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Review

Important infectious diseases in goat production in Mexico: history, challenges and outlook

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Abstract:

Goat production in Mexico is concentrated in poorer areas in arid and semi-arid areas of the country's north and center, particularly in the Mixtec region of Oaxaca, Guerrero and Puebla. Because goats can survive in near desert conditions their production of milk and animals is a valuable nutritional contribution to human diets in these areas. Disease in goats in Mexico has generally received scant attention, however researchers at the INIFAP have studied this species and its pathologies. This review focuses on the main diseases affecting goats in Mexico and the research in this area by the INIFAP. In most of the goat herds studied in Mexico reproductive disorders are often caused by diseases such as brucellosis, leptospirosis and chlamydia, all considered to be endemic and potentially zoonotic. Respiratory and gastrointestinal disorders are the main ailments in kids. High frequencies of arthritic encephalitis, a disease caused by infection with small ruminant lentiviruses, and paratuberculosis and caseous lymphadenitis, both bacterial in origin, have been documented in productive-age goats throughout Mexico. All three are chronic, causing producers to mistakenly assume they have no major impact on productivity. Q fever, a known zoonotic, is currently considered exotic in Mexico, but in other countries is frequently associated with reproductive disorders, abortions and occasional respiratory problems in goats. The INIFAP has addressed all the above diseases. It was instrumental in diagnosing and controlling brucellosis, the principal bacterial zoonosis in Mexico. Researchers at INIFAP have also helped to determine that diseases previously considered exotic in Mexico have become endemic, and then developing the tools needed for their diagnosis. The INIFAP has made vital contributions to understanding the national disease panorama in goats and transferring diagnostic and treatment technologies to livestock laboratories nationwide.

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The importance of goat farming in Mexico

The goat population in Mexico is currently 8,791,894[1], most of which is distributed in the states of Zacatecas, San Luis Potosí, Coahuila, Puebla and Oaxaca. All have a traditional cuisine that includes goat meat in dishes such as *birria*, *cabrito*, *mole de caderas* and *barbacoa*. Specialized meat production or dual-purpose breeds, such as Boer and Nubia, have been developed, but most of the goat population continues to be Creole or local animals, which are descendants of Spanish breeds. Specialized dairy breeds, such as Saanen, French Alpine, Toggenburg and Nubia, are found mainly in the states of Coahuila, Guanajuato, Durango, Jalisco and Chihuahua[1]; cheese, *cajeta* (caramel) and candys are produced from goat's milk in these states[2].

Goat farmers in the Bajío region of central Mexico and those in northern Mexico have technified production more than those of the south, such as in the Mixtec and Guerrero regions. This is probably due to the primary focus of production being milk to supply several companies that produce goat dairy products. Even so, regional production systems in Mexico are predominantly heterogeneous, utilize traditional technology, face myriad animal health problems, and suffer from minimal organization among producers and throughout the value chain[3].

Goats' importance as producers of food and valued-added derivatives is more pronounced in arid and semi-arid areas, which is also where human populations tend to be poorer. Goats are capable of utilizing the vegetation found in these areas, making it the preferred livestock for its ability to adapt and produce, even in challenging desert conditions[4].

Brucellosis

Brucellosis melitensis is the principal etiological agent of brucellosis in goats. It is also the main species of the genus and is considered to be one of the causative agents of human brucellosis, known as Malta fever[5]. Transmission of *B. melitensis* is principally oral, normally through intake of food or water contaminated with vaginal secretions or the remains of abortions from infected animals. For smooth phenotype brucellae, venereal transmission is not generally accepted as a main route of infection. However, *B. melitensis* is excreted in the milk and colostrum, suggesting that most latent infections may be contracted through their consumption[5].

Infected cattle manifest clinical signs that can have substantial financial impacts. In sexually mature females it causes reduced fertility, abortion and decreased milk production. In males it colonizes the reproductive system, causing orchitis and epididymitis. Cases of arthritis have also been reported[6].

Serological diagnosis of brucellosis in goats is most commonly done with the card test using 3 % *B. abortus* antigen. Its sensitivity is near 100 %, and it is also simple, inexpensive and practical. However, this test cannot be used in goats vaccinated with Rev 1 at any dose until

8 mo post vaccination. Before eight months the test cannot differentiate between antibodies generated in response to the vaccine and those generated in response to infection. In these cases, techniques such as radial immunodiffusion (IDR) with native hapten are used because they allow differentiation between vaccinated and infected animals[7].

In Mexico. Brucellosis is the main bacterial zoonosis in the country. Its control relies on diagnosis, identification of infected animals, their elimination, and especially vaccination. Goat farmers (especially in poorer goat farming communities), veterinarians, and slaughterhouse workers are the most vulnerable human populations, but laboratory personnel and consumers of unpasteurized dairy products are also at risk[5].

Contributions from research at INIFAP

The National Campaign against Animal Brucellosis was restarted in Mexico in the late 1990s. At this time there was still limited scientific data on the protection conferred by the Rev 1 vaccine in goats. To date, this has been the only available option worldwide for preventing brucellosis in small ruminants. Using experimental challenge techniques, INIFAP researchers have evaluated the protection conferred against brucellae. They found that application of reduced doses of Rev 1 were sufficient to protect vaccinated goats in endemic areas for at least 5 yr after immunization. These results are the first of their kind worldwide; they scientifically support that the Rev 1 vaccine protects vaccinated goats throughout their life and that revaccination is therefore unnecessary[8,9]. Based on these results a reduced dose of Rev 1 was implemented during the National Campaign against Animal Brucellosis.

There has also been a notorious lack of scientific information on the sensitivity and specificity of caprine brucellosis diagnosis tests. In their evaluations of diagnostic tests INIFAP researchers have found that techniques used with success in cattle, such as the milk ring and rivanol tests, did not generate effective diagnosis of brucellosis in goats. This research found that the card test, which is both basic and an important screening technique for serological diagnosis of brucellosis in animals, should be used at a 3 % cell concentration, a modification which increased its sensitivity. In goats, this screening test exhibits 98 % sensitivity and 100 % specificity as determined by Official Mexican Standards (Norma Oficial Mexicana - NOM). The antigen preparation methodology developed by INIFAP was transferred to the National Veterinary Biological Production Company (Productora Nacional de Biológicos Veterinarios - PRONABIVE)[10,11].

In an effort to test a widely held dogma that male goats cannot be vaccinated against brucellosis due to development of lesions in the reproductive organs from bacterial tropism, researchers from the INIFAP and the UNAM conducted a study with 48 six-mo-old kids from brucellosis-free herds. They found that both the tested vaccines exhibited a low colonization capacity in the reproductive tract, and that this dogma was a myth[12].

Challenges and outlook in Mexico

Over the short-term, changes and updates can be expected in the National Campaign against Brucellosis in Animals (Official Mexican Standard, NOM-041-ZOO-1995). Over the medium-term, disease control programs need to be implemented and adapted to the particular conditions of the goat farming regions throughout Mexico. If the short- and medium-term goals are met then over the long-term, it is possible that caprine brucellosis could be controlled.

Chlamydiosis

Chlamydiosis is an infectious-contagious and zoonotic disease caused by bacteria of the genus *Chlamydia*. The species that most affects goats is *C. abortus*, an obligate intracellular bacterium with an asynchronous multimorphic development cycle[13]. It has been reported to affect pregnant women, mainly after exposure to infected goats[13].

In goats, chlamydiosis is characterized as causing abortions in the last two or three weeks of gestation, or birth of weak offspring[13]. Abortion generally occurs without previous signs, although behavioral changes and vaginal discharges containing a large number of elementary bodies can occur between 24 to 48 h beforehand. Placental lesions develop initially in the hilum of the placentaloma and extend to the intercotyledonary membranes. This leads to destruction of placental tissue which affects nutrient acquisition and hormonal regulation, resulting in premature expulsion of the fetus. Histological changes in the placenta and appearance of lesions typically occur after 90 d gestation[13].

In Mexico. The first report of isolation of chlamydiosis' etiological agent in goats was published in 1997[14]. Initially considered exotic in Mexico, *C. abortus* is now viewed as common in goats based on increasing evidence. For example, a 2015 study was aimed at isolating *C. abortus* in dairy goats from herds with abortion problems in the state of Guanajuato, and developing adequate diagnostic tests for its detection[15]. Analysis by ELISA of serum samples and vaginal swabs taken from six goat herds found that 9.60 % of the evaluated animals were seropositive for *C. abortus*. A PCR analysis using vaginal exudate

DNA identified 23.8 % positive animals, and *Chlamydia* spp. was isolated in 26.98 % of the sampled animals. These three diagnostic methods were complementary, and all were applied in areas where *Chlamydia* is suspected of causing abortions. The combined results confirmed that this pathogen is present in dairy goat herds in Mexico[15]. In a 2016 study, 1,307 serological samples were collected from goats distributed in 14 municipalities in Guanajuato, and analyzed using indirect ELISA. Frequency in females with a history of abortion was 46.62 %, whereas it was 27.13 % in females with at least one parturition that were clinically healthy but lived with females that tended to abort[16]. A study done in Culiacán, in the state of Sinaloa, identified the presence of *C. abortus* in a goat herd with abortion problems, further supporting its presence in the country[17].

Contributions from research at INIFAP

The first isolation of *C. abortus* in goats in Mexico was achieved as part of a collaboration between researchers from the then INIP and the UNAM[14]. From 2012 to 2013, a total of 186 samples were collected from 49 herds in the states of Coahuila, Jalisco, Puebla, Veracruz and Querétaro. After bacterial isolation, PCR and sequencing, analysis of the amplification products found 99% homology with four *C. abortus* strains: A.22, FAS, S26, EBA and VPG[18]. In an analysis of goats from various municipalities in Guanajuato, *C. abortus* was identified in goats from herds with abortion problems, even in herds administered tetracyclines in an attempt to prevent it. Analysis of samples from organs and vaginal exudate corroborated that the treatment does not prevent infection, and may or may not cause abortion[19].

Challenges and outlook in Mexico

Regional livestock laboratories need to have the ability to run end-point PCR and real-time PCR to correctly diagnosis chlamydiosis, generate data on the *Chlamydia* species affecting goats and thus establish effective prevention and control measures within herds[17,19]. Improved diagnosis will require development of routine techniques, such as serological tests like ELISA[20].

Colibacillosis

Colibacillosis is caused by *Escherichia coli*, and one of the main conditions caused by this bacterium is diarrhea in goat kids. Two main forms of the disease are recognized: enteric and systemic colibacillosis. The enteric form affects animals 2 to 8 d of age in which it causes diarrhea that is usually yellowish white in color, and creamy to almost liquid in consistency, while the kid exhibits weakness, cachexia and dehydration. If not quickly and adequately treated, infected animals can die within 12 h of clinical onset. The systemic, or septicemic, form affects animals between two to 6 wk of age. The bacteria crosses the intestinal or respiratory mucosa and enters the circulatory stream, causing animals to exhibit higher rectal temperature, meningitis and arthritis, but without diarrhea. Infected animals are the most important source of transmission, the most common route being fecal-oral. Reducing exposure to *E. coli* is attained through proper hygiene and handling practices. Lack of colostrum makes kids more susceptible to diarrhea[(21)].

In Mexico. One of the two main causes of mortality in goat kids is diarrhea[(22)]. Little research has been done on the pathogenic mechanisms and identification of virulence genes involved in *E. coli* diarrhea in goats. Most of the strains isolated from animals have been enterotoxigenic *E. coli* (ETEC), which express adhesins and enterotoxins as pathogenicity factors, and cause neonatal enteritis. Other pathogens isolated from diseased animals include enteropathogenic *E. coli* (EPEC), which also cause diarrhea, and enterohemorrhagic *E. coli* (EHEC), a known pathogen in humans[(23)]. The EHEC pathotype O157:H7 infects humans and its reservoirs are ruminants. Fecal contamination of water and other foods, as well as cross contamination during food preparation (with contaminated meat products, surfaces and kitchen utensils), are common infection routes[(24)].

Contributions from research at INIFAP

A study done in 2014 characterized *E. coli* isolates from diarrhea collected from kids in some of Mexico’s goat-producing regions. Most of the isolates were found to belong to the B1 phylogenetic group of the O25:H8 serotype. This group and serotype have a wide variety of virulence genes, particularly *st* and *stx2*, which combine in the EHEC and ETEC pathotypes, as well as exhibiting low resistance to pharmaceutical treatment[(25,26)]. Using three of the isolated strains, a bacterin was developed to control the disease. When administered to pregnant goats it provided passive immunity to kids through colostrum, with only 2.31 % of the vaccinated females producing kids with diarrhea. In addition, administration of the bacterin raised antibody levels in vaccinated females and their offspring. The protection provided the animals was identified as a serotype specifically against purified O25 LPS [27].

Challenges and outlook in Mexico

Research is still needed into the behavior of the virulence genes involved in *E. coli* diarrhea to develop an exact diagnosis that would allow identifying and developing specific preventive measures. The bacterin developed at INIFAP for *E. coli* diarrhea prevention in kids is promising and should be included in the development of immunization protocols.

Respiratory disease complex (RDC)

The causes of RDC in goats include the environment, animal condition and the presence of infectious agents such as viruses and bacteria. Kids are particularly susceptible to RDC. The adverse environmental conditions that predispose goats to respiratory problems are sudden changes in climate, overcrowding of animals, inadequate pens, lack of ventilation, accumulation of dust and ammonia, poor protection against drafts and stress from transportation[28]. Among infectious agents, some viruses are known to be primary agents, particularly the parainfluenza-3 and respiratory syncytial viruses[29]. The bacteria that can generate RDC include *Pasteurella multocida*, *Mannheimia haemolytica*, and *Mycoplasma* spp., all commonly found in the upper respiratory tract of healthy animals[30]. When immune system mechanisms become depressed these bacteria colonize the lungs, causing RDC. Various host-related factors can contribute to development of RDC or pneumonia. These include deficient colostrum intake in kids, damage from viruses in the mucociliary clearance system (which causes insufficient bacterial clearance from airways), a depressed immune system, malnutrition, parasitosis, dehydration, etc. When pneumonia occurs, symptoms can range from 40 to 41 ºC fevers, cough, shortness of breath, lack of appetite, mucopurulent nasal and ocular discharge, depression, prostration and death[31].

In Mexico. Goat producers in Mexico recognize pneumonia as one of the most frequent health problems in herds, but rarely is a diagnosis made or a prevention program implemented[22].

Contributions of research carried out at INIFAP

The INIFAP began research on this problem by identifying and characterizing the virulence factors of the bacteria participating in RDC, finding *P. multocida* (biotype D:3) to be present in goats. A valuable complement to this study would be to isolate lesion microorganisms directly from the lungs of diseased individuals to confirm that this strain (and/or others) is the cause of pneumonia[32-35].

Challenges and outlook in Mexico

Controlling RDC in goats in Mexico will require creation of a vaccination program and producer education. An important aim is formulation of a *M. haemolytica* toxoid from isolates collected in Mexico and its evaluation in kids, together with the bacterin already developed. The results would contribute to implementing a vaccination program to prevent RDC. Training courses are needed for goat farmers that focus on improving RDC prevention. These can use a comprehensive approach that reviews and corrects problems leading to RDC factors, such as management practices that generate excessive stress, while promoting adequate hygiene protocols, reviewing nutritional status, identifying parasitosis status, and improving production installations (e.g. redesign to prevent sudden temperature changes, and provide proper ventilation).

Q fever

A worldwide zoonotic disease, Q fever is caused by the bacterium *Coxiella burnetii*. Its hosts are myriad, and range from domestic (cows, sheep, goats, dogs, cats, rabbits) to wild animals (small rodents, foxes). Most hosts are chronic carriers and do not suffer from the disease, but they excrete the bacteria via urine, feces, milk, and birth by-products such as amniotic fluid, the placenta and abortions. These secretions form aerosols that can transmit the microorganism by air to susceptible human populations[36].

In Mexico. *Coxiella burnetii* is an exotic species in Mexico, and as such has been considered by SADER as a notifiable disease since 1994[37]. The first serological evidence of this bacterium in animals was reported in the state of Baja California in 1990[38], and the first reports of it in humans were from the Comarca Lagunera region[39].

Contributions from research at INIFAP

In a study done from 2018 to 2019, researchers from the INIFAP and the Ministry of Health identified *C. burnetii* in goats that exhibited a tendency to abort. Using endpoint PCR, they identified the IS*1111* insertion sequence; this was the first molecular evidence that goats in Mexico can be reservoirs of *C. burnetii*[40].

Challenges and outlook in Mexico

Over the short-term, *C. burnetii* will probably transition from being an exotic to an endemic disease. Research will also be needed to develop diagnostic tests. Over the medium-term, high sensitivity and specificity diagnostic tests need to be established in laboratories to detect Q fever in both animals and humans, and programs developed and implemented to control the disease in animals.

Small ruminant lentivirus

Caprine arthritis encephalitis virus (CAEV) and Maedi-Visna virus show genetic, structural and pathogenic similarities; consequently, they have been reclassified as small ruminant lentiviruses (SRLV)[41]. In goat production, SRLV can have negative financial impacts directly related to the presence of multisystemic and incurable chronic-degenerative infections. In adult goats, arthritis and mastitis occur, while in kids the viruses manifest in the nervous system during the first months of age[42]. Replication of lentiviruses in mammary gland epithelial cells plays an important role in viral particle transmission. Mononuclear cells and infected macrophages can also be shed through colostrum and milk. Direct contact with aerosolized respiratory secretions, urine, and feces from infected animals are considered sources of infection that can become exacerbated by overcrowding. Water and feed, as well as inadequate disinfection of facilities, machinery and milking equipment, allow the spread of SRLV[43].

In Mexico. A seroprevalence study of CAEV in Mexico's goat-producing regions in 1985 determined that the disease entered the country through import of live breeding animals from the United States[44]. The SAGARPA subsequently classified CAEV as an endemic disease and required mandatory monthly reporting. It was isolated, and sequencing done of the entire genome of a recombinant SRLV belonging to the B1 subtype[45].

Contributions from research at INIFAP

INIFAP researchers are developing SRLV diagnostic techniques based on the genetic and antigenic characteristics of strains that circulate naturally in Mexico and which affect goat production. Expression of a recombinant antigen of the CAEV p25 protein has been achieved in the *E. coli* system. The generated antigens are considered to be excellent candidates for establishing an ELISA-type serological test for CAEV diagnosis[46]. In addition, a real-time PCR test is being standardized to identify the presence of provirus in SRLV and the production of the recombinant proteins CA, p25 and MA, p16 in CAEV.

Challenges and outlooks in Mexico

Further research is needed to understand the circulation of other SRLV genetic groups in Mexico and to identify their genetic diversity. To date, the B1 genogroup has been identified and found capable of infecting both sheep and goats. Tools and techniques have been developed for serological and molecular diagnosis of subtype B1 (ELISA and PCR). No serological or molecular test has yet been developed that is capable of detecting all existing SRLV groups or subtypes. Results have been most promising when SRLV diversity is characterized and this data used to complement or adapt tests developed to meet current or future needs in each country. Breed stock and registered cattle producers are also advised to participate in government programs for SRLV-free herd certification, while producers with fewer resources are reached through government social programs. An important long-term goal is to certify Mexico’s main goat-producing regions as SRLV-free, and establish a culture among producers of animal health based on timely diagnosis that allows increasing productivity.

Leptospirosis

Leptospirosis is an infectious disease caused by bacteria belonging to the genus *Leptospira*. It is distributed worldwide in rural and urban areas with specific climatological and orographic characteristics, natural drainage networks, extensive agricultural areas and seasonal rainfall; these conditions favor the spread of *Leptospira* spp. Infection with *Leptospira* affects domestic and wild mammals differently, and cases can range from asymptomatic to acute or chronic infection. This microorganism is eliminated in the urine of infected animals continuously or intermittently, thus contaminating the environment. Acute leptospirosis in goats can cause symptoms such as an increase in body temperature, anorexia, depression, jaundice, and anemia. In its chronic form it causes abortions, mummifications, infertility, premature births and neonatal mortality, all resulting in financial losses[47]. Humans can occasionally host *Leptospira* spp. When infected they can manifest pathological disorders such as fever, headache, muscle and joint pain, cough, stroke, nausea, vomiting, jaundice, and kidney and liver disorders[48].

In Mexico. In a study in the state of Veracruz, an analysis of 873 serum samples identified the most frequent serovars to be Wolffi (45.58 %) and Icterohaemorragiae (45.13 %)[49]. In the Lagunera region, an analysis of 802 serum samples showed 60.1% to be seropositive for leptospirosis[50]. In goat herds from the state of Guerrero, 64.26 % of a set of serum samples had antibody titers against at least one *Leptospira interrogans* serovar[51].

Contributions from research at INIFAP

A 2016 study by INIFAP researchers of the serological frequency of antibodies against *Leptospira* spp. in the main goat-producing region of Guanajuato, found a leptospirosis frequency of 37.90 %[52]. In 2018, also in Guanajuato, a study evaluated the seroprevalence of *Leptospira* spp. serovars in goats, their geographic distribution and co-exposure patterns. By analyzing 1,640 samples with the microscopic agglutination test, total prevalence was found to be 45.5 %, that of Icterohaemorrhagiae was 34.16 %, that of Hardjo was 6.77 %, and the remaining serovars represented less than 5%. All the identified serovars exhibited an aggregation pattern that suggests risk areas and transmission vectors. Analysis of antibody co-occurrence showed Icterohaemorrhagiae to be dominant over the other identified serovars[53]. A 2019 study did a serological diagnosis of the main abortive diseases in goats from Guanajuato using samples from dairy farms with different levels of technology, breeds and management practices; *Leptospira* spp. seropositivity was confirmed[54].

Challenges and outlook in Mexico

Leptospirosis prevention and control measures are needed in herds throughout Mexico. Immunization should be implemented using *Leptospira* spp. serovars previously identified in goats in an effort to reduce problems caused by the disease, such as abortions, mummifications, premature births and infertility.

Caseous lymphadenitis

Caseous lymphadenitis is a chronic infectious disease affecting goats caused by the Gram-positive bacterium *Corynebacterium pseudotuberculosis*, a facultative intracellular pathogen capable of replicating and surviving inside phagocytes. The disease is characterized by presence of suppurative lesions in the lymph nodes, lungs and other internal organs. At a subclinical level the disease manifests in the viscera in the form of abscesses in internal organs (e.g. lungs, liver and mesenteric lymph nodes), and occasionally animals may exhibit chronic pneumonia and progressive weight loss(55).

Contributions from research at INIFAP

INIFAP researchers have contributed to development of caseous lymphadenitis diagnostic tests, and genetic characterization of *C. pseudotuberculosis* strains from sheep, goats and horses(56). Another study established a multiple PCR test for diagnosis of caseous lymphadenitis in goats, showing it to be an efficient technique based on clinical samples which can also differentiate between biovars *ovis* and *equi* of *C. pseudotuberculosis*(57). An initial study of mutant *C. pseudotuberculosis* strains as candidates for development of immunogens found that a mutant strain failed to protect Balb/c mice after an experimental challenge, and did not demonstrate adequate humoral or cellular immune responses in this murine model(58).

Challenges and outlook in Mexico

Further research is needed to better understand the prevalence and distribution of *C. pseudotuberculosis* in Mexico. This in turn would contribute to development of an immunogen capable of reducing morbidity in goat production and its consequent financial impacts in Mexico.

Paratuberculosis

Caused by the bacterium *Mycobacterium avium* subspecies *paratuberculosis*, paratuberculosis is an infection characterized by chronic regional inflammation in the small intestine of ruminants. Its most frequent signs in goats are a decrease in body condition and weight, declining milk production, loss of stool consistency and diarrhea (only in the terminal phase)(59). This bacterium has been associated with Crohn's disease, a chronic disease leading to inflammation and ulceration of the gastrointestinal tract (mainly in the ileum and colon)(60), although it is not recognized as the main etiological agent.

In Mexico. Paratuberculosis was first identified in goats in a 1983 study that reported a clear clinical picture of the disease, including intestinal lesions such as enteritis and granulomas in mesenteric lymph nodes, presence of *M. avium* subsp. *paratuberculosis* in the injured tissues, and antibodies in blood serum(61). Various reports have since addressed seroprevalence, isolation and detection of *M. avium* subsp. *paratuberculosis* genetic material in infected animals in various states in Mexico(59,61,62).

Contributions from research at INIFAP

Although paratuberculosis prevalence in goats is variable, research at INIFAP helped establish the risk factors for transmission in Mexico, which include high population density, introduction of infected animals to herds, permanent coexistence with other species, permanence of infected animals and poor hygiene conditions(63).

Challenges and prospects in Mexico

Over the short-term, strategies are needed to differentiate the clinical manifestations of paratuberculosis (e.g. low body condition and declining milk production) from other conditions common in herds throughout Mexico, such as poor nutrition from lack of good quality food (especially frequent in areas where community grazing is common). In the medium-term, monitoring of herds in the primary goat-producing areas of Mexico is needed to assess paratuberculosis' health, productive and financial impacts on a national level. Long-term challenges include substantially reducing paratuberculosis prevalence and incidence, guaranteeing food safety, increasing productivity and thus opening new markets. This will be vital because countries such as the United States and the European Union produce disease-free goats the derivatives of which are consequently more valuable and marketable.

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