positive and negative animals showed that CFT provided the same sensitivity as both RBT and indirect ELISA (iELISA). However when tested under field conditions the sensitivity of CFT was lower than RBT and iELISA. The parallel use of RBT and CFT greatly increases the sensitivity of the diagnosis (any animal positive in either test is considered positive) compared to use in series (only animals positive to both RBT and CFT are considered positive).

CFT and RBT have low specificity when testing sera from small ruminants vaccinated sub-cutaneously with Rev.1. However, when the vaccine is applied conjunctivally this problem is significantly reduced. In infected flocks/herds/areas the predictive value of positive results in either test is close to 100 percent.

The Enzyme Linked Immuno-sorbent Assay (ELISA) tests give good results in small ruminants, using either iELISA or, to a lesser degree, with cELISA using various antigens, but generally those with a high content of smooth lipopolysaccharide are the most reliable. These ELISAs provide similar or better sensitivity than both the RB and CF tests but, like the classical tests, are unable to differentiate infected animals from recently vaccinated animals or other causes of false-positive serological responses. An OIE goat international standard will be available soon to allow the standardization of ELISAs in small ruminants.

Native-hapten (NH) gel precipitation tests have been developed and tested to allow for differentiation of infected versus vaccinated sheep. Fluorescence Polarisation Assays (FPA) are already regarded as an official test for the diagnosis of bovine brucellosis by OIE. This is presently under evaluation in small ruminants in Europe.

A CMI-based brucellin skin-test is another alternative test. The antigen (brucellin) should be purified (S-LPS free) and standardized. It should only be used in unvaccinated flocks/herds; where its high sensitivity makes it useful in the interpretation of potential false-positives in brucellosis-free areas. Subcutaneous inoculation of the lower eyelid with readings after 48-72 hours is recommended.

Comparison between FPA and conventional serological tests for the diagnosis of Brucellosis in ocular Rev.1 vaccinated and unvaccinated populations *(M. Banai)*

The FPA was evaluated in comparison with conventional serological tests (RBT and CFT) on a farm with 1 000 goats. Of 30 CFT positive goats, only 13 were positive by FPA. The FPA identified 83 additional responders that were negative by CFT. Neither test showed good concordance with the RBT. The FPA also showed poor concordance with isolation of *B.melitensis* on another farm. As the FPA test is rapid, it may have application as a screening test.

Time-Resolved Fluoresecence Energy Transfer Assay for the simple and rapid detection of anti-Brucella antibodies in ruminants *(J. Stack)*

A new, time-resolved fluorescence energy transfer (TR-FRET) was described and evaluated against sera from infected and uninfected sources. This test matched the performance of the iELISA which had 100 percent sensitivity and specificity and surpassed the performance of both cELISA and FPA. It is effective on poor quality sera and may have future applications if validated under field conditions.

Serological tests in humans - their ability to detect various anti-*Brucella* antibodies *(I. Moriyon)*

Serological tests in humans included RBT, tube serum agglutination (SAT) with and without 2-mercaptoethanol, Coombs, *Brucella*capt, iELISA, cELISA, lateral flow immunochromatography and FPA. Most of the tests are used to confirm clinical suspicions and also to assess the evolution of an infection and diagnose relapses. However, many of these tests are difficult to maintain and operate in developing countries. The iELISA or combinations such as SAT/Coombs, or SAT/*Brucella*capt may be used where there are adequate facilities, but in rural settings and in small or understaffed hospitals the RBT is preferred and obviously the most economical.

A potential drawback of the RBT is that, in endemic areas, a positive result may occur from simple contact, not necessarily followed by infection and disease, which decreases slightly the diagnostic specificity. However, while the RBT is usually interpreted as a qualitative test, it can be used to test serum dilutions to obtain a diagnostic titre. In the study of a large number of sera, 195 of 210 hemoculture positive patients had an RBT titre higher than 1:4, whereas only 1 of 105 contacts showed a titre above 1:4. Therefore, RBT with serum dilutions correctly identifies the vast majority of infections, leaving only a reduced number of patients for confirmation by more sophisticated tests. Also, in the follow up, and contrary to what happens with the SAT, RBT titres increase and may reveal seroconversion.

Use of rough strains of *Brucella melitensis* for vaccines *(P. Pasquali)*

Live attenuated vaccines such as *B.abortus* strain 19 and *B.melitensis* strain Rev.1 have been, and continue to be essential elements in control programmes. They induce good levels of protection against *B.abortus* in cattle and *B.melitensis* in small ruminants respectively, primarily by preventing abortions. Their major disadvantage is that serological differentiation between vaccinated and infected animals is often difficult. Both vaccines retain their pathogenicity and they may cause abortion if used in pregnant animals. Accidental human exposure can result in infection.

A rough strain of *B.melitensis* (strain B115) lacking S-LPS was evaluated in mice. The results showed that a significant protective immunity against challenge with virulent *B.melitensis* developed and did not induce interfering antibodies to S-LPS. Further studies are planned using natural hosts (sheep and goats) as models. While *B.abortus* strain RB 51 is also a rough strain and is generally considered protective in cattle, it is not effective against *B.melitensis* in small ruminants, in addition to being expensive.

3.4 PUBLIC HEALTH ISSUES AND INTERSECTORAL COLLABORATION

Overview of public health aspects of *Brucella melitensis* *(H. Kruse)*

The goal of WHO with regard to managing zoonotic health risks at the human-animal interface, is to minimize the health and economic burden of these diseases by preventing, controlling, eliminating or eradicating zoonotic disease risks originating from direct or indirect contact with animals, their products, or their environments. This is carried out by:

- defining policies and sustainable programmes for prevention and control of priority zoonotic diseases;

- strengthening early detection, characterization and rapid response to zoonotic public health risks including outbreaks;
- developing international and national tools and mechanisms for the assessment and reduction of zoonotic human health risks.

It is worth noting that brucellosis is one of seven zoonotic diseases which have been listed by WHO as "neglected". These zoonoses all have a very strong association with poverty.

The basic science and epidemiology of human brucellosis is known, including its control and eradication methods, exposure sources and methods of transmission, food safety issues, especially the need for heat treatment of milk and other dairy products, as well as diagnosis and treatment of the disease. However, it is often under-detected and therefore under-reported despite inflicting a high burden of disease. It affects all age groups and both sexes. The infection has a variable incubation period of several days to several months. Unless treated promptly, the infection persists and progresses to a chronic incapacitating disease with severe complications.

Clinical diagnosis is confirmed by immunological and bacteriological tests. Human infection occurs directly from infected animals via the oral and conjunctival routes or through breaks in the skin allowing contact with bacteria from tissues, blood, urine, vaginal discharges, aborted foetuses, and placentas. These infections are more likely to result in sporadic cases, whereas outbreaks occur following ingestion of contaminated non-heat-treated dairy products. Airborne infections have also been reported in microbiology laboratories and abattoirs. Where the infection persists in livestock, human transmissions continue.

WHO plays a major role in providing technical advice and country support through capacity building. Examples include setting guidelines on brucellosis in humans and animals, and developing networks of experts and collaborating centres and laboratories. For any control programme to be successful, it is crucial that there be good intersectoral collaboration between all governmental and non-governmental agencies involved.

Where the infection has not been controlled or eradicated, human infections continue to occur. In those countries in western Europe that have been successful in eradicating or at least significantly reducing the level of *B.melitensis* and *B.abortus* infections in their livestock, human infections occur rarely and most may be the result of immigration or visits to endemic countries. Human infections with *B.melitensis* tend to peak during birthing months of small ruminants. Human incidence data can be used as an indicator of the success or failure of any programme to control or eradicate *B.melitensis*, especially in sheep and goats.

Brucella melitensis **infections: food-borne versus animal contact** *(A. Robinson)*

A review of both human case reports and series of cases have identified risk factors for brucellosis. These include occupational factors as well as certain food exposures - usually associated with consumption of raw milk or other dairy products, and rarely raw meat. While case reports are useful, they do not provide quantitative risk estimates for intervention measures. A series of six case-control studies undertaken in Eurasia and the Middle

East were reviewed. These were carried out in Kyrgyzstan, Yemen, Egypt, Iran, Palestine, and Greece.

Elevated, statistically significant odds ratios (>2.0) were found for the following foods: home-made milk products from markets or neighbours, eating of ice-cream from street vendors and consumption of unpasteurized dairy products, such as buttermilk and yoghurt-type products. Eating other animal products such as meat or offal (e.g. liver) did not appear to carry an increased risk of infection.

Risk factors associated with human infection due to animal exposure included, exposure to aborted animals, working with animals, occupation (farmer or shepherd) and exposure to animal foetuses or discharge during parturition, including trauma during animal delivery, and rural residence.

In three of the studies it was found that knowledge of the mode of infection or the importance of pasteurization significantly reduced the risk of infection, thus confirming the importance of public health education.

Brucella sp. has been found in a wide variety of unpasteurized dairy products. Soft fresh cheeses present a higher risk than hard aged cheeses. Products that are home produced or from small-scale processors also present a higher risk of infection than products from large processors.

While all persons coming into contact with infected livestock are theoretically at risk, exposure to animal tissue, blood, discharges or body fluids during abortion, parturition and slaughter are high-risk events. Besides direct contact, ocular and aerosol spread is possible.

It is recommended that, if practicable, case-control studies be carried out to better identify and quantitatively analyse the risk factors in a country or region so that this information can be coordinated with surveys of knowledge, attitudes and practices (KAP) related to brucellosis.

The Syrian and Jordanian examples of integrated public and veterinary health programmes *(D. Tabbaa)*

Since 1990, the Mediterranean Zoonoses Control Programme (MZCP) has conducted four inter-country workshops/training on the surveillance of brucellosis in humans and animals, four laboratory diagnosis bench courses and has funded two country projects (Jordan and Syria) involving the respective ministries of health and agriculture in developing collaborative surveillance systems for human and animal brucellosis and also in strengthening laboratory capacity through building infrastructure, equipment and supplies.

This integrated public health and veterinary brucellosis surveillance system was designed to address the limitations of the surveillance systems, which included multiple incompatible diseases databases, incomplete and delayed data entry, additional burden of reporting and overload of data to be managed.

The objective of the integrated system was to serve the needs of both departments at local, provincial and national levels in the following areas:

- monitoring and assessing disease trends by time and place
- guiding prevention and intervention programmes
- informing public health policy makers
- identifying research needs

- providing a basis for community and programme planning
- protecting confidentiality while providing information to those with a need to know.

The software for this programme can be obtained from MZCP. Further development is currently underway.

Control strategies for *Brucella melitensis* *(L. Knopf)*

The World Organisation for Animal Health (OIE) is mandated under the Sanitary and Phytosanitary Agreement (SPS) of the World Trade Organization (WTO) to develop minimum standards, guidelines and recommendations to facilitate trade in animals and their products. These standards are science/evidence based and also serve the overall objective of OIE in promoting both global and animal health, as well as strengthening member countries' veterinary services. In the case of a zoonotic disease such as *B.melitensis* infection in small ruminants, OIE believes that protection of human health must be achieved through the control of the disease in the animal population.

Some key OIE recommendations for *B.melitensis* control within a country include:

- programmes must be properly planned, coordinated and resourced;
- both control and prevention require effective collaboration within and between sectors;
- eradication can only be achieved by test-and-slaughter combined with animal movement control and preventive measures;
- vaccination is a vital component of both control and prevention;
- selection of an effective vaccine and a strategy for its use is a critical decision;
- development of a coordinated surveillance programme to measure progress ;
- need for flock/herd management and food/occupation hygiene programmes;
- need for education and awareness programmes.

Other considerations at the national and regional levels include:

- programmes must be adapted to local specific conditions;
- brucellosis must be a national/regional priority and capacities must be available;
- national legislation must be developed and implemented;
- as animals, their products, and pathogens often ignore borders; collaboration between neighboring countries and regions is desirable.

Some of the generic OIE disease control and eradication policies that are applicable to *B.melitensis* include:

- use of standardized definitions and concepts to promote harmonization and equivalence;
- surveillance to establish the status quo;
- transparency in notifications, including humans, domestic and wild animals;
- application of minimum standards for diagnostic techniques and vaccines to meet OIE and WHO criteria;
- scientifically based criteria for disease control programmes and national legislation;
- application of ethical principles in trade and animal disease control;
- zoning/compartmentalization with a biosecurity border, where appropriate, within a country;
- import risk analysis and evaluation of veterinary services.

Provisions for *B.melitensis* are described in Chapter 14.1 of the OIE Terrestrial Code. This considers sheep and goats as susceptible species for trade purposes. There are also provisions for qualifications needed for the disease free status of a country, zone or flock level, both with and without vaccination. Maintenance of a disease free status and recommendations for surveillance are included. Recommendations for safe trade in live small ruminants for breeding and slaughter, as well as semen, embryos, and ova, are also set out.

The OIE Terrestrial Manual also includes disease specific information on *B.melitensis* for diagnostic tests and vaccines, as well as biosafety and biosecurity considerations for veterinary microbiology laboratories, quality control and principles of vaccine production.

The OIE World Animal Health Information Database (WAHID), which is linked to the World Animal Health Information System (WAHIS), provides extensive information and search capability for *B.melitensis* occurrence status by animal species, including notification legislation, vaccinations used and current control measures.

The OIE/FAO/WHO Global Early Warning System (GLEWS) provides for rapid notification of major animal diseases, including zoonoses. *B.melitensis* infection is a priority disease.

In summary, application of international standards in *B.melitensis* control and eradication programmes can significantly contribute to an effective control policy and the ability and capacity of a country to apply such a policy, i.e. good veterinary governance.

A critical step for decision makers: control or eradication of *Brucella melitensis*? *(J.M. Blasco)*

A critical step for decision makers in any country tackling a *B.melitensis* problem is to determine whether to control, i.e. lower, the disease effects by reducing the prevalence to a minimum, or to eradicate the disease and ultimately the causative agent from all reservoir animal species.

In Eurasia and the Middle East, besides sheep and goats (the major reservoir species), cattle, camels, yaks and buffaloes are often reared together. Breeding is often uncontrolled and grazing systems vary greatly. Also the current prevalence of infection is often unknown.

Current diagnostic and prophylactic tools are adequate, but even the simplest control programmes will not be successful unless there are well functioning public veterinary services and administrative institutions. If eradication is to be attempted, all susceptible animals must be identified, all animal movements controlled and an adequate budget has to be available to compensate livestock owners for the real market value of their culled animals.

The first major step is to determine the actual collective prevalence of brucellosis in the epidemiological unit of intervention. This unit could be the flock, herd, village, province, etc, with a similar epidemiological condition. All susceptible species and test eligible animals (sexually mature) should be included in this survey. A random-based sampling programme should be developed using systematic, stratified or multistage techniques. Sample sizes can be obtained based on expected prevalence and the confidence levels desired.

A frequent error is to assume that the prevalence in a country or region will be homogeneous. This is most unlikely and thus a countrywide mean prevalence could be very misleading. The collective prevalence (villages or herds) and approximate individual animal prevalences are required for proper selection of the control or eradication programmes. Where the collective prevalence (percentage of infected flocks/herds or villages) is uniformly very low (<1-2 percent), an exclusive test-and-slaughter programme with the ban of vaccination could be recommended. Where the collective prevalence is uniformly moderate (approximately 5 percent), a combined eradication programme based on young replacement vaccination and test-and-slaughter in adults could be recommended to eradicate the infection in the medium to long term. Where the collective prevalence is very high (>10 percent) even though the veterinary services and economic resources are available, mass (whole flock) vaccination of all animals involved in the epidemiological cycle is the only practical strategy to control the disease.

In countries with minimal veterinary services and limited socio-economic resources, vaccination is the most feasible option, irrespective of the prevalence levels identified.

Choice of vaccines and vaccination strategies

Currently there are two vaccines available that are effective enough and inexpensive. These are *B.melitensis* strain Rev.1 for small ruminants given at full dose (1 x 109 CFU) by the conjunctival route, and *B. abortus* strain 19 for cattle given individually at full dose (10 x 1010 CFU) subcutaneously or at reduced dose (5 x 109 CFU) conjunctivally. Both vaccines can be hazardous to humans and also may induce abortion when vaccinating pregnant animals.

At this stage there is inadequate information on the use of these vaccines in camels, yaks, and buffaloes

A budget should be prepared based on vaccine cost/animal, costs of identification, and operator costs to deliver vaccines.

When mass vaccination has to be applied, it can be carried out in two ways:

- mass vaccinate all animals every two years, including males (in the case of sheep and goats). This is the simplest method and only requires the ability to locate 100 percent of flocks/herds and to vaccinate all animals, at the ideal window of opportunity to avoid vaccine induced abortions, i.e. when animals are lactating or at the end of the parturition season, and fewest are pregnant. This procedure assumes that, at the actual replacement rates of these countries, every two years about 30-40 percent of the population will be susceptible;
- mass vaccination and individual identification of all animals in the first year and then identification and vaccination of the replacement animals only in subsequent years. This option, the main advantage of which is minimizing vaccine induced abortions, is obviously more complex, involving identification of young replacement animals each year. Assuming that 10-25 percent of the total population needs to be replaced each year, this programme will take 4-10 years before the whole population is fully vaccinated. Unfortunately this option has often failed in developing countries with nomadic husbandry systems, as owners keep replacements year round and several visits may be needed to ensure 100 percent vaccination coverage.

Once the prevalence of brucellosis can be reduced to minimal levels by either of the above mass vaccination procedures, and provided that the veterinary infrastructure and economic resources are available, eradication can be achieved through a programme based on the vaccination of young replacement animals combined with testing and slaughtering of infected adults. This programme will require individual animal identification and effective control of animal movements.

One practical eradication approach would involve no testing of mass vaccinated adult animals for two years following the first mass vaccination, to avoid culling healthy but seropositive animals. The only interventions during these two first years would be vaccinating 100 percent of young replacements, ensuring individual identification of the whole population and establishing effective animal movement controls. The use of the NH based gel precipitation tests, followed by immediate culling of infected animals, could be recommended as the most reasonable strategy to avoid the excessive culling of healthy but seropositive animals. Once the percentage of positives in these NH based tests is zero for at least two consecutive years, the testing schedule could be modified using OIE official tests - such as RBT, iELISA, and CFT - to reach and maintain brucellosis free status.

Vaccination should cease only when the prevalence is zero for at least one entire generation, in order to avoid relapses. Premature cessation of vaccination has been a frequent error in many countries. As a general rule, vaccination should never be abandoned until the prevalence is zero, the situation is maintained for 8-12 years, and the risk of transmission from infected epidemiologically related units is negligible.

Criteria for defining a vaccination programme for *Brucella melitensis* *(A. Giovannini)*

The choice of control strategies depends on several factors, including epidemiological, economic and organizational, e.g. veterinary services' capabilities and animal husbandry practices.

An efficient surveillance system is needed to determine incidence and prevalence at both individual animal and herd/flock levels. OIE standard reagents and tests should be used and quality controlled. Laboratories should participate in inter-laboratory proficiency testing.

The major strategies for *B.melitensis* control are:

- elimination of infected animals by test-and-slaughter: this method is expensive and in the short term needs an efficient veterinary service, individual animal identification and good laboratory and epidemiological support services;
- vaccination of young animals combined with the elimination of infected animals: with this option, herd immunity is established slowly and there is the need to distinguish vaccinated from infected animals;
- vaccination of young animals only: this can be done at lower cost and there is no need for testing;
- mass vaccination of both young and adult animals: this option is relatively economical and easy to manage. Rev.1 vaccine may be excreted in milk but usually at very low levels. It may also cause abortion in animals. Herd immunity is rapidly established with this technique;
- heat treatment of milk without any action in animal populations: this is obviously the lowest cost option, but those in contact with infected animals remain at risk. The economic effects/losses in animals also remain.

Where brucellosis is present at high rates, or when small ruminants are managed under extensive transhumant or nomadic systems, any strategy to control *B.melitensis* can benefit from a preliminary vaccination programme aimed at reducing the incidence/prevalence of infection. When a significant reduction in flock/herd prevalence has been accomplished, the control programme can be reviewed and alternative strategies considered.

The situation in Sicily: when tested in 2008, approximately 26 percent of flocks had at least one positive animal. This situation could have been the result of two different conditions. Either the infection was spreading among flocks continuously or the infection was confined to a group of infected flocks and actually spread very little. In the first case, vaccination would have been the best choice, but in the second case vaccination would have been useless for non-infected flocks. The second situation might have been due to delays in re-testing of infected flocks, delays in culling infected animals, or husbandry conditions impairing disinfection. Epidemiological investigations suggested that the latter situation was the most likely case.

National brucellosis control programmes: constraints, gaps in understanding and lessons learned *(D. Ward)*

Brucellosis has re-emerged from low prevalence to become an important endemic disease, especially in Eastern Europe, the Balkans, and the Commonwealth of Independent States. In part, this has been the result of conflicts, political changes and shortages of funds. Even when test-and-slaughter and annual vaccination programmes have been operating, infection rates have increased. Some of the technical constraints include: laboratory tests conducted under poor conditions, with minimal or no quality assurance; reactors remaining in flocks; no permanent identification of reactor or vaccinated animals; and ineffective movement controls. Mixing of animals at the village level and during summer migrations (transhumance) is an added complication. Some vaccines used have been of poor quality, especially if the cold chain was not maintained and where only young replacements were vaccinated instead of all animals. Vaccine induced abortions have also adversely affected farmer compliance.

Reported outbreaks in humans or animals often surprise authorities, indicating a lack of good surveillance systems to either detect problems or measure progress. There have been major changes in livestock ownership patterns, from state-owned collectives to numerous smaller, privately-owned flocks and herds within communities. Additionally, the privatization of veterinary services has not always been compatible with effective brucellosis control. Finally, control strategies have often been administered as task-based rather than risk-based.

Methods used in developed countries to control/eradicate brucellosis may not be appropriate for developing countries and those in transition. However many veterinary services can manage Rev.1 vaccination programmes successfully and high prevalences can be reduced within two to three years, provided good quality vaccine is used and high coverage attained. Mass vaccination is usually necessary initially and if there is extensive out of season breeding, twice yearly vaccination is recommended. Identifying and keeping count of vaccinated animals is essential to monitor coverage and surveillance, as well as to know the status of purchased animals. Vaccination can be promoted to owners, not only on the basis of protection from abortion, but also improved lamb/kid viability, improved fertility and milk production, added value of livestock and lowered risk of human illness. While there may be gaps in knowledge and information, this is not a valid reason not to start control programmes.

At both the field and laboratory levels some questions occur periodically:

- how significant are latent infections with *B.melitensis*?
- where do young uninfected animals most likely become infected? From their immediate environment or during mixing on summer pastures?
- why do some flocks/herds/villages have high prevalences?
- how is it best to deal with test positive animals where no compensation is available?
- should advice be given to communities with very high prevalence, as slaughter will have a large negative effect on livelihoods?
- are male animals clinically affected or significantly involved in transmission, and if not should they be vaccinated?
- does consumption of meat or offal from infected animals pose any human health risk?
- what, if any, are the risks of vaccinating seropositive animals?
- is it necessary to be concerned about distinguishing vaccine versus infection titres during mass vaccination phases?
- can the use of Rev.1 to vaccinate cattle, camels, buffalo and yaks be justified?
- what are the risks to humans of Rev.1 shedding in the milk following vaccination?
- at what level should the decision be made to cease vaccinating and commence test-and-slaughter?
- is there any evidence to show that control of *B.melitensis* in sheep and goats leads to elimination of the infection in cattle?
- is it feasible to combine multiple vaccinations with Rev.1, such as Peste des Petits Ruminants (PPR), Foot and Mouth Disease (FMD) and sheep/goat pox?

In summary, since 1996, FAO and several donors have assisted several countries in re-establishing control of brucellosis. A number of lessons have been learnt and practical answers to other field and laboratory concerns are needed. It is known that *B.melitensis* infections can be reduced to low and stable levels with Rev.1 vaccine. Countries in these regions are encouraged to start or, if necessary, modify existing strategies based upon results of other countries. For example, in Greece the incidence of human brucellosis has been significantly reduced since 1975 and in Tajikistan the seroprevalence in small ruminants has also been reduced since 2003, following extensive Rev.1 vaccination programmes.

Socio-economic aspects of *Brucella melitensis* control: challenges for impact assessment *(A. McLeod)*

Impact assessment measures a change resulting from something that was done, such as an intervention or a project, or something that has happened, such as a disease outbreak. Commonly used tools for economic analysis include partial budgets, cost benefit analysis, cost-utility analysis and general equilibrium models. To take social factors into account, a livelihoods analysis or gender analysis might additionally be used, depending on the particular circumstances.

Many brucellosis affected flocks or herds are small-scale or extensive and their owners often have limited access to animal health and human health services. However *B.melitensis* infection is not a “crisis” disease and there is time to plan accordingly. It is also assumed that vaccination is effective, progressive control is possible, but the recurrent costs may be high.

It is necessary to know why an intervention is being made, who is affected and how people perceive their risk, what has changed or might change, changes should be quantified and put into economic values and decisions taken about who might pay for what. For example, the factors that need to be taken into account when estimating the impact of two approaches to dealing with brucellosis, namely test-and-slaughter to eradicate compared to vaccination to reduce abortion and exposure potential. Each would be appropriate to use in different epidemiological situations. The comparison is summarized in the table below.

There are several assessment challenges, including:

Lack of data: in many developing countries there is only limited data on human and animal incidence, and limited reliable data on livestock productivity. It may be possible to borrow from countries with similar systems or to carry out rapid surveys to improve some of the estimates.

There are two kinds of benefit: the first can be estimated from the increased value of output from livestock systems, and the second from improved human health.

The latter can be quantified using indicators such as DALYs (a measure of overall disease burden and defined as one year of healthy life lost) or QALYs (a measure of disease burden and based on the years of life added by an intervention). It may or may not be possible to translate these indicators into economic values.

	Regular vaccination to reduce outbreaks of *B.melitensis*	**Test-and-slaughter to eradicate *B.melitensis***
Reason for the intervention	Public health concerns	Public health concerns, wish to increase trade
Most at risk from human disease	Consumers of raw milk; producers handling/slaughtering sick animals	
Others affected by intervention	Producers; traders; veterinary services; vaccine suppliers; public health services	As for vaccination PLUS Exporters BUT NOT Vaccine suppliers
What might change if the intervention is successful	Increased productivity in some flocks; less human disease; less treatment costs	As for vaccination PLUS better trade prospects AND reduced vaccination costs if vaccination was previously used.
Practical issues that may affect the intervention	Vaccine efficacy; vaccine supply; delivery system	Passive surveillance; Reliability of tests; Compensation system; Carcass disposal
Perceptions that may affect the intervention	Previous experience of vaccination; farmer concern about production losses or abortion; farmer experience of human symptoms; veterinary service confidence in the vaccine	Farmer concern about production losses or abortion; farmer experience of human symptoms; “what does improved trade offer for me?”

Finally, a decision must be made on who will pay or how costs might be shared. Some practical considerations, such as how much people can afford to pay and what kind of cost sharing might work, will need to be evaluated. As an example, paying for test-and-slaughter may only be possible through public funds (i.e. taxes) or as a negotiated use of a public-private health fund. For vaccination, however, it may be possible to share costs by farmers paying for vaccination at the time their animals are vaccinated.

The extent of willingness to pay for brucellosis control - experience from Tajikistan *(A. Ward)*

Currently, the direct cost of Rev.1 vaccine for owners of small ruminants in Tajikistan is 0.65 (USD)/head. The question is, who will pay for long-term vaccination, as the government is unable to finance all costs and donors will not finance long term projects? A study was undertaken in 2009 to assess the willingness of 500 smallholder livestock owners in 55 villages to pay for vaccines. An administered questionnaire asked for detailed information on ownership of livestock, recent use of animal health services, disease awareness and household demographics. The average herd sizes were: cattle = 4 animals and small ruminants = 12 animals. Willingness to pay (WTP) for continuing brucellosis vaccination (starting in 2010) was estimated by offering four primary price points: 0.13, 0.26, 0.39 and 0.51 USD.

Currently, livestock owners pay for several animal vaccinations, such as FMD, anthrax and sheep pox, but coverage is irregular. Approximately 88 percent of owners were aware of brucellosis, 60 percent were aware of symptoms in humans, but less (28 percent) in cattle. Cattle owners reported three percent of abortions, while sheep and goat owners reported ten percent of abortions during the last 12 months.

While 86 percent of respondents had had their animals vaccinated during the last 12 months, only 26 percent reported vaccinating against brucellosis. However, post-vaccination monitoring of sheep and goats following Rev.1 vaccination showed that more than 75 percent in the survey area were seropositive. This indicated that possibly owners were not well informed by veterinarians as to what diseases their animals were being vaccinated against. The average price paid for all vaccinations was between 0.26-0.29 (USD). Only four percent of vaccinations were given free.

Respondents were presented with a scenario stating that free "eye drop" vaccination (with Rev.1) would cease later in 2009 and that owners would be required to pay if they wished to continue the preventive vaccination.

When asked to pay for the four levels as described above, responses were as follows: eighty-eight percent agreed @ 0.13, 78 percent @ 0.26, 65 percent @ 0.39 and 55 percent @ 0.51 USD. There did not appear to be any significant differences across herd sizes. The vaccinator fee is approximately 0.20 (USD). It is unlikely that farmers would be prepared to pay the total costs. Given these results, the cost recovery price will need to ensure that coverage levels do not drop below 80 percent. What remains is to devise a system that can be "sold" to farmers and is practical, easily administered, guards fiscal integrity of funds collected, provides incentives and "delivers the goods" to owners as they have come to expect and will now have to pay for.

Economic impact of brucellosis in Kyrgyzstan *(E. Schelling)*

As part of the preceding discussion on prevalence of brucellosis in Kyrgyzstan (see previous communication of Schelling on Kyrgyzstan), the average annual losses to national livestock production have been estimated as follows:

Total costs were 10.6 M (USD), of which 6 percent was attributed to public health costs. These include in- and out-patient costs, out-of-pocket expenses, loss of income and coping costs. Losses in small ruminant production were estimated at 30 percent and in cattle at 64 percent. However, considering the variability of parameters and pending a full sensitivity analysis, the range of annual losses for the country was estimated to be 5-15 M (USD).

Experience from other Central Asian countries shows that mass annual vaccination of cattle (first two years, then calves only) and of all small ruminants for ten years, combined with public awareness campaigns and assuming vaccination coverage of 80 percent, will reduce human transmission. Mass screening for brucellosis may not be needed as the elimination of seropositive animals without compensation will not lead to an effective reduction of transmission due to the low number of seropositive animals actually eliminated.

Knowledge, Attitudes and Practices (KAP) studies in brucellosis *(A. Ramlawi)*

The success or failure of a disease control and prevention programme depends on many factors, but broadly speaking these can be divided into technical aspects (such as tests, vaccines, and regulation infrastructure) and non-technical aspects (such as willingness of the community to cooperate and its understanding of the disease). Knowledge of local customs, beliefs, practices, and marketing movement patterns of livestock and their owners is key information.

A KAP study was carried out in 1999 under the auspices of the National Zoonotic Committee. The findings were as follows:

- the number of participants was 1 196, of which 16.8 percent were illiterate, 18.1 percent had completed high school and 10.9 percent had post high school education;
- approximately 47 percent felt they were somewhat informed about brucellosis (mostly in the 26-35 year old age group) and from this group 86 percent were informed regarding transmission to humans;
- knowledge of the animal species involved in transmission: 78 percent included sheep, 66 percent cattle and only 15 percent goats;
- approximately 97 percent believed milk was involved in transmission, 92 percent white cheese, 65 percent aborted foetuses and placentas, 80 percent offal (liver, spleen, kidney) and 42 percent insect bites;
- approximately 60 percent were aware of some symptoms of brucellosis in humans. Person to person transmission was thought to occur by 52 percent of respondents, and vertical transmission by 58 percent;
- as far as treatments were concerned, 44 percent believed that only up to 15 days of treatment were needed. Availability of free treatments from the Ministry of Health was known by 74 percent. Approximately 53 percent believed that people with brucellosis should be isolated and 72 percent that complications were likely to occur, but 88 percent felt that complete recovery did occur;

- in terms of preventive measures, 98 percent believed that it was necessary to boil milk, 91 percent to boil cheese, 83 percent to wear gloves when handling foetuses and 64 percent to control flies and mosquitoes;
- animal owners and their families were considered most susceptible by 71 percent of respondents;
- other preventive measures were: using gloves when dealing with animals (89 percent), washing hands after handling animals (99 percent) and vaccination of animals (96 percent).

Information on family dairy product consumption included the following:

- pasteurized milk was consumed by 39 percent, fresh milk by 54 percent, and powdered milk by 28 percent (categories not exclusive);
- of those consuming fresh milk, 97 percent boiled it prior to use. Laban (raw) was consumed by 30 percent and pasteurized or cooked by 28 percent. Fresh white cheese was consumed by 38 percent without prior heating. Only 6 percent of respondents ate raw or undercooked spleen, liver or kidney;
- finally, 90 percent of persons surveyed indicated they needed more information on brucellosis.

Another KAP study was conducted in 2007 by the staff of the Palestinian Brucellosis Control Programme (PBCP) (see paper by Alfukaha). This survey included both livestock farmers and consumers. Educational levels of the two groups differed, as follows: illiteracy - farmers 24 percent/consumers 9 percent; attended school - farmers 67 percent/consumers 71 percent; post–high school - farmers 10 percent/consumers 20 percent.

- of the farmers, 82 percent had sheep, 55 percent goats and approximately 8 percent cattle. The majority of the farmers (>75 percent) knew that small ruminants were prone to infection;
- disposal of a dead foetus by farmers was as follows: throw away and likely to be eaten by a dog - 37 percent; bury - 50 percent; burn - 9 percent; and other methods 5 percent. The majority of abortions occurred in barns;
- if farmers suspected brucellosis in their animals, 60 percent would be likely to report this to a ministry official, 83 percent would seek veterinary assistance, 11 percent would sell the animal(s), 17 percent would slaughter the animals, 55 percent would keep the animals; and 67 percent would treat them;
- for personal protection, 57 percent reported they did not use gloves. Others used gloves, but only if dealing with a foetus/abortion, retained placenta or normal delivery;
- when purchasing animals, 92 percent of farmers relied on their own experience. Some (28 percent) had the animals inspected by a veterinarian, percent required laboratory tests, and 5 percent demanded immunization certificates;
- approximately one-third (32 percent) of farmers believed their families were at risk of acquiring brucellosis. A total of 126 farmers reported that one or more of their household members had been diagnosed with brucellosis. In these cases 30 percent were believed to be infected directly from livestock, 57 percent from contaminated, unheated milk or cheese and 4 percent from uncooked meat products;

- a survey of consumers revealed that dairy products were acquired from a wide variety of sources, including dairy factories, retail shops, unknown or known farmers, street vendors or were home produced;
- of the latter products, 80 percent were boiled prior to consumption.

The results of this survey show that the PBCP needs to be revised and some of these findings need to be integrated. Over 80 percent of animals are not slaughtered on licensed premises, under veterinary supervision, and those carrying out slaughter are at risk. In addition, 57 percent of milk in Palestine is from sheep and goats, in small scattered, family-run units and traditionally processed. Much of this milk production needs to be redirected into pasteurization schemes to minimize the risk to urban populations. Non-authorized sale of infected animals and contaminated products must be prohibited, especially if eradication of brucellosis is to be achieved. Movement control is extremely difficult due to the current political situation. Two recent outbreaks in Hebron from Israeli originated sheep are evidence of this problem. There is also a need for improved intersectoral collaboration in occupational and food hygiene. Finally surveillance of humans and animals, as well as outbreak investigation, needs to be improved. Both Palestinian surveys also highlighted the significance of illiteracy, especially in rural areas, presenting a challenge for health educators.

Brucellosis: a complex communication challenge *(S. Sarkar)*

A fundamental premise is that communication can address or influence information and perception related factors, but it cannot replace the provision of services and has a complementary function in the prevention of brucellosis, a disease posing important challenges due to the complex supply chain with millions of people involved and dependent on the production and distribution of animals and dairy products. While brucellosis has serious health implications, it is designated by WHO as a "neglected" zoonosis. Tradition and cultural practices contribute to disease transmission. Here communication and behaviour change play important roles in complementing disease control tools such as vaccination, test-and-slaughter and movement control. It needs to be recognized, that the communication capacities of ministries of agriculture and health of most affected countries are limited and seriously under-resourced. Brucellosis competes with other health and development priorities.

If prevention and control strategies are going to be successful, it is important to assure that livestock farmers, communities and frontline staff agree with the proposed control strategy and will fully engage in the response. The media and organizations such as on-site NGOs and external donors, as well as national governments, need to be fully and demonstrably committed to the brucellosis control strategy.

Communication tools and guidance needed by ministries and other FAO or WHO partners need to be identified and provided. However, high levels of awareness do not necessarily lead to changes in behaviour and practices. The "practicability" of a recommended practice and its costs influence the adoption of new behaviours and practices. Real and perceived risks need to be differentiated. Individuals or communities respond differently to health hazards depending on how they perceive a risk, as their perception is influenced by their context, i.e. their own life experiences, values, and culture.

Some key recommendations on developing a communication framework for brucellosis should include the establishment of a multi-disciplinary, technical working group on brucellosis communication at global and national levels. In addition, guidelines for standardized rapid KAPs, as well as qualitative studies are needed to establish behavioural baselines, understand risk perceptions and identify motivational factors. Training packages for key communication staff and stakeholders need to be developed that specifically deal with brucellosis outbreaks, risk and behaviour change communication. The allocation of a minimum of 15 percent of total programme budgets to undertake communication/ advocacy interventions is recommended in order to be able to develop and implement a three-track communication campaign directed at: public education and participation; targeted behaviour change communication; and policy change advocacy.

In summary, the perception of risk is central to any communication or advocacy strategy and communication should be seen as an integral component of the overall technical strategy and while it cannot replace the provision of services, effective communication can influence the availability and uptake of those services.

4. Outcomes of the meeting

4.1 DIAGNOSTIC TOOLS FOR SURVEILLANCE IN ANIMALS AND HUMANS

Human brucellosis

Serological diagnosis of suspected human infections, following development of symptoms consistent with the WHO case definition, have been described in the "Guidelines for Coordinated Human and Animal Brucellosis Surveillance", FAO Animal Production and Health paper 156. These recommendations remain valid with some modification necessary, taking into account the results of more recent studies, e.g. SAT (titre equal/greater than 1:160) or any of the following tests, as previously recommended - iELISA, CFT, Coombs, FPA, *Brucella*capt, RB (titres equal/greater than 1:8). The RBT is particularly useful in small laboratories and clinics, but positive results should always be confirmed by one of the above tests. The sensitivity of the RBT is reported as approximately 99 percent.

Antibodies may remain detectable for long periods after infection, even if treated and also following exposure to *Brucella sp.* It is important to note that serological responses to infections vary and it is not clear why some individuals develop high titres while others have only low values during the disease.

The investigation of clinically suspect cases, such as "fevers of unknown origin", is recommended as a useful tool to determine the incidence of the disease in humans and/or monitor the efficacy of control/eradication programmes in animals. While familial brucellosis does occur, especially following point source exposure from contaminated dairy products, screening of family members is likely to result in both symptomatic and asymptomatic results. Screening of "at risk" occupational groups may be justified for epidemiological investigations.

Animal brucellosis

In general serological tests in animals have been used mainly in the following situations:

1. baseline prevalence survey in areas before deciding on strategy to be implemented to control and/or eradicate animal brucellosis;
2. monitoring the efficiency of the first stages of control programmes based on mass vaccination, which includes a representative sample of vaccinates two-to-three weeks after vaccination to monitor serological responses;
3. eradicating infected animals from flocks/herds in control/eradication programmes, based either on a combined vaccination of replacement animals and a test-and-slaughter scheme in adults, or the implementation of an exclusive test-and-slaughter policy of animals over 12 months of age;
4. surveillance of flock, herd, region, or country status after eradication.

Baseline prevalence survey

For such a survey, epidemiological units should be defined according to the organization and distribution of husbandry systems. The sampling frames may include regions, villages, communities, flocks or herds, species (including mixed), intensive/extensive, sedentary, transhumant, or nomadic. The sampling frames should be consistent with OIE standards, as defined in the OIE manuals or codes.

Prevalence estimates from surveys are based on an assumption of random sampling. For accuracy, a probability (random) sampling is preferred. Systematic, stratified or multistage sampling techniques can be used. Sample sizes can be calculated based on the appropriate confidence limits determined and the expected flock or herd prevalence. For further details, consult "Guidelines for Coordinated Human and Animal Brucellosis Surveillance" (FAO Animal Production and Health paper 156). It is important that prevalence levels be established at both the collective (village, flock, herd) and individual animal level. Only sexually mature animals should be sampled for brucellosis status.

Depending on laboratory availability and expertise and in the absence of previous vaccination, a basic low cost test such as the RBT and/or more expensive tests (iELISA, cELISA or CFT) could be used to provide information for decision-making. In the absence of previous vaccination, RBT is recommended as the test of choice for baseline surveys.

The use of complementary/confirmatory tests in baseline surveys would systematically decrease the sensitivity of the survey and are therefore not recommended due to their very low predictive value in areas where the infection is historically endemic and where no effective control/eradication programme has been in place for long periods.

Tests should always be carried out according to the OIE manual "Standards for Diagnostic Tests". Antigens should be obtained from reputable sources and standardized according to the above manual. Positive and negative control sera should be included in testing procedures periodically.

By definition, in areas where vaccination has been practised recently or is currently being carried out, sampling should be confined to either unvaccinated animals or adult animals vaccinated when young, in order to prevent potential serological interference due to vaccination.

Information on concurrent surveillance to establish human incidence provides additional information on the effectiveness of the control measures in animals.

Monitoring the efficiency the vaccination programme

A strategy similar to that described above for the baseline survey could be used to monitor vaccination programmes (provided that careful attention is paid to avoid detecting seropositive animals due to vaccination, that a lot of time has elapsed since vaccination, that vaccinated animals have been identified and that confirmatory tests have been used, etc.). One additional modification would be to periodically check recently vaccinated animals (approximately three weeks after vaccination) to determine whether animals have seroconverted and that vaccine coverage is adequate. This will evaluate maintenance of cold chain and vaccine efficacy, as well as the degree of quality of the vaccination performed by the technicians involved. Preferably, vaccinated animals will have been identified.

Eradicating infected animals from flocks/herds in control/eradication programmes

In the early stages of a control programme, test sensitivity is of paramount importance because the objective is to reduce the number of infected animals in the population.

There is no perfect test strategy for diagnosing disease and tests should not be used as final answers, but rather as tools which are combined with other skills and information to work out a specific control programme for each flock or group of animals. Careful history taking, herd examination, analysis of patterns of test positives and appropriately timed sequential testing can all be used to investigate the infection status of a herd or flock. Successful control or eradication can be best achieved by using testing strategies designed to achieve accurate herd diagnosis, followed by progressive resolution of problem herds and flocks diagnosed as infected.

Once the infected herds/flocks are identified, individual testing should be implemented in such a way that sensitivity is "maximized". Therefore parallel testing is recommended. Suitable parallel testing strategies are RB or modified RB (75/25) as screening and CF test as confirmatory. Other suggested combinations could include iELISA as screening and CF test as confirmatory. With such a testing strategy (high specificity in detecting infected herds/ flocks and high sensitivity in detecting infected animals), the efficiency of control/eradication can be monitored.

Surveillance of the free status after eradication of the infection

In areas where the infection has been fully eradicated, the positive predictive value of any available test is generally low. Therefore a "series testing" protocol is recommended in order to increase the predictive value, taking into account that any positive result would require an investigation in order to rule out *Brucella* infection. Very specific tests or series of tests are recommended. Considering that none of the available serological tests are sufficiently specific to identify false serological reactions due to *Yersinia enterocolitica* O:9, the allergic test (brucellin test) is the recommended confirmatory test for surveillance.

Abortion notification is a useful tool for detecting *Brucella* infection in low prevalence and free areas, but it should not be used as a primary tool. The differential causes of small ruminant abortion should be investigated wherever possible to avoid potential blaming of Rev.1 vaccine. Testing can be carried out at public "windows", such as markets and slaughterhouses (abattoirs). The sampling frame chosen for the declaration of freedom and maintenance of the free status in the area should comply with OIE standards.

Other recommendations

- Research studies should be carried on the test characteristics of the different formats of the cELISA in small ruminants.
- The differentiation between infected and vaccinated sheep and goats, despite considerable research over the last few years, is still problematical. However the use of Rev.1 vaccine by the conjunctival route has proven to be effective in limiting diagnostic interferences, especially when used in young replacement animals.
- Regional coordination for laboratory diagnostics should be encouraged.
- All tests should be OIE recommended and standardized.

- Molecular typing of *Brucella*, while very useful for epidemiological purposes, is expensive and not easily applicable in routine diagnostic laboratories. Its use should be restricted to reference laboratories.
- Bacteriological investigations are an efficient and independent tool for confirming infection and should be used to improve the efficiency of a programme, provided that well-equipped safe laboratories and well-trained staff and adequate budget are available

4.2 CONTROL STRATEGIES

Brucella melitensis infection remains one of the most important zoonotic diseases of major economic and public health concern in many parts of the world and especially in the Middle Eastern and Eurasian regions.

In many countries in the Middle East and Eurasia where the disease is endemic, there is in general a positive correlation between the level of *B.melitensis* infection in small ruminants and the number of infections in humans. Humans are usually infected with the organism through contact or through ingestion of contaminated milk or dairy products. Control of the disease in animals is a pre-requisite to reducing its burden on public health.

Guidelines for surveillance and control of *Brucella melitensis*

Over the years there have been a number of guidelines and manuals published on brucellosis, with particular emphasis on *B.melitensis.* These are listed in Appendix 3. The participants recommend reviewing the available documentation and updating the guidelines for control and surveillance of *B.melitensis* in susceptible animals. These guidelines should be accessible to countries in local languages.

Control of *Brucella melitensis* in small ruminants

There are different strategies to reduce the incidence of infection with *B.melitensis*. These strategies aim at controlling and ultimately eradicating the disease. Brucellosis control strategies are not necessarily mutually exclusive, but rather complementary. The prevalence level of infection and control of the spread need to be considered as main critical factors.

Which control and eradication strategies are applied depends on regional and geographical animal management, husbandry and individual host factors, on patterns of commerce and trade, acceptance of strategies by livestock owners and, most importantly, on the distribution of diseases and infection and the financial, technical, and personnel resources available.

Different countries and even ecologically distinct areas within a country may require different strategies for the prevention and control of brucellosis in small ruminants, depending on epidemiological and socioeconomic conditions.

The farming community needs to understand and accept the needed control strategies.

Mass vaccination

If *B.melitensis* is endemic in small ruminants, vaccination should be considered as the main control tool, particularly when sheep and goats are managed under extensive transhumant or nomadic systems and animal movements cannot be effectively controlled.

Any strategy to control *B.melitensis* can take great advantage from a preliminary vaccination programme aimed at reducing the incidence and the prevalence of the infection (including the risk of abortions and shedding).

Mass vaccination implies vaccination during the first years of the programme of all animals (destined for breeding), with vaccination of young replacement animals only in the subsequent years. An alternative vaccination approach would be to apply mass vaccination the first year with repeated mass vaccination campaigns every two years. The selection of one or the other is based on the vaccination coverage desired and the ability to identify animals.

Mass vaccination should be adapted to find the window when animals have been at the end of gestation or immediately after parturition in order to minimize abortions due to the vaccine. It must be emphasized that vaccination should continue for many years until the presence of *B.melitensis* is significantly reduced or close to zero and beyond for at least one generation.

Vaccination of young replacement animals combined with a test-and-slaughter policy

Combination of a test-and-slaughter policy and vaccination of young replacement animals could be considered where the prevalence is low and where animal movement is controlled, as well as an adequate budget for full compensation of farmers for their slaughtered animals.

Test-and-slaughter

The test-and-slaughter strategy compared to vaccination is only justified economically when the herd prevalence of infection in an area is very low. In addition, the following conditions are essential to embark on a test-and-slaughter strategy:

- financial resources and facilities must be available for testing and payment of compensation, for an effective surveillance programme;
- a proper legal framework to enforce the slaughter strategy is in place;
- slaughter can be carried out in a manner that minimizes human health risks;
- full cooperation of farmers in accepting the slaughter policy of infected animals.

Role of male animals in the transmission and maintenance of infection

Different opinions have been expressed by experts at this meeting about the role of male animals in the transmission and maintenance of infection and the need for them to be vaccinated. However, while the role of the male in the epidemiology of *B.melitensis* is still contentious, it is known that the organism can be recovered from semen periodically. Vaccination of males destined for breeding purposes will increase herd/flock immunity. Rev.1 vaccine also protects against *B. ovis* which may also be present in a flock.

Surveillance and monitoring progress

Control programmes for brucellosis must be accompanied by strong surveillance systems to detect newly infected herds/flocks and to monitor progress. A brucellosis control programme should be regularly monitored for progress and changes in disease incidence. When incidence is revealed to have been significantly reduced, the strategy could be reviewed and updated. Surveillance of human and animal brucellosis should be coordinated.

Brucella melitensis Rev. 1 vaccine

The *B.melitensis* Rev. 1 vaccine (strain Elberg) is the best vaccine available for the control of brucellosis in small ruminants. Rev. 1 vaccine is the most widely used vaccine for small ruminants throughout the world and has been applied successfully on a large-scale in many countries. However, some concerns have been expressed over different Rev.1 vaccines being used in countries which may not all be based on the original Elberg strain. Therefore, it is strongly recommended that countries use Rev.1 vaccines that comply with OIE quality standards, including identity of the seed strains.

The Rev.1 vaccine displays residual virulence and can induce abortions, especially when administered to animals in the first months of pregnancy. Technical approaches (dosage and route) to optimise the vaccination scheme and to minimize adverse effects are available and well documented. The use of the standard full dose (1 x 109 colony forming unit/dose) through the conjunctival route has been shown to be the most effective option.

Use of Rev. 1 vaccine in cattle, camels and buffaloes

There is a growing incidence of *B.melitensis* in cattle, camels and buffaloes in many countries as a result of high prevalence of the infection in sheep and goats. Unfortunately, insufficient information is available on the safety and efficacy of Rev.1 vaccine in these animal species and further studies are required.

4.3 CROSSCUTTING ISSUES

Institutional issues

Collaboration between FAO, OIE, and WHO on brucellosis control and prevention should continue and should expand, where necessary. This should involve consultations with national and international experts to raise awareness, especially with regard to research needs, and the development of guidance for and review of national action plans.

WHO's MZCP should be further enhanced with the collaboration of OIE and FAO headquarters and regional staff to develop, evaluate and support brucellosis surveillance, control and prevention programmes in the region.

At the national level, governments should adopt/encourage a mulitisectoral, interdisciplinary and integrated approach for the prevention, surveillance and control of brucellosis, involving public health, animal health, emergency response, environmental and wildlife authorities, as well as other relevant stakeholders.

Collaboration between the veterinary and public health sectors, especially involving joint outbreak investigations, the sharing of surveillance data and monitoring progress towards control, needs to be fostered. Furthermore, the sectors need to engage in joint advocacy and obtain political commitment for the agreed strategy. Underpinning this recommendation is the concept of "One Health", defined as the collaborative effort among multiple health disciplines, working locally, nationally, and globally, to achieve optimal human, animal and environmental health. Examples would be vaccination programmes targeted at children and livestock in isolated regions.

Communication and behavior change

A multidisciplinary, technical risk communication working group should be established to develop guidance on health education for brucellosis prevention and control, taking into account:

- food safety and options for safe processing and handling of traditional (dairy) products;
- the building of communication capacity and strategies to target specific groups, such as farmers, herders, slaughter-plant operators, dairy processors, community leaders and children, via school activities. etc;
- communication should target women in particular, as facilitators of change and their role in animal husbandry, milking, care of children and newborn animals, as well as food preparation;
- make optimal use of veterinary public health (VPH) networks and other FAO, OIE and WHO websites.

Potential for multiple vaccinations in small ruminants

The feasibility of simultaneous, multiple-disease interventions to control transboundary animal diseases, such as combining vaccination against *B.melitensis* with other vaccines such as PPR, FMD and sheep/goat pox, needs to be investigated. FAO should make this a research priority.

Biosecurity

While biosecurity is now becoming an important element of modern farming procedures, these procedures in countries in transition or developing countries have not been promoted at village, farm or market levels. Further studies are needed to develop and evaluate practical options.

Standard Operating Procedures

It is recommended that standard operating procedures used in brucellosis control be included in a tool box to be developed by FAO in collaboration with OIE, WHO and member countries. The tool box should contain specific information on a wide range of techniques, information systems, reagents, vaccines, recent scientific peer reviewed articles, etc. This would be posted on institutional websites and be available in Russian, Arabic, and French. It would be subject to continual updating, as required.

4.4 DISEASE CONTROL ECONOMICS: FROM PLAN TO PROGRAMME

When planning a *B.melitensis* control and, ultimately, eradication strategy, funding is obviously required and the following budgetary components should be included:

- a baseline prevalence survey to include risk assessment and to allow for selection of the strategy most likely to be successful in terms of benefits to human health and also livestock productivity;
- funds for research projects to include epidemiological studies to identify not only risk factors but to assist in trouble-shooting problems as they arise, husbandry studies, and also cost-benefit analyses;

- laboratory services at both central and local levels. This would involve equipment, reagents, and training of staff, personnel salaries and a computerized data information system. The latter should include staff and equipment for data entry at various levels to ensure readily available results for staff at all levels;
- field service operations for vaccinations, test-and-slaughter oversight, animal identification etc;
- public and livestock owner education programmes and materials based on area-specific KAP surveys, suitable for media presentations;
- compensation funds for a test-and-slaughter programme;
- funds to monitor animal movement controls, certification and testing;
- a dedicated brucellosis surveillance unit to continually monitor progress or lack thereof and communicate results to those with a "need to know";.
- identification equipment for livestock to include tags and microchips, etc;
- vaccines, equipment and supplies for vaccination campaigns, as needed;
- ongoing in-service training of field and laboratory staff.

The benefits of a brucellosis control and/or eradication programme need to be identified and evaluated for cost-benefit analyses. The following would be included:

For the human sector:

- averted treatment costs;
- lost labour/income;
- DALYS and/or QALYS.

For livestock owners:

- reduced abortions, neonatal losses and infertility, replacement costs;
- reduced treatment costs;
- increased milk production;
- premium price trade advantages.

For the industry:

- improved efficiency of dairy plants;
- less human exposure risks at slaughter plants.

For the government:

- increased tax revenues.

Based on experiences in countries that have eradicated brucellosis, programmes will require long-term commitments to be successful. Therefore it is recommended that governments develop cost-benefit analyses to assess profitability of long-term control options and scenarios. Governments are advised to identify the main beneficiaries and "drivers" to target awareness and as potential sources of funding.

5. Conclusions

Control and eventual eradication of *B.abortus* from cattle in a number of developed countries has been achieved using standardized bacteriological, serological and epidemiological surveillance techniques. A prerequisite has been a commitment by governments to adequately develop, fund and train competent veterinary and public health services, as well as active cooperation from livestock owners. These programmes have taken many years to reach their goals. *B.melitensis* has been eradicated from several western European countries, but it is still a major concern both for public health and livestock production in many countries around the world. If effective control of *B.melitensis* in the Middle East and Eurasia is to be achieved, it will require a long-term commitment with application of appropriate control strategies.

Individual country programmes must be developed on the basis of reliable, science-based data and information. Estimates of prevalence in both humans and livestock reservoirs must be undertaken so that a strategy can be planned that has a high likelihood of success. To accomplish this, realistic cost-benefit studies will be needed to support strategy selection and planning. Pilot studies in certain regions would also be beneficial.

OIE provides guidance and clear standards for the diagnosis, surveillance, control and eventual eradication of *B.melitensis*, from small ruminants as well as cattle. While programmes need to be adapted to meet local conditions, there must be a clearly defined legislative mandate from governments to develop specific regulations to underpin the programme. Governments will need to provide the major portion of the funds needed, but there may be opportunities for some contributions from the farming sector. FAO can provide assistance to member countries in developing and monitoring new programmes, building capacity for surveillance and promoting regional cooperation.

There are very significant benefits to human health and poverty alleviation from controlling and eradicating *B.melitensis* infections in animals. Besides acute illness, the long debilitation associated with chronic brucellosis often severely impacts ability to work. Raw milk and other dairy products, as well as close contact with infected livestock, especially following abortion, are the two major risk factors for humans. Children are at particular risk from consumption of contaminated milk products. Effective health education has been shown to be very useful in lowering attack rates. Given high rates of illiteracy, especially in rural populations, the challenge is to utilize a wide variety of media technologies to achieve success. WHO can provide assistance in these areas.

A range of laboratory-based diagnostic techniques are now available to detect infected animals and herds/flocks. Providing these are used according to OIE guidelines, they can be relied on to provide the basis for prevalence surveys and test-and-slaughter programmes. In the latter situation, it becomes important to distinguish between infected and vaccinated animals. The use of standardized reagents, rigid adherence to test protocols and quality control oversight are mandatory.

Brucella melitensis Rev.1 live strain is a very effective vaccine for use in sheep and goats. It will prevent most abortions and thus significantly reduce the widespread dissemination of bacteria associated with this event. Based on solid epidemiological evidence, continued use of Rev.1 will result in a significant reduction in human brucellosis over time. The excretion of Rev.1 vaccine strain in milk has been documented, but human illness from this source is apparently very unlikely. Use of quality assured vaccines made of the appropriate strain (Elberg) and maintenance of the cold chain are critical.

Rev.1 vaccine can be used in sheep and goats in several ways to reduce infection levels in herds or at village level. Where the group prevalence is high, mass vaccination of all sexually mature animals is advised. This can be repeated every two years, or all animals can be vaccinated in the first year with only replacement young animals being vaccinated in subsequent years. Animals should not be vaccinated during the first months of pregnancy (the middle of pregnancy being the most critical period), as Rev.1 will result in abortion. Information on the safety and efficacy of the Rev 1. vaccine in cattle, camels, yaks and buffaloes is scarce and limited and its use in these species cannot therefore be recommended.

Based upon periodic prevalence surveys, it may be feasible to commence test-and-slaughter when the level of disease has been reduced and stabilized at a very low level. This strategy however takes the programme to a new level requiring, besides testing, animal identification, compensation, movement controls and basic biosecurity measures.

To encourage vaccination by livestock owners, the health benefits, not only to themselves and their families but to their animals, should be emphasized. Identified vaccinated animals are also likely to have added value

For brucellosis programmes to be successful, they must become risk-based, rather than just task oriented. This requires, however, a high level of epidemiological expertise to ensure that programmes are based on accurate and representative data and that decisions are made on the basis of this information.

FAO, OIE and WHO should collaborate to develop a standard "peer review" evaluation process of national and regional brucellosis control and eradication programmes. Individual countries should be strongly encouraged to submit their strategies for review, which would include a written report and advice as required. However it should be emphasized that such programmes are country specific and subject to modifications at the country level.

Annexes

Annex 1
Brucella melitensis tool box

INTRODUCTION

A "Toolbox" is a set of CD-ROM or web-based documents and other materials designed to provide information that supports the needs of a specific set of users. For the purposes of this toolbox a TOOL is defined as a set of information that assists the user to gain a better understanding of a particular topic or technique. These include technical interventions such as diagnostic/surveillance tests, simple statistical and epidemiologic techniques, options for control/eradication strategies, computer and telecommunication resources, examples of public health and livestock owner informational materials, techniques for intersectoral cooperation, and economic cost benefit analyses, including evaluation of programmes. Finally, a section on searching for additional information is included especially to answer research related issues.

This toolbox is aimed at all individuals or organizations involved in the control and eradication of *B.melitensis* from reservoir hosts - primarily small ruminants (sheep and goats), but also cattle, buffalo, yaks, camels etc. As this disease is also a major human health problem (a zoonosis), materials will also be included on diagnostic tests, methods of surveillance, health education resources, etc. Brucellosis is a disease associated with poverty in many instances and therefore materials related to informing resource-poor farmers should be included. Brucellosis control programmes are primarily the responsibility of government veterinary and public health administrations. It is critical that these groups have access to reliable and current methodologies related to rules and recommendations as promulgated by international organizations such as OIE, FAO and WHO, as well as regional organizations such as EU, PAHO, etc.

SUGGESTED TOOLS

Surveillance and epidemiology

Reference: FAO. 2003. *Guidelines for Coordinated Human and Animal Brucellosis Surveillance*. FAO Animal Production and Health Paper No.156. Rome

- test definitions and evaluation;
- design of a prevalence survey for determination of infection in sheep and goats in a region;
- selection of a random programme (individual animal and herd/flock/village) based on confidence limits for accuracy and expected prevalence;
- example of case definitions and criteria for reporting;
- a decision tree for choice of strategy and implementation modalities;
- examples of forms needed for data collection, such as herd/flock/village; individual animal, laboratory results, outbreak (abortion) investigation, results of off-farm (slaughterhouse) testing;

- examples and sources of software programmes, such as TAD info, Epi info, FAO/IAEA programme, MZCP/Syrian example; others?
- examples and calculations of performance indicators of brucellosis surveillance;
- example of a protocol for evaluation of a brucellosis surveillance programme;
- simple case-control methodology for identification of population risk factors for *B.melitensis* infections;
- examples of resources for epidemiological training of veterinarians and other staff;
- collection of epidemiological data by remote use of cell phones (e.g. "EpiSurveyor").

Laboratory resources

- minimum requirements (including specifications) for a simple laboratory to carry out basic serological tests only;
- minimum requirements (including specifications) for a laboratory to carry out bacteriological tests including biosafety;
- basic quality control standards for above-mentioned laboratories, including documentation of all tests and recording of results;
- some sources of laboratory equipment;
- examples of resources for training of laboratory staff;
- standards for movement of specimens;
- sources of diagnostic antigens and antisera;
- list of OIE recognized reference laboratories and experts;
- investigation protocols for differential causes of sheep and goat abortion.

Vaccine sources and techniques

- sources of Rev.1 and Strain 19 vaccines;
- quality control of vaccines;
- examples of maintenance of cold chain in the field;
- sites and techniques of vaccine administration (sub-cutaneous and conjunctival) to minimize human exposure (including visuals);
- examples of post-vaccination sero-monitoring;
- design of vaccination protocols consistent with defined strategy;
- serological interpretation of vaccinated animals;
- issues relating to vaccination of male animals;
- issues relating to vaccination of potentially pregnant animals.

Animal and group identification

- examples of simple identification systems, such as notching, tagging, tattooing, etc;
- identification of vaccinated animals;
- need for owner/village identification.

Human brucellosis

- WHO case definitions and diagnostic criteria.;
- example of standard history taking for surveillance purposes;
- examples of passive surveillance of *B.melitensis* infections, such as screening of vers of unknown origin;
- examples of active surveillance of *B.melitensis* infections, such as screening high-risk groups;
- families, occupationally exposed;
- food-borne illness surveillance focussing on dairy products.

Extension, communication and public health information

- example of a standard KAP study for brucellosis;
- examples of veterinary and public health materials for target groups, including women, livestock-keepers and schools/children;
- pros and cons of different media sources;
- small group (focus) meeting techniques;
- given levels of illiteracy and also language barriers, use of visuals plus translation resources needed.

Principles of biosecurity and hygiene

- design of simple facilities for lambing/kidding, including "isolation" pens;
- simple cleaning and disinfection procedures;
- safety of milk products, including boiling/pasteurisation;
- principles for purchasing *Brucella*-free animals;
- examples of hand-washing techniques;
- movement control principles and techniques.

Intersectoral collaboration

- examples of national coordination of governmental and non-governmental coordinating committee;
- examples of coordinated surveillance documentation;
- coordination examples with adjoining countries/regions;
- data/information required for review of progress.

Potential agencies for research or other support of *B.melitensis* programmes

- World Bank and other regional banks, FAO, WHO, Gates Foundations, Carter Foundation;
- access to list serves such as ProMED, VPH-l;
- lists of standard texts and laboratory manuals.

Occupational health and safety issues

- What to do after accidental exposure to Rev 1 vaccine (needle stick, conjunctival route, open wound)

Annex 2
Key publications and references

1. FAO/WHO. 1986. *Joint FAO/WHO Expert Committee on Brucellosis*. WHO Technical Report Series No. 740. WHO. Geneva.
2. FAO/WHO/OIE. 1993. *Guidelines for a regional brucellosis control programme for the Middle East*. Amman. Jordan 14-17 February 1993.
3. FAO. 1998. *A perspective of brucellosis surveillance in North Africa and the Middle East*. RADISCON. Consultancy mission report.
4. FAO. 2003. *Guidelines for Coordinated Human and Animal Brucellosis Surveillance.* FAO Animal Production and Health Paper No.156. Rome.
5. *FAO/WHO/OIE Round Table on the use of Rev. 1 vaccine in small ruminants and cattle*. CNEVA. Maisons-Alfort. 21-22 September 1995.
6. EU Scientific Committee on Animal Health and Animal Welfare. 2001. *Brucellosis in Sheep and goats* (*Brucella melitensis*).
7. World Health Organization (eds). 2006. *Brucellosis in Humans and Animals*. Geneva.
8. World Organisation for Animal Health. 2004. Manual of Standards for Diagnostic Tests and Vaccines for Terrestrial Animals, 5th edition. OIE. Paris
9. World Organisation for Animal Health. 2005. Terrestrial Animal Code, 14th edition. Chapter 2.7.2 *Caprine and Ovine Brucellosis* (excluding *Brucella ovis*). OIE. Paris.

Annex 3
Programme

MONDAY 11 MAY 2009

Opening and context setting

Chairperson: J. Lubroth
Rapporteur: D. Ward

13:30-14:00	Registration
14:00-14:15	Opening and welcome (*J. Domenech*)
14:15-14:30	Introduction of participants
14:30-14:45	Objectives of the meeting and working methodology (*K. de Balogh*)
14:45-15:10	Overview of the epidemiology and control of *Brucella* melitensis in Near East and Euroasia (*A. El Idrissi*)
15:10-15:30	Coffee break

Field experience with the control of *Brucella melitensis* from selected countries

Chairperson: W. Amanfu
Rapporteur: D. Tabbaa

15:30-16:00	Field experience with using Rev. 1 vaccine for control of brucellosis in sheep and goat in Israel (*M. Banai*)
16:00-16:20	Surveillance and control of brucellosis in Tajikistan (R. Jackson) and Armenia (*A. Sedrakyan*)
16:20-16:40	Whole herd vaccination for control of *Brucella melitensis* in Mongolia implementation in Mongolia (*F. Roth*)
16:40-17:00	The Macedonian experience (*T. Kirandinski*)
17:00-17:20	Brucellosis control Programme in West Bank and Gaza Strip (*S. Alfuqaha*)
17:20-17:35	Egyptian-Spanish cooperation project for the control of brucellosis in the Upper Egypt (2005-2008) (*B. Molina Flores*)
	Discussions and defining the scope of the working groups
18:30-19:30	Reception (Indonesia room 8th floor)

TUESDAY 12 MAY 2009

Tools for diagnosis and control of *Brucella melitensis*: myths and realities

Chairperson: R. Jackson
Rapporteur: W. Amanfu

9:00-9:20	Latest developments in diagnostic and surveillance tool (*B. Garin-Bastuji*)
9:20-9:40	Time-Resolved Fluorescent Resonance Energy Transfer Assay for the Simple and Rapid Detection of Anti-*Brucella* antibodies in Ruminants (*J. Stack*)
9:40-10:00	Comparison between FPA and conventional serological tests for diagnosis of small ruminants in ocular Rev.1 vaccinated and unvaccinated mixed populations (*M. Banai*)
10:00-10:20	Criteria for defining a vaccination program for *B.melitensis* (*A. Giovannini*)
10:20-10:40	Use of *B.melitensis* rough strains for *Brucella* vaccines (*P. Pasquali*)
10:40-10:50	Discussion
10:50-10:55	Group picture
10:55-11:10	Coffee break

Public health issues and intersectoral collaboration

Chairperson: A. Giovannini
Rapporteur: A. Rozstalnyy

11:10-11:30	Introduction and overview on public health aspects of *B.melitensis* (*H. Kruse*)
11:30-11:50	Serological tests: their ability to detect various anti-*Brucella* antibodies in humans and their use in different contexts (*I. Moriyon*)
11:50-12:1	*Brucella melitensis*-foodborne sources versus animal contact? (*A. Robinson*)
12:10-12:30	The Syrian and Jordanian examples for integrated public and veterinary health programmes (*D. Tabbaa*)
12:30-12:40	Discussion
12:40-14:00	Lunch

Working groups 14:00 – 16:20 hours

Working group I:	Surveillance in animals and humans and diagnostic tools (*R. Jackson*)
Working group II:	Control strategies and control tools (*B. Garin-Bastuji*)

14:00-14:15	Introduction to working groups

14:150-15:30	Working groups
15:30-15:50	Coffee break
15:50-16:20	Working groups (cont.)
16:20-17:30	Presentation of working group I and group II (plenary)
20:00	Dinner (at participants' own expense)

WEDNESDAY 13 MAY 2009

Control strategies, socio-economics and communication

Chairperson: M. Banai
Rapporteur: K. de Balogh

9:00-9:20	Control or eradication? A critical step for decision makers (*J.M. Blasco*)
9:20-9:40	Options for brucellosis control in central Asia: from study design to intersectoral health economics (*E. Schelling*)
9:40-10:00	Control strategies for *B.melitensis* (*L. Knopf*)
10:00-10:20	National Brucellosis control: Constraints, Gaps in Understanding and lessons learned (*D. Ward*)
10:20-10:30	Discussion
10:30-10:50	Coffee break
10:50-11:10	Socio-economic aspects of *B.melitensis* control: challenges for impact assessment (*A. McLeod*)
11:10-11:30	Knowledge, Attitudes and Practices in Brucellosis (*A. Ramlawi*)
11:30-11:50	Challenges in Risk Communication for Zoonoses with particular reference to Brucellosis (*S. Sarkar*)
11:50-12:10	The Extent of Willingness to Pay for Brucellosis Control Preliminary Experience from Tajikistan *(D. Ward*)
12:10-12:30	Discussion
12:30-14:00	Lunch

Working groups

Working group III:	Disease control economics – from plan to programme (*D. Ward*)
Working group IV:	Cross-cutting issues (*K. de Balogh*)

14:00-14:15	Introduction to working groups
14:15-15:30	Working groups
15:30-15:50	Coffee break
15:50-17:15	continuation of working groups

THURSDAY 14 MAY 2009

Towards a sustainable brucellosis control

Chairperson: A. McLeod
Rapporteur: B. Mehraban

9:00-9:20	Presentation of working group III and group IV
9:20-9:40	Discussion
	An epidemiological investigation of the occurrence of brucellosis in communities in Armenia during 2006 and 2007 (*R. Jackson)*
9:40-10:30	Finalisation of working groups and elaboration of conclusions and recommendations
10:30-11:00	Coffee break

Chairperson: D. Ward
Rapporteur: A. Robinson

11:00-12:00	Conclusions and recommendations (final discussion)
12:00-12:15	Closure
12:15-14:00	Lunch

Side meetings

14:00-17:00	Meetings with FAO, OIE, WHO, WB, EC and selected countries

Agenda for the working groups

Working Group I: Surveillance in animals and humans and diagnostic tools
Chairperson: R. Jackson

- Reporting
- Assessing prevalence
- Sampling and epi approaches for prevalence studies
- Surveys, sampling frames
- Diagnostic tests for brucellosis in animals and humans (RBT, CFT, ELISA, PCR, FPA, etc)
- Standardization and PT/EQA for testing protocols, tests and quality of reagents

Working Group II: Control strategy and control tools
Chairperson: B.Garin-Bastuji

- Vaccines and vaccination protocols, tests, vaccine specifications
- Guidelines for vaccination vs test and slaughter
- Alternative control approaches
- Regional approaches
- Legislation, (national, international regulations)
- Research gaps

Working Group III: Disease control economics – from plan to programme
Chairperson: D. Ward

- Control programmes: options and funding requirements
- Economics
- Compensation funds
- Sustainability and recurrent budgets
- Resource mobilisation
- Trade implications (Border controls)

Working Group IV: Cross-cutting issues
Chairperson: K. de Balogh

- Intersectoral collaboration
- Public awareness
- Behavior change and Cultural practices
- An integrated (One Health) approach for also addressing other zoonoses
- Expansion of brucellosis control to address other transboundary diseases related to ruminants
- Gender issues
- The role of wildlife

Annex 4
List of participants

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Brucella melitensis infection is recognized as a significant public health challenge, with a major economic and financial burden in countries where the disease remains endemic. In Eurasia and the Middle East *Brucella melitensis* infections in sheep and goats are still widespread, resulting in significant human illness, primarily from consumption of contaminated dairy products or from occupational exposure to infected livestock. In small ruminants (sheep and goats), abortion, reduced fertility, reduced milk production and lowered newborn viability are the major impacts.

There are very significant benefits to human health and poverty alleviation from controlling and eradicating *B. melitensis* infections in animals and the Food and Agriculture Organization of the United Nations (FAO) has been responsible for advancing practical knowledge and experience on brucellosis in various countries and assisting in the development of sound strategies and policies for sustainable control programmes. As part of these efforts a technical meeting of brucellosis experts was convened in Rome from 11 to 14 May 2009 by the FAO in collaboration with the World Health Organization (WHO) and the World Organisation for Animal Health (OIE), in order to develop further guidance to support and improve surveillance and control of *Brucella melitensis* infection in affected countries.

This document provides an account on the objectives, discussions and outcomes of the meeting and provides an up to date account of the available options for the prevention and control of *B. melitensisi* as well as the identified gaps that still need to be addressed.