Executive Summary

In developing countries urbanization and the production of food within and around cities is increasing dramatically. West Africa, with an urban growth rate of 6.3% per annum is no exception. In this region subsistence, small-holder and commercial scale production systems all play a role in satisfying the growing urban food demand. While these urban production systems have the potential to improve both household food security and welfare, they also pose risks to both humans and animals in the form of zoonotic infections and environmental contamination. The presence, prevalence, and transmission of disease depend on cultural practices, the types of livestock production systems, environmental factors and husbandry methods. However, the deficiency in baseline epidemiological data on the occurrence of zoonotic diseases in humans and animals in West Africa poses a challenge in identifying zoonotic infections of primary importance.

Part A reviews the available literature on zoonoses of potential public health significance in different livestock production systems in West Africa, namely tuberculosis, brucellosis, anthrax, cysticercosis, Escherichia coli, campylobacter and Salmonella enteritidis infections. These diseases have the potential to negatively impact animal productivity and welfare as well as human health. Part B discusses evidence from a field project in Cameroun assessing bovine tuberculosis and risk factors for transmission in the peri-urban area of Bamenda, Northwest Province, Cameroun.

In order to satisfy the constantly increasing demand for milk and milk products, dairy production systems in urban and peri-urban regions have become a dynamic and fast-growing sector in Africa. Dairy products, in the absence of adequate processing, are a potential source of bovine tuberculosis and brucellosis. Tuberculosis is a slow progressive disease and if untreated can lead to death. People who are HIV-infected are more susceptible to developing the disease when infected with the tuberculosis organism (Mycobacterium bovis). Brucellosis transmission occurs via the ingestion of contaminated or unpasteurized dairy products or following direct contact with infected animal tissues. In non-Muslim regions, where pigs are raised and consumed, cysticercosis is common. The condition is a result of ingestion of tapeworm-infected, undercooked meat, and often associated with poor sanitation. The presence of cysts in the brain is referred to as neurocysticercosis and is a common cause in cases of late-onset epilepsy in endemic areas. Diarrheal diseases are a major cause of morbidity and mortality in developing countries. Campylobacter, is a bacteria which is widely distributed in nature, inhabiting the intestinal tracts of wild birds and domestic animals. Although transmissibility of the organism is low, it contributes substantially to the burden of childhood diarrhoea. Escherichia coli and Salmonella enteritidis are bacteria commonly associated with intensive livestock production systems. The S. enteritidis and E. coli have recently been identified in African poultry and dairy systems respectively. These bacteria, if not appropriately monitored and controlled, are potential sources of serious enteric infections in humans.

Although there is limited evidence of emerging organisms in urban livestock production systems in West Africa, most of the infectious agents identified as being present in livestock production systems in the region are associated with traditional zoonotic diseases. In most cases eradication of the organism is often not economically or environmentally feasible. Public health officials need to approach the control of zoonoses in urban agriculture at the grassroots level, with a focus on education and benefits, targeting both producers and consumers.
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Urban Agriculture and Zoonoses in West Africa: 
An Assessment of the Potential Impact on Public Health 
Part A: Literature Review 

1. Definition and Concepts 

1.1 Urban Agriculture 

Recent data suggest that both urbanization and the production of food within and around cities are increasing at an unprecedented rate, particularly in developing countries. West Africa’s urban population is growing at a rate of 6.3% per year and the projected figure for 2020 estimates that approximately 63% of the 430 million people will reside in urban centers (Drechsel et al. 1999). Although the literature is scant on Urban-Peri-Urban Agriculture (UPA) particularly in the area of urban livestock-keeping, in West Africa, there is evidence that subsistence, small-holder and commercial scale livestock productions systems all play a role in satisfying the needs of the urban consumer. Pigs, chickens, dairy cows and small ruminants are all kept to varying degrees in urban/peri-urban households, depending on means, and cultural and religious practices of the area. In the last several decades, intensive animal production systems have also been adopted in West African cities (Drechsel et al. 1999). One intractable consequence of rapid urbanization is a deficiency in affordable food. Hence the rise in urban agriculture (UA) within and around cities in response to this demand.

There are numerous definitions of urban agriculture. A comprehensive definition provided by de Zeeuw (2000) expressed UA as the growing of plants and the raising of animals for food and other uses, and the processing and marketing of the resultant products within urban and at the periphery (peri-urban) of cities. UA is an integral part of urban household economies in many
developing countries. Horticulture (vegetable gardening, flower production), staple crops (maize, etc.) And livestock rearing (milk, meat, eggs), the most important components of UA, can contribute to ameliorating household welfare by improving nutrition and providing a source of revenue. Urban farms are mainly small-scale enterprises, although medium and larger systems are present. Small-scale farmers are often subsistence producers, but could also be commercial producers, thus contributing directly to both food security and household well-being. Medium and/or large scale farmers who produce mainly off-plot for commercial purposes, and who occasionally use state of the art techniques, often target their products to specialized urban markets.

In other words, urban agriculture contributes to urban food security, by potentially improving the individual household economy and the economy of the community at large. However, in as much as urban agriculture has the potential to reduce urban food insecurity, improve diets and facilitate access to food for the urban poor it also poses risks to human and animal health, and to the environment. Although the general health hazards associated with peri-urban and urban agriculture, such as pesticide and wastewater use are known, the relationship between urban and peri-urban livestock rearing and zoonotic diseases has not been fully elucidated. While traditional smallholder livestock farming systems may not have been an important source of disease to humans (zoonoses), increased demand for their products have arisen due to rapidly intensifying, market-oriented systems, thereby leading to changes in production systems.

1.2. Zoonoses

Zoonoses are defined as diseases that are naturally transmitted between vertebrate animals and humans (Dorland, 1985). Concern over zoonotic diseases in industrialized countries is focused on infections arising from newly emerging strains or variants of disease agents. However, traditional livestock-related zoonotic diseases for which effective control measures and cures are available in more affluent countries, are still a cause of morbidity and mortality in humans and animals in developing countries (Wastling et al. 1999; Cosivi et al. 1998). And yet, organisms until recently associated with intensive production systems in the developed countries, such as Escherichia coli O157:H7 and Salmonella enteriditis are now being detected in parallel systems in Africa. Therefore in addition to the classical zoonotic infections, public health officials need to be increasingly aware of the potential of these emergent infections. Some epidemiologists have noted the emergence of zoonotic diseases in urban regions and the changing epidemiology of these diseases has become a
public health concern (Flynn 1999).

Estimates by the United Nations suggest that urban dwellers will constitute 60% of the world’s population by the year 2020 (Birley and Lock 1999). With more people living in cities, the intensification of urban and peri-urban agriculture will play an even greater pivotal economic and public health role in these regions.

This report focuses exclusively on zoonoses as a potential health hazard, with a special emphasis on West Africa.

1.3 Urban Agriculture and Zoonoses in West Africa

At present, the acquisition of data and the control of zoonotic diseases in West Africa is hampered by varying degrees of diagnostic capabilities resulting from poor infrastructures and lack of resources across the different countries. Available diagnostic and prevalence data is often based on small-scale surveys, poorly designed studies, abattoir surveys and hospital records. Inadequate disease reporting systems and insufficient collaboration and communication between human health and veterinary services further compound the problem (Wastling et al. 1999). Often reports focus on public health or animal aspects but seldom both. This deficiency in baseline epidemiological data on the occurrence of zoonotic diseases in humans and animals poses a challenge in identifying the zoonotic diseases of primary importance to public health in West African countries. Increasing urbanization, the intensification of livestock production in close proximity to humans, and the rising rate of HIV are factors which exacerbate the transmission, persistence and impact of zoonotic diseases on public health in Africa.

Tuberculosis (TB) (Mycobacterium bovis), brucellosis, anthrax and cysticercosis are the most commonly cited zoonotic diseases of concern. There is patchy evidence that in addition to TB, toxoplasmosis and cryptosporidiosis, are opportunistic infections in HIV positive individuals (Pichard et al. 1990). Livestock are hosts and amplifiers for trypanosomiasis, Rift Valley Fever (RVF), and Crimean-Congo Haemorrhagic Fever (CCHF). However, environmental factors and ecological changes moderate these diseases which are often associated with specific agro-ecological zones and have limited impact on public health in urban and peri-urban regions. They will therefore not be addressed in detail in this document. This report reviews the available literature on zoonoses of (potential) public health significance in different livestock production systems in West Africa. The section on dairy cattle has been expanded with a view to illustrating the complexity of the dynamics of zoonotic diseases when evaluating and re-developing policy and follow-up research strategy on
urban livestock husbandry.

2. Overview of Dairy Production in Africa

In the 70s and 80s, the demand for milk products increased approximately 2.5% per year in sub-Saharan Africa (Walshe et al. 1991 in Cosivi et al. 1995). In order to satisfy the constantly increasing demand for milk and milk products, dairy production systems in urban and peri-urban regions have become a dynamic and fast-growing sector. Since low-income groups dominate the market, the increased demand for dairy products is expected to favour the informal market, particularly where the milk is produced primarily by small and medium-scale producers. The success of the informal market is based on consumer reluctance to pay the extra costs of pasteurisation and packaging (Anon in de Zeeuw et al. 2000). Market factors (proximity to market, infrastructure) play a major role in determining the type of dairy production systems found in the tropics and are highly influential on small-holder development (deZeeuw et al. 2000).

Sub-Saharan Africa accounts for 8% of the 200 million metric tonnes (MMT) of milk produced in developing countries, which amounts to 15 MMT. Approximately 73% of this (11 MMT) is produced by cattle, while the balance of 4 MMT by camels and goats. Dairy systems in the form of small-holder producers and large scale farms are commonly concentrated in peri-urban and urban regions.

In East Africa, (Kenya, Tanzania, Ethiopia, Uganda) small-holders and informal raw milk channels dominate the supply of marketed products, compared to the large-scale dairy farmers and cold chain market channels that predominate in the Republic of South Africa. In East and Southern Africa (Zimbabwe and South Africa) high-grade dairy cattle constitute the primary source of milk. An exception is Tanzania, where agro-pastoral zebu cattle play an important role in dairy production.

In the sub-humid regions of West Africa (Gambia, Ghana and Nigeria) Fulani agro-pastoralists supply the majority of milk to urban centres. In Bamako (Mali, West Africa) milk is supplied to the capital by two types of producers: 1. High-input, capital-intensive, large-scale dairies using cross-bred and pure-bred cattle located in and around the city; and 2. Communal dairies producing milk from herds of local cattle assembled from several owners. Some of the large-scale owners deliver the milk to processing plants to be added to reconstituted imported milk. Other producers sell directly to the consumers. Direct sales from producer to consumer account for fifty percent of the informal market, the rest is sold through one to three intermediaries.

Consumption preferences in African cities are generally for low-cost liquid raw or soured milk.
except for Ethiopia and some West African nations, where traditional butter and soft cheeses comprise an important part of the marketed milk products (Omore et al. 2000).

National self-sufficiency in dairy production varies substantially within and between regions (Table 1). In west and central Africa marketed domestic dairy products are limited, necessitating large quantities of dairy imports, whereas east and south Africa supply the majority of their own milk products.

2.1 Classical Zoonoses of Dairy Cattle

In addition to Escherichia coli, three other bacterial infections (Tuberculosis, Brucellosis and Anthrax) detected in cattle and reported widely throughout Africa are reviewed in this section. Both Tuberculosis and Brucellosis constitute potential health hazards in dairy production systems. Recent investigations indicate that Escherichia coli O157:H7 is an emerging organism in the dairy producing industry of East Africa and may be gaining importance as a milk-borne organism (Arimi et al. 2000).

2.1.1 Tuberculosis

Although there are numerous mycobacterial diseases, this paper focuses on those that are relevant to humans and livestock. Mycobacterium tuberculosis and Mycobacterium bovis are the etiological agents of tuberculosis in humans and cattle and infection results in a chronic granulomatous disease in the respective hosts. M. bovis is infectious to humans and can pose a serious zoonotic risk (Gallagher and Jenkins 1998).

Worldwide, tuberculosis (Mycobacterium tuberculosis) is still the single leading cause of human morbidity and mortality due to an infectious agent. Approximately 10% of people infected with the bacteria will progress to fulminant disease at some point during their lives. In immune-suppressed and HIV positive individuals this figure rises to 40%. In sub-Saharan Africa two million new cases arise every year and 32% of deaths in HIV infected individuals is due to TB, making it the largest attributable cause of death in this group (Guleria et al. 1996). As a result of the HIV epidemic, the crude incidence rate of TB is expected to increase in this region from 191 cases per 100,000 in 1990 to 293 (per 100,000) presently (Cosivi et al. 1998).

Most of human TB infections are due to M. tuberculosis. Information on human disease due to M. bovis is scarce. Where African data have been available, approximately 1-5% of isolates from human cases have proved to be M. bovis (Elsabban et al. 1992; Idigbe et al. 1986; Mposhy et al. 1983). The relatively low isolation rate of M. bovis from human TB cases in developing countries, including Africa, may be partly attributable to the extensive use of microscopy for confirmation of
suspected cases, a technique that does not permit differentiation between species of mycobacteria. Furthermore, accurate diagnosis is often difficult even when culture facilities are available as *M. bovis* grows poorly in the standard and most widely used Lowenstein-Jensen medium. Nonetheless, given the estimated existing infections and expected new cases, *M. bovis* may still constitute a significant proportion of total TB cases.

2.1.2 Epidemiology of Tuberculosis

In the case of bovine TB, the infected animal is the main source of infection although mediate contagion can occur. Organisms are excreted in the exhaled air, in sputum, feces, milk, urine, vaginal and uterine discharges and discharges from peripheral lymph nodes. Both *M. bovis* and *M. tuberculosis* are manifested in a primary and a post-primary form, the site of disease reflects the route of infection. *M. tuberculosis* is usually inhaled and leads to primary lesions, with occasional extra-pulmonary lesions due to lymphatic and haematogenous dissemination; whilst *M. bovis*, which is usually acquired through consumption of contaminated milk, is more likely to cause non-pulmonary lesions and this is the primary means of transmission of this agent to suckling/young animals and to humans. Young children consuming milk from infected herds are at particular risk of disease, because of their age-related susceptibility, even when infected with small numbers of bacilli. Infection can become established in the cervical, and somewhat less frequently, in the axillary lymph nodes. The condition is referred to as scrofula, and is commonly found in regions where bovine tuberculosis is widespread and milk is not usually pasteurised. Extra pulmonary tuberculosis also occurs in the intestinal tract, kidneys, bones and the central nervous system (Moda et al. 1996).

Farm workers are more prone to inhalation of infective droplets from diseased cattle (Plommet et al. 1998). Development of overt disease after infection under field conditions may be dependent not only on the number of virulent organisms to which a susceptible host is exposed, but also on the frequency of exposure and route of infection, as well as the general health and immunological status of the animal. In contrast to human infection the primary lesions in cattle rarely heals spontaneously, but tends to disseminate locally through the natural cavities. *M. bovis* is less virulent than *M. tuberculosis* in humans and as a result less likely to proceed to post-primary infections of disease. However, Grange et al. (1994) have postulated that the differences in virulence may be the result of differing susceptibility to the host defense mechanisms. The authors surmised that if this is true, the immuno-suppression induced by HIV infection could annul these differences.

The condemnation of meat and milk, poor weight gain, decreased milk production, infertility
and eventual death are the primary contributors to losses in the cattle industry. Housing and zero grazing predispose the animals to the disease, thereby increasing the risk to humans. The highest incidence of bovine TB is generally observed where intensive dairy production is most common, notably in the milk sheds of larger cities (Acha & Szyfres (1987) cited by Cosivi et al. 1998) where the bulk of the milk is destined for market in urban regions.

2.1.3 Status of Bovine Tuberculosis in West Africa

Of 55 African countries, 25 reported sporadic/low occurrence of bovine TB; 6 reported enzootic disease; 2, Malawi and Mali, were described as having a high occurrence; 4 did not report the disease; and the remaining 18 countries did not have data.

Of all the nations in Africa, only 7 apply disease control measures as part of a test and slaughter policy and consider bovine TB a notifiable disease, the remaining 48 countries control the disease inadequately or not at all (Cosivi et al. 1998). About 15% of all the cattle are found in countries where bovine TB is notifiable. Approximately 85% of the cattle and 82% of the human population of Africa are in areas where bovine TB is either partly controlled or not controlled at all (Cosivi et al. 1998).

Reports of bovine TB vary among the west African nations (Table 2). In Ivory Coast (OIE 1993) 50% of cases condemned at slaughter were due to TB (10% sheep & goats and 90% cattle). The prevalence of *M. bovis* in the Dangme-West District of Ghana was estimated at 11.3-19.0% and is considered one of the principle zoonoses in the country (Wastling et al. 1999). In a five-year study in southern Nigeria on trade cattle (N= 5407) destined for slaughter 8.2% of cows tested positive for TB despite claims that the animals originated from disease free herds (Wehke and Berepubo 1989). Sixteen positive reactors were detected, (N=781)between 1989 and 1990 in Niger. Official figures for 1999 published by the Organization for International Epizootics (OIE) for all of West Africa indicated that bovine TB was reported as present in Burkina Faso, Ivory Coast and Mali but no information was available on the number of cases, outbreaks or deaths. Similarly, in Ghana at least 23 outbreaks and 35 cases were noted.

In a retrospective analysis of hospital records of tuberculosis patients (Vekemans et al. 1999) pulmonary TB was the most common form amongst all the cases. The Peul herdersmen (a cattle-tending tribe) in Bobo Dioulasso, Burkina Faso, were 6 times more likely (p<.05) to be infected with pulmonary TB than Peul who did not tend cattle. This suggests that TB is an occupational hazard, strongly associated with cattle rearing. Ninety-five percent of the herdsmen had pulmonary
infections, indicative that the primary form of transmission was aerosol and not contaminated food (ie. Milk). However, the study did not indicate the species of the aetiological agent and therefore it is not possible to determine whether the herdsmen were truly infected with *M. bovis* (and therefore probably attributable to infection through exposure to cattle). In addition to assessing hospital cases, the authors conducted dermal testing, collected milk samples from the market and dairy farms and animal tissues from the abattoir. Twenty-two percent of the pooled milk samples cultured positive for *M. bovis* and *M. tuberculos*, and *M. africanum* was isolated from 4% of the samples, suggesting that the potential for milk-borne transmission does exist.

As exemplified in the data presented, the methods of collecting and presenting information are haphazard and random. When assessing or interpreting the available data it is evident that one cannot draw, with confidence, any conclusions about the prevalence or incidence of each strain in either humans or animals nor the route of transmission between the two.

The risk of transmission of *M. bovis* to humans through the consumption of contaminated milk and eventual establishment of infection depends on the right permutation of numerous factors:

1. *M. bovis* must be present in the udder of the cow at time of milking. This occurs only when the disease is at an advanced stage and has disseminated throughout the animals body. However, this is probably a rare occurrence even where tuberculosis is still present. At a time when tuberculosis was prevalent in European dairy cows, only 1% of udders of slaughtered tuberculous animals had visceral lesions (O’Reilly and Daborn 1995). (Tuberculous human milkers can transmit the disease to cows through handling);

2. Treatment (pasteurization, boiling, fermenting,) through a commercial system or at home, affects the bacterial composition of the milk product. Therefore, improper or complete absence of processing commercially and domestically increases the probability of transmission;

3. Infection is dependant on the dose of *M. bovis* bacteria being shed by the animal (generally a large inoculum is required to establish infection (O’Reilly and Daborn 1995) and a smaller infecting dose of tubercle bacilli often results in a protective immunity). This in turn rests upon a variety of physiological conditions in the animal, and finally;

4. The establishment of infection in the consumers depends on their immune status.
Although the risk of transmission and infection is real, not a single study has been conducted in West Africa to establish an epidemiological association between tuberculosis in cows and bovine tuberculosis in humans in this region nor are there any studies providing information on the distribution of risk factors. Furthermore, tuberculosis acquired through the consumption of raw milk, resulting in extra-pulmonary infection, may be less likely to be detected or diagnosed than pulmonary disease. Considering the limitations on data compilation in the region, the figures presented here are possibly a conservative estimate of the prevalence and distribution of the disease in West Africa.

2.2 Brucellosis

Brucellosis is a bacterial zoonoses with worldwide distribution and remains a major source of disease in humans and domesticated animals. From the viewpoint of human health, the disease is important because the causative organism can cause undulant fever. Losses in animal production due to this disease can be of major importance primarily because of the decreased milk production in dairy cows. Although more than 6 brucella species have been identified, only Brucella abortus, Brucella melitensis, and Brucella suis are zoonotic and are transmitted directly or indirectly to humans from cattle, sheep and goats, and pigs respectively. The prevalence and incidence of brucellosis varies widely. While brucellosis has been practically eliminated in developed countries, it is still endemic and of economic importance in Africa, the Middle East, Central and South-East Asia, South America and in some Mediterranean countries.

2.2.1 Epidemiology of Brucellosis

The 3 species of brucella of concern to public health are of bovine, ovine-caprine and swine origin. Brucella melitensis is the most invasive and pathogenic for humans of the three classical species and is the cause of “Malta” fever in humans. Sheep, goats and their products remain the main source of infection, but more recently it has begun to emerge as a disease of cattle.

Large numbers of organisms are excreted at and following parturition, providing a source of infection for humans managing the herd or flock and for those within the immediate environment. The risk of infection is high for those cultures that cohabit with their animals or in situations where sick or weakened animals are brought into the house for warmth and care. Humans become infected by ingestion, direct contact, inhalation, or accidental inoculation by penetration through conjunctival, nasopharyngeal, pulmonary, and/or intestinal mucosa, or through skin abrasion or injury. Milk, cream, and fresh cheese are the main source of human brucellosis.
Excretion in milk may attain its highest \((10^4/\text{ml})\) at the beginning of lactation and then decline to a few bacteria (approximately \(10/\text{ml}\)) but may persist during successive lactation periods. During cheesemaking, the bacteria are first concentrated in the curd and then decline with the acidification produced by the lactic bacteria. Therefore, survival depends on the type of cheese and the ripening involved. *Brucella* are destroyed by pasteurization.

Excretion from the genital tract at abortion or normal birth, (which continues for some weeks), is the second most important source of infection for humans. In animal herds, this is the major source of infection. Infection can occur by direct contact or mechanical transmission. *Brucella* survive in the soil, water, solid or liquid manure, depending on the material, temperature and sun exposure. Bacteria can also contaminate drinking water. Indirect transmission via airborne dust has been observed in villages along the transhumance routes as well as contamination of abattoir workers through airborne droplets. The latter is particularly of concern when high pressure jets or water are used during the washing of premises. Meat products, mainly spleen, liver, genital organs, lymph nodes and meat with remnants of lymphatic tissue constitute an important source of human and animal infection. *Brucella* are also destroyed by cooking.

### 2.2.2 Brucellosis in Africa

Brucellosis is regarded as a major problem of ruminants in Africa (Wastling et al. 1999), yet the true incidence of human brucellosis is unknown and there is scant evidence of the impact of this disease on public health in West Africa. Worldwide-reported incidence in human endemic-disease areas varies widely, from \(<0.01\) to \(>200\) per 100,000 populations (Corbel 1997). According to the Office of International Epizootics (OIE, 1999) Burkina Faso, Cameroon, Mali, and Ivory Coast were the only West African countries cited as either reporting or suspecting the presence of bovine brucella. While some areas may have a high incidence of acute infections the low incidence reported in other known brucellosis endemic areas may reflect low levels of surveillance and reporting. Furthermore, factors such as livestock species raised, methods of food preparation, heat treatment of dairy products, and direct contact with animals also influence risks to the human population. In animals the presence and transmission of *brucella* is moderated by an interrelationship of factors including climate, types of production systems (nomadic/transhumance or sedentary; extensive vs. intensive), herd size, livestock breeds and the age of the animal (Akakpo 1987; Plommet et al. 1998).

Most studies of brucellosis in West Africa have focused either on animals or humans (Table
One exception is a comprehensive qualitative study on the disease in bovines, caprines and ovines in different ecological regions and its impact on public health between 1970 and 1973 in Ivory Coast, Niger, and Burkina Faso (Gidel et al. 1976). However, this study did not establish any associations or risk factors between the disease in animals and the infection rate in humans. The prevalence varied substantially between types of animals in the same ecological zone and between different ecological regions. Two different testing procedures were used on animals, the milk ring test (MRT) and serology. Results from of the ring-test (MRT) indicated that the prevalence of brucellosis in all ruminant species was highest (0 - 51%) in the woody savanna and decreased in the savanna (11-21%) and dry zones (4-6%). No brucellosis was detected in the forest zone, probably a function of the small to non-existent ruminant livestock in this ecological region. Although the milk ring test is satisfactory and inexpensive, its sensitivity is relatively low and may produce a large number of false positives. Serology results were based on the Rose Bengal test (RB) and the complement fixation test (CFT). Results were based on a series interpretation, any animal that tested positive to either one of the tests was deemed positive, thereby increasing the sensitivity of the serological testing. Serological results indicated that the prevalence in bovines ranged from 2% to 54% in the woody savanna, 20% in the savanna and only 1% in the dry zone. Brucellosis was not detected in goats or sheep. Serology is a more sensitive test than the MRT, but the absence of brucella-positive blood may be a function of the small number of caprines and ovines sampled.

The prevalence of human brucellosis, as evidenced by serologic examinations, did not coincide with the prevalence of brucella in animals within the same region. In most areas the prevalence of human brucellosis was low; 0% in the humid forest zone and ranging from .2% to 1.0% in the savanna and woody savanna, and transition zones. Ironically, in the dry zone, where animal brucellosis was lowest, the human brucellosis was most prevalent (ranging from 1.4% up to 10%) (Gidel et al. 1976). Since the ovine/caprine B. melitensis is the most pathogenic brucella species to humans, consumption of contaminated raw goat milk poses the greatest (public) hazard in transmission of brucellosis. The discrepancy between brucella seropositivity in humans and goats and sheep in the dry region may be at least in part, explained by the very small sample of these animals tested.

Akakpo (1987) conducted a serological study of animal brucellosis in 5 West African countries. The prevalence of the disease was similar for Benin, Cameroun, and Burkina Faso (10.4%-12.3%), but was relatively higher in Niger (30.5%) and Togo (41%). However, in another study
(Wehkpe and Berepubo 1989) in Niger only 1.4% of 2815 serum samples tested positive for brucella. In general, there appeared to be greater abundance of infected animals in intensive production systems at the periphery of urban centres and in urban areas than in the more traditional rural systems. This highlights once again the increased risk of disease transmission to humans from urban livestock production systems.

2.3 Prevention and Control Measures

2.3.1 Tuberculosis and Brucellosis

National cattle TB eradication schemes have greatly reduced or minimized the risk of bovine TB for humans in developed countries. However, the cost of national eradication, together with the requirement for veterinary infrastructure necessary to operate it reduces its feasibility in developing countries. To manage TB at the national scale, intersectoral collaboration between the medical and veterinary professions, surveillance of the disease in humans and animals, and establishing diagnostic methods which are able to differentiate between *M. bovis* and *M. tuberculosis* are necessary. This approach, which has been successful in varying degrees in developed nations, requires important human and financial resources.

Control strategies in livestock need to be adapted to local conditions. Although culling of positive animals helps reduce the incidence of TB, this also results in a very real and direct loss to producers, since each animal represents a large economic and social investment. Compensation from national authorities is often not forthcoming.

In the absence of sufficient veterinary supervision, the intensification of dairy production (in urban and peri-urban systems) may be the single most important determinant in increasing the prevalence of bovine TB in humans and animals. Milk plays a potential key role in transmission of TB and brucellosis and therefore may be the most practical level for intervention. Pasteurisation or other adapted techniques should be evaluated and implemented concurrent to the establishment of a dairy producing system. Incentives to produce TB-free milk appear to be successful. In Ghana farmers are offered a premium price for their milk if it is free of *M. bovis* when presented for sale (Wastling et al. 1999).

As de Zeeuw et al. (2000) have suggested, the informal market channels will continue to persist. In the absence of the infrastructure and technologies for the commercialisation of safe milk,
education is the most effective tool for prevention of transmission to humans. Treatment (adequate boiling, fermentation) of milk at the household level is the consumer’s opportunity to reduce or eliminate the risk of infection from TB, brucellosis and other organisms that may have contaminated the milk in the processing system and distribution.

Carefully planned epidemiological studies in peri-/urban regions, in combination with appropriate diagnostic assessment need to be carried out to determine the risks of exposure and acquisition of diseases. These investigations also assist in determining whether transmission is occurring from human to human or animal to human, thereby identifying control points for the various diseases.

Prevention of milk-borne tuberculosis and brucellosis in humans relies whenever possible upon the pasteurization (or otherwise adequate treatment) of milk. People, who through their profession are exposed, require instruction on appropriate hygiene practices and need to be tested regularly for infection.

Control methods of brucellosis in herds is dependent on the type of brucellosis present and whether a functioning surveillance programme is available. Systematic vaccination is recommended in the absence of an adequate surveillance system and where the prevalence is greater than 5%. Vaccination increases individual resistance to systemic infection, and in infected animals decreases the probability of placental infection, abortion and massive shedding of infectious organisms. These combined facts interact at the herd level, by improving herd immunity, to confer good overall protection, provided that individual animals are properly vaccinated. All females kept for reproduction should be vaccinated. A combined approach of systematic vaccination and test and slaughter is suggested for situations where 1%-5% of animals are infected and test and slaughter alone in cases where the prevalence is less than 1%. However, both approaches require authorities to replace the animals that are culled. Therefore, vaccination may be a more appropriate method of controlling brucellosis in some resource-scarce countries.

2.4 Emerging Zoonoses in African Dairy Cattle

2.4.1 Escherichia coli

Escherichia coli is a bacterium that is a common inhabitant of the gut of warm-blooded animals, including man. Most strains of E.coli are harmless. However, some strains, such as E. coli O157:H7, can cause severe foodborne disease. They are referred to as enterohaemorrhagic E. coli (EHEC) and produce toxins. The bacteria is destroyed through cooking of foods until all parts reach
a temperature of 70°C or higher.

Symptoms of the illness caused by *E. coli* O157:H7 include abdominal cramps and watery diarrhoea that can develop into bloody diarrhoea (haemorrhagic colitis). Although most patients recover within 10 days, the infection can result in life-threatening complications, such as haemolyticuraemic syndrome (HUS), in a small population of patients, particularly young children and the elderly. HUS is characterized by acute renal failure, haemolytic anaemia and thrombocytopenia. It is estimated that up to 10% of patients with EHEC infection may develop HUS, with a case-fatality rate ranging from 3% to 5%.

The reservoir of this pathogen appears to be mainly cattle. It is transmitted to man principally through consumption of contaminated foods, such as raw or undercooked ground meat products and raw milk. Faecal contamination of water and other foods, as well as cross-contamination during food preparation will also lead to infection. The oral-faecal route plays an important role in human to human.

Verocytotoxic *E. coli* has not yet to be identified as a zoonoses of public health importance in Africa. However, a few studies has raised the spectre of its presence on the continent and its potential impact on urban health. Based on the premise that milk can easily be contaminated with faecal matter, that cows can experience *E. coli* mastitis, and that milk is often consumed unpasteurized (although 95% of unpasteurized milk consumers boil their milk), Arimi et al. (2000) investigated the overall bacterial quality and the prevalence of *E. coli* in raw milk collected in rural and urban locations in central Kenya. According to the Kenyan Bureau of Standards, 85-88% of samples from urban regions were deemed to have unacceptably high counts of coliform, compared to 41% of samples from rural areas. The authors attributed this difference to the shortened channel between producer and consumer, thereby decreasing points of exposure to contaminants. Of 264 samples cultured for coliforms, 91 were positive for *E. coli*, 2 of which were confirmed to be *E. coli* O157:H7. One of these was a verocytotoxin producing *E. coli* O157:H7. The prevalence of the potentially fatal strain of *E. coli* is very low. However, in the presence of unhygienic handling practices of milk and the numerous opportunities for contamination from producer to consumer, the potential for its propagation and dissemination is real. The public health implications could be significant, particularly for households that do not boil their milk or do so inadequately.

3. Other Bacterial Zoonoses of Ruminants

3.1 Anthrax
Anthrax is an acute infectious disease caused by *Bacillus anthracis*, a spore-forming, encapsulated, Gram-positive rod-shaped bacterium. *B. anthracis* is one of several species, and the most pathogenic, of the genus Bacillus. Anthrax is primarily a disease of herbivorous mammals (cattle, sheep, goats and ungulate wildlife). Humans are incidental hosts and fairly resistant to infection. The virulence of the bacteria is due to the production and release of a toxin resulting septicaemia. Most of the other species of Bacillus are ubiquitous saprophytes (soil-dwelling bacteria) (OIE 1999). The disease is considered primarily an occupational hazard generally acquired directly or indirectly from animals by handling infected meat, hides, wool, hair, or bones. Animals are commonly infected by ingestion of spores from contaminated soil, although in some countries fly bites have been implicated in the transmission (Thurnbull 1998). In industrialized countries, improved factory hygiene and working conditions, together with vaccines have made occupational anthrax a rare event but the disease remains enzootic in several countries of Africa and Asia, at times resulting in human epidemics.

### 3.1.1 Epidemiology of Anthrax

Infection in livestock or wildlife normally commences by entry of the spore into the body by either ingestion (or sometimes inhalation of spore-laden dust). The spores germinate (into the vegetative form) and multiply locally or after transport to the regional lymph nodes where systemic infection is initiated, followed by involvement of the spleen. In the systemic disease, bacilli multiply with few or no symptoms (clinical signs) until a toxin-induced breakdown of the organs results in an explosive release of toxin and massive numbers of bacilli. This leads to a highly acute illness starting with a fever and a few hours later a rapid sequence of disorientation, shock, coma and death.

*Bacillus anthracis* is considered an obligate pathogen; its continued existence in the ecosystem appears to depend on a multiplication phase within an animal host and its environmental presence reflects contamination from an animal source at some time in the past rather than self-perpetuation within the environment. The vegetative forms, shed at the death of animal in haemorrhagic exudate from the nose, mouth or anus or in spilt blood, is fragile. Nonetheless, the characteristic terminal haemorrhage to the exterior is an essential part of the cycle of infection (WHO 2000). The survival of the bacteria (vegetative form) depends on rapid sporulation on exposure to air, but the sporulation success rate does not exceed 0.1%. However, once it does sporulate, the spores can survive decades resisting extremes in temperature, pH, dessication, and other adverse environmental conditions.
3.1.2 Human Anthrax

Traditionally, human anthrax can take 3 forms depending on the route of entry of the spores. Of the 3, pulmonary, cutaneous, and intestinal, cutaneous is the most common. Except when taken in through the pulmonary route, *B. anthracis* requires a lesion through which to enter the body. Human anthrax is further classified into non-industrial or industrial anthrax; depending on whether the infection is acquired directly from animals or indirectly during the handling and processing of contaminated animal products. Non-industrial anthrax is most often in the cutaneous form. Industrial anthrax usually takes the cutaneous form but has a greater probability of being pulmonary through the inhalation of spore-laden dust.

3.1.3 Environmental Factors and Transmission

The incidence of the disease is influenced by temperature, rain and drought through its direct effects on sporulation and indirectly on the feeding behaviour of animals. Spores will germinate outside an animal if they fall into appropriate conditions, i.e. a temperature between about 8°C and 45°C, a pH between about 5 and 9, a relative humidity greater than 95% and the presence of adequate nutrients. Seasons affect the source of foods available to animals. During the dry season grasses are short and sparse and animals graze closer to the soil bringing them into closer contact to spores. Furthermore, climate affects the animals’ level of resistance to infection.

Livestock may acquire the disease through grazing on contaminated pastures, from spores that have reached fields in sewage sludge, or through contaminated feedstuffs. The implication is that cattle raised in both extensive and intensive, as in urban and peri-urban livestock systems, are potentially at risk of acquiring the disease. In economic and public health terms, the importance of the disease lies in its ability to affect large numbers of livestock at any one time. Carcasses pose a hazard to humans and other animals both in the vicinity and at a distance through hides which are transported long distances.

3.1.4 Incidence of Anthrax in West Africa

The disease remains enzootic in parts of Africa and Asia where the value of a carcass (following sudden death) as meat for local consumption and as hide, wool etc. for sale, outweighs the perceived merits of burying or burning it. Consequently the cycle of infection in humans and animals continues to occur locally and in non-endemic regions to where the animal products are shipped.

Of the west African countries, Ghana, Burkina Faso and Togo consider it to be amongst one
of the most significant zoonotic diseases (Wastling et al. 1999). Ghana reported an outbreak of anthrax in 1997 where 26 people died out of 185 infected cases. The incident was traced to the butchering and consumption of meat from cattle that had died suddenly. A Nigerian study in 1985 reported that 5% of cattle (N=60) and 3% of sheep (N=30) were positive for anthrax. The prevalence of the disease in humans associated with the infected animals was 20% (N=10).

The incidence of human anthrax is dependent on the level of exposure to affected animals. National incidence data for non-industrial cases reflect the national livestock situation. Industrial anthrax incidence data can be inferred from the volume and weight of potentially affected material handled or imported and taking into account the quality of prevention (vaccination of personnel, ventilation etc.). For countries where the disease is infrequent, or erratically or incompletely recorded the above formulation is the only way to assess the extent of the disease. Compounding the lack of information is the fact that some countries suppress reporting data at the local and/or national levels.

The main form of transmission of the anthrax bacillus to animals is via soil contamination. Therefore, animals kept under extensive systems in rural areas are most susceptible to infection. In urban settings, the disease is an occupational hazard for veterinarians, abattoir and tannery workers. In most developing countries the disease is endemic in pockets of wildlife and sporadic outbreaks occur in livestock and humans. Therefore, prevention and control would best be addressed through education of workers in the field to recognize the signs and symptoms of anthrax in animals and approaches to disposal of animals that die of the disease. Simple laboratory tests are available for the anthrax antigen that can be used to investigate animals products suspected of being infected. Environmental (ventilation), personal hygiene measures (protective clothing) and vaccination can reduce the occupational hazard.

4. Swine and Poultry Production

Urban and peri-urban agriculture play an increasing role in supplying food to towns and cities and poultry and swine farming have developed in response to the growing demand for animal proteins. Since 1988 the government of Ivory Coast has been encouraging intensive, short-cycle livestock production in the region of Abidjan and in Senegal, peri-urban poultry farming has developed considerably also in response to the demand for animal protein. On the other hand, in Burkina Faso the contribution from modern urban producers to consumers in Ouagadougou is low. The main suppliers of poultry meat to the city are rural producers living 10-200 km from the urban centre (Ouedraogo and Zoundi 1999).
**4.1 Zoonoses of Pigs**

**4.1.2 Cysticercosis (Taenia solium)**

*Taenia solium*, a porcine tapeworm, is important in pig-eating regions with poor sanitation, where human faeces are an important part of the diet of scavenging pigs (Lloyd 1998). In some areas, where resources are scarce, housed pigs are fed human feces and in some cases pig-pens serve as the household latrine (Zoli, pers.comm).

**4.1.3 Epidemiology of Cysticercosis**

Infection of *T. solium* in humans is achieved through pig-human contact (Figure 1). The consumption of pig meat infected with viable cysts results in the development of adult taenia in humans. Chains of proglottids, or eggs, are passed in infected human faeces and are consumed by pigs that either scavenge or otherwise have access to it. Dessication is lethal to eggs but they will survive from several weeks to months in sewage, river water or on pasture (Lloyd 1998). Once consumed, the eggs develop into metacestodes in the pig, the intermediary host. The cysts, infective in the pig about 10 weeks after ingestion, occur primarily in the skeletal and cardiac muscles and the brain. Infection in humans arises due to culinary preferences of eating raw flesh or light smoking. Certain groups of people favour the taste and texture of measly pork (Zoli pers comm.), which results in the ingestions of vast numbers of cysts.

Human to human transfer through faeco-oral transfer of eggs by contaminated hands, the use of contaminated night soil on vegetables for fertilization, a common practice in urban areas in China, or contaminated irrigation water, leads to human cysticercosis. Although the presence of cysts in human subcutaneous, intramuscular or visceral tissues is usually asymptomatic, about 60-90% of cysticercosis-infected persons also have metacestodes in the central nervous system. The small encysted larvae in the brain cause few symptoms until their death triggers local inflammation, seizures and focal neurologic dysfunction. This condition is referred to as neurocysticercosis and the most common presenting sign is seizures. Medina et al. (1990) attributed neurocysticercosis as the causative agent in 50% of cases of late-onset epilepsy (defined as recurring seizures) in endemic areas. Medical centers with the required diagnostic equipment (Magnetic Resonance Imaging and Computed Tomography Scanning) are often unavailable, and therefore the proportion of neurocysticercosis cases remains unknown (Lloyd 1998) in many parts of the world.

Palpation of the tongue revealing nodules remains the technique used to detect infection in living pigs. Meat inspection is the most widely used method to identify and divert infected carcasses.
for treatment or condemnation. Neither ante- or post-mortem detection methods are sensitive. Overall detection rate in lightly infected animals is 31% (in carcasses with less than 20 cysts) and 78% in carcasses with greater than 20 cysts. Where *T. solium* is endemic, meat that has by-passed inspection or in which inspection has failed to detect inspection, will be sold in urban and peri-urban markets.

### 4.1.4 Cysticercosis in West Africa

The prevalence of Cysticercosis varies within countries and between regions but is the main reason for pig carcass condemnation. In Burkina Faso 84% of pig meat condemned was due to infection with *Cysticercus cellulosae* (The cyst stage of *Taenia solium*). The national prevalence at slaughter was 0.57% (Total number of pigs inspected = 117,026) (Coulibaly and Yameogo 2000). Data available on human cysticercosis infection is scarce, perhaps due to both the lack of appropriate diagnostic equipment and the fact that the condition can remain inapparent for long periods of time. Across 6 departments in Benin, 1.3% of people sampled (N=2525) tested positive for cysticercosis with a prevalence of up to 3.0-3.3% in 2 (non-Muslim) regions studied (Houinato et al. 1998). In northern Togo Balogou et al. (2000) determined there are 38 cases of cysticercosis per every 1000 people in the general population. In the same study in a sample of epileptics (N=9,155) the rate of cysticercosis was 135 cases per 1000 human diagnosed with epilepsy. The authors suggested a significant relationship existed between occurrence of cysticercosis and epilepsy ($X^2=74.1; p<.000001$).

The control of the disease is implicitly rooted in the husbandry of the pigs. Management of the animal needs to include the restriction of access to human faeces, through a form of animal confinement and public health campaigns.

### 4.2 Enteric Zoonoses of Poultry and Swine Systems

Diarrheal diseases are a major cause of morbidity and mortality in developing countries. Attack rates range from 5 to 12 illnesses per child per year, with the peak age-specific attack rates occurring during the first 2 years of life (Guerrant et al. 1990). *Campylobacter* and *Shigella* are among the more common zoonotic etiologies of diarrhea. As livestock production intensifies, particularly in urban systems, *Salmonella enteriditis* and *E. coli* O157:H7 become more prominent.

#### 4.2.1 Campylobacter

*Campylobacter* bacteria have been the focus of attention during the last 10 years due to the increasing frequency with which they have been isolated from humans, animals, foods and water.
It is now recognized as being among the most important agents of enteritis in the world. Campylobacter infections are a frequent cause of morbidity in developing countries (WHO 1998). Campylobacter enteritis is mainly a human disease, but animals are affected. The morbidity in animals is not fully known since the organism is often found in both healthy and sick animals. The organism is widespread and animals exposed to it early in life develop antibodies to the agent. Humans are not a natural hosts and infection is normally transient. Therefore humans do not constitute a significant reservoir of the disease.

Enteritis due \textit{Campylobacter jejuni} and \textit{C. coli} are the only form of campylobacteriosis of major public health importance. Both of these species are widely distributed in nature, inhabiting the intestinal tracts of wild birds and domestic animals. Poultry in particular become heavily colonized with \textit{C. jejuni} and to a lesser extent \textit{C. coli}, whereas pigs are almost universally colonized with \textit{C. coli} rather than \textit{C. jejuni}. Human infection, which is mostly sporadic, may be acquired directly from animals or their products, by eating raw or under-cooked meat or foods that have been cross-contaminated. Raw milk and contaminated water are sources that have given rise to major outbreaks of infection (Skirrow 1998).

Although the transmissability of campylobacter is low, without taking proper hygienic precautions there are definite risks associated with handling infected or colonized animals or their carcasses. Occupational risks are the greatest. Indirect transmission via milk, water, and food is believed to account for the majority infections. Case control studies in Western countries have consistently shown that the consumption of raw milk carries up to a nine-fold increased risk of infection. Faecal contamination at the time of milking is considered to be the main route of transmission into the raw milk, but may also be excreted into the milk directly from an infected udder.

Enteric \textit{Campylobacter} species are more prevalent in developing than developed countries (Georges-Courbot et al. 1990) and contributes substantially to the burden of childhood diarrhoea (Taylor 1992). In a Nigeria study approximately 14\% of children (N=46) admitted to the hospital tested positive for \textit{Campylobacter}. \textit{C. jejuni} accounted for 76\% of the isolates. In the same study \textit{Campylobacter} was isolated from almost 50\% of urban chickens (N=101) sampled. In a cohort study of 111 children conducted in Bangui (Central African Republic) over a 2-year period the incidence of diarrhoea per child year in Bangui was 1.6 episodes.

Forty-three percent of children presented at least one infection before 6 months of age and
30.6% had diarrhoea associated with campylobacter infection before they were 2 years old. The authors assessed the incidence of campylobacter infections in relation to the presence of domestic animals. In children less than 6 months old, the relative risk of acquiring campylobacter infections was 2.5 (CI = 1.08 - 5.54) times greater in households that kept poultry than those that did not. In households without piped water the risk of acquiring a campylobacter infection was 13.4 (CI= 1.65-52.1).

Although Campylobacter is predominantly an infection of chickens and pigs, in a small-scale investigation Jiwa et al. (1994) demonstrated that husbandry practices influence transmission to other domestic species. Urban goats in Tanzania which were not housed separately were almost 14 times more likely (OR=13.9; p<.0114) to be infected with the organism than goats that were kept isolated from chickens and pigs.

4.3 Non-typhoidal Salmonellosis

4.3.1. Salmonella enteritidis

Human cases of Salmonella enteritidis have been increasing worldwide in the last 2 decades. Human infection is usually acquired by ingestion of contaminated water and food, mainly poultry, eggs, and egg products. Although S. enteritidis is more common in large poultry production systems in the developed nations, the prevalence may increase in developing countries as they adopt similar large-scale production systems often situated in urban settings. In an 8-month investigation conducted in an urban center of Zimbabwe the prevalence of S. enteritidis was determined to be 1.8% (N=4155 stool samples) with phage type 4 strain being the most common (Simango and Mbewe 2000). In another study in Zimbabwe 113 isolates of S. enteritidis from chickens and eggs identified phage type 4 as the most common. A similar distribution pattern to that of human isolates observed in the more recent study was noted suggesting that chicken and egg consumption is an important cause of S. enteritidis in humans in the study area.

5. Protozoal Zoonotic Infections of Ruminants and Pigs

5.1 Toxoplasmosis

Toxoplasmosis is a world-wide zoonosis impacting both human and animal health and resulting in production losses in sheep. The definitive hosts of Toxoplasma gondii, the causative agent, are members of the feline family. However, the parasite has a wide-range of intermediate hosts. T. gondii has 3 infective stages: 1. The rapidly multiplying form of the parasite, tachyzoites, present during the acute stage of the infection in the intermediate host; 2. Bradyzoites, present in the
tissues cysts; and 3. Oocysts present only in cat faeces. Oocysts are the infective stage of importance in farm animals, and the only infective stage for herbivores. The parasite (oocysts) once ingested by the intermediate host, invades the tissues and produces tissue cysts. The invasion can include the fetus. Tissue cysts in the intermediate hosts cause damage to the nervous system, the myocardium, lung and placental tissues. Bradyzoites are a source for toxoplasmosis in humans.

5.1.1 Epidemiology of Toxoplasma gondii

The sole source of infection for sheep, goats, cattle and horses is the oocyst passed in the cat faeces, whereas pigs can also be infected through the ingestion of tachyzoites or bradyzoites present in meat (dead rodents, cannibalized piglets), or through the ingestion of blood while tail or ear-biting (Figure 2). Direct sheep to sheep transmission can occur through close contact of highly infected placenta. However, with the exception of abortion and neonatal disease in sheep, toxoplasmosis is not considered to be of clinical significance in farm animals. The major significance of toxoplasmosis in livestock is its zoonotic potential.

Cats become infected and shed oocysts in their feces as a result of consuming tissues of intermediate hosts (birds, rodents) infected with the parasite. Rodents pass the organism congenitally, from generation to generation, and thus can provide a long time reservoir of infection. Domestic and feral cats nesting and defecating in and around livestock bedding and feed provide a direct source of infection.

Oocysts are extremely resistant to external influences. The can overwinter in cold climates but are less viable in arid climates. Oocysts are destroyed by exposure to high temperatures. Where the disease has been studied, a high infection rate in sheep has been shown to be related to high rainfall. The warm, moist conditions allow longer survival of oocysts on pasture. The prevalence of infection in small ruminants is much lower in hot and dry regions. In some areas, swine housed outdoors are at a significantly greater risk of being exposed to contaminated matter.

5.1.2 Zoonotic Implications for Humans

Humans are intermediate hosts for Toxoplasma gondii. Human infection can arise from ingestion of oocysts from cat faeces that have contaminated food. Or from the ingestion of bradyzoites and tachyzoites in meat or tissues that are handled or consumed raw/undercooked. Consumption of raw goat or sheep milk poses a small risk of infection. T. gondii infection commonly does not result in clinical disease or is mild and self-limiting. People who are at greatest risk of significant disease due to T. gondii infection are the immune-suppressed, HIV-infected individuals,
and the very young and old. Pregnant women are also at risk for abortion or congenital infection of the fetus. It is also an occupational hazard for those handling infected tissue: farmers, veterinarians and abattoir workers.

5.1.3 Toxoplasma in Humans and Livestock in West Africa

In West Africa, there is little documented evidence on the epidemiology of toxoplasmosis in livestock and humans. In livestock the main studies have focused on seroprevalence in Ghanaian goats and sheep (van der Puije et al. 2000), and pigs (Arko Mensah et al. 2000). Sheep, overall showed a higher prevalence of exposure to toxoplasmosis than goats. Sheep in the wetter regions of Ghana (the coastal savannah and the forest belt) had the highest prevalence, 48% and 43% respectively of anti-toxoplasma antibodies compared to goats from the same area (30% and 32%). The sero-prevalence of toxoplasmosis in sheep also differed significantly between the management systems under which the animals were kept; 54% in extensively raised animals and 24% in the semi-intensive system. Since environmental conditions influence the viability of oocysts and housing types modify the exposure to contaminated material, the ecological differences may confound the actual influence of housing on the prevalence of antibodies. The authors did not report whether they controlled for ecological region when assessing management systems. Although the authors speculated that sheep may be more susceptible to infection than goats, experimental infection has shown that caprines and ovines are equally susceptible to infection (Radostits et al. 2000), therefore the differences in prevalence between sheep and goats may be a function of their consumption patterns. Sheep tend to graze, increasing the likelihood of direct contact with infected soil and vegetation, whereas goats are browsers, often not feeding directly from the ground.

Arko-Mensah et al. (2000) reported the Ghanaian national seroprevalence of toxoplasmosis in pigs was 39% with a range of 30.5-43.9% in 3 different ecological zones. The lowest prevalence was in the forest belt. The authors speculated that this was probably due to the fact that most animals were housed year round and therefore access to T. gondii oocysts in the environment was restricted.

Toxoplasma infection in otherwise healthy humans is usually asymptomatic. In one study in Benin 54% of pregnant women tested positive for toxoplasma which is indicative that they were exposed to the organism at some point in their lifetime. Women who are infected before conception normally do not transmit toxoplasmosis to the fetus, unless the infection is reactivated during pregnancy by immunosuppression. Abortions, stillbirths or malformations may result as a cause of congenital toxoplasmosis. Ocular toxoplasmosis result from congenital infection that is reactivated
later in life. In a study on hospital patients in Sierra Leone, Ronday et al. (1996) found that toxoplasmosis was the most important cause of uveitis (inflammation of the vascular middle coat of the eye). However, whether the resulting uveitis was due to a pre- or post-natally acquired disease was not determined.

In immunocompromised patients, toxoplasmosis is an opportunistic disease and can cause severe disease. Clinically apparent toxoplasmosis develops in 30-40% of AIDS patients, in whom disease is more often due to reactivation of a preexisting latent infection than to newly acquired infection. Untreated infections in this group are usually fatal. Therefore, the risk of HIV infection and AIDS may be the single-most important factor in determining the impact of this infection on public health. Lucas et al. (1993) reported that 53% (N=294) of deaths in HIV-positive individuals in a hospital in Ivory Coast were due to cerebral toxoplasmosis.

5.1.4 Control measures for Toxoplasmosis

Control is achieved at two levels: 1. Animal husbandry; and 2. Reduce the risk for human disease associated with the consumption of infected meat. The risk to animals is reduced by the removal of cats from the “farm environment” which will in turn preclude feed and pasture contamination. If this is not feasible, then storage of feed can reduce feline contamination. Proper cooking or irradiation destroys T. gondii-infected meat.

Watson and Zinsstag (2000) surmise that primary Toxoplasma infection in West Africa occurs at an early age yet epidemiological questions of relevance remain:
What is the source of the initial infection? What is the role of undercooked meat? Given the absence of large feline populations in this region, what is the explanation for the broad soil contamination? Addressing them as part of epidemiological studies may serve in reducing the original exposure to the organism.

6. Conclusions

Urban agriculture has, over the last decade, contributed to meeting urban food demand, household welfare and livelihood, and will continue to increasingly fulfil these roles in the near and medium term future, particularly in the developing countries. However, most urban and peri-urban environments do not have the infrastructure, particularly in the area of sewage disposal and provision of potable water to process increased livestock production. Hence an increase in peri-urban farming potentially contributes to a rise in zoonotic infections. Given the paucity of information on zoonotic diseases in West Africa further investment in disease surveillance is essential. In addition, the control
of the zoonoses needs to rely heavily on a greater level of public awareness.

In developing countries, many of the infectious agents associated with traditional zoonotic diseases are well established in the environment. Eradication of the organism is often not economically or environmentally possible nor desirable. Public health officials would be well-advised to approach the control of zoonoses in urban agriculture at the grassroots level, with a focus on education and benefits. Laws and government regulations are often ineffective in eliciting compliance unless these laws already coincide with local customs and belief systems. That is, for successful adherence to rules and procedures, individuals and communities need to recognize that benefits they will reap as a result of complying. Non-Governmental Organizations working with both consumers and producers may have an advantage here, since they are often viewed as working for the local good. The most effective public education plan will include the following two characteristics:

1. The connection between prevention and control of the various zoonotic diseases and the consumer’s own health (short and long term) and production/wealth will be clear and compelling.
2. The suggested methods for reducing transmission will be cost-effective, easily accessed and require a minimum of effort and time. The pertinent approaches need to be presented to both the consumer and producer.

The public health educator, supported by public health authorities, should approach the tasks as follows:

1. Identify local UA practices and conditions, perceived problems and desired outcomes. Identify whether there is a concept or awareness of animal-human transmission.
2. Identify the current facilitators of transmission as well as locally available methods of prevention and controls.
3. Use relevant community-based centres, organizations, and media to reach both literate and non-literate consumers.
4. Educate the consumer on the following:
   a. the route of transmission;
   b. the effect on animals, symptoms and eventual outcome;
   c. the effects on humans, symptoms and eventual outcome;
   d. provide a forum for facilitating questions, requests, clarification, review of issues;
e. provide and illustrate the use of cost-effective, time-efficient methods for control and prevention of transmission; where possible illustrate the outcomes of successful applications of these prevention principles.
## Table 1. Milk production and consumption in sub-Saharan Africa by region.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>West</th>
<th>Central</th>
<th>East</th>
<th>Southern</th>
<th>South Africa</th>
</tr>
</thead>
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<tr>
<td>Production (MT)</td>
<td>1,995,039</td>
<td>624,359</td>
<td>8,484,352</td>
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<td>Domestic Supply (MT)</td>
<td>2,758,099</td>
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<td>8,615,920</td>
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<td>2,945,390</td>
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<td>198,706</td>
<td>90,336</td>
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<td>Supply/caput/yr (kg)</td>
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<td>7.8</td>
<td>29.8</td>
<td>46.2</td>
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</tr>
<tr>
<td>Protein/caput/day (Gr)</td>
<td>1.0</td>
<td>0.7</td>
<td>2.7</td>
<td>5.4</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Source: http://www.fao.org

## Table 2. Bovine Tuberculosis in West Africa

<table>
<thead>
<tr>
<th>Country</th>
<th>Prevalence% (Range)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burkina Faso</td>
<td>8-26.5(^1)</td>
<td>Vekemans et al., 1999</td>
</tr>
<tr>
<td>Ghana</td>
<td>1-60</td>
<td>Lit Review (ILRI)</td>
</tr>
<tr>
<td>Ivory Coast</td>
<td>50 (^2)</td>
<td>OIE, 1993</td>
</tr>
<tr>
<td>Mali</td>
<td>Present</td>
<td>OIE, 1999</td>
</tr>
<tr>
<td>Niger</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Nigeria</td>
<td>0.2-8.2</td>
<td>Alonge &amp; Ayanwale, 1984, Wehke &amp; Berepubo, 1989</td>
</tr>
</tbody>
</table>

\(^1\)Range derived from type of sampling: dermal testing isolation from milk and tissue

\(^2\)Figure based on carcass condemnation at abattoir
<table>
<thead>
<tr>
<th>Country</th>
<th>Species</th>
<th>Prevalence (%)</th>
<th>Type of Test&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benin</td>
<td>Bovines</td>
<td>10.4</td>
<td>MRT</td>
<td>Akakpo (1989)</td>
</tr>
<tr>
<td>Burkina Faso&lt;sup&gt;2&lt;/sup&gt;</td>
<td>Bovines, Caprines, Ovines, Humans</td>
<td>12.3, 6-31.3; 2.3-10.9, 4.8-28.6; 0, 11.2; 4.3, 0.2-10.1</td>
<td>MRT, MRT; SRL, MRT; SRL, MRT; SRL, SRL</td>
<td>Akakpo (1989), Gidel et al. (1974)&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ivory Coast</td>
<td>Bovines, Caprines, Ovines, Humans</td>
<td>23-51; 2.6-25.8, 12-45; 0, 10.3-75; 0.4-1.0</td>
<td>MRT; SRL, MRT;SRL, MRT;SRL, SRL</td>
<td>Gidel et al.(1974)</td>
</tr>
<tr>
<td>Mali</td>
<td>Bovine</td>
<td>present</td>
<td>N/A</td>
<td>OIE (1999)</td>
</tr>
<tr>
<td>Niger</td>
<td>Bovines, Caprines, Ovines, Humans</td>
<td>30.5, 21.2; 2.4, 45.1; 0, 22.2; 0, 1.4</td>
<td>SRL, MRT; SRL, MRT; SRL, MRT; SRL, SRL</td>
<td>Akakpo (1989), Gidel et al. (1974)</td>
</tr>
<tr>
<td>Togo</td>
<td>Bovines</td>
<td>41</td>
<td>SRL</td>
<td>Akakpo (1989)</td>
</tr>
</tbody>
</table>

<sup>1</sup> Burkina Faso: Formerly known as Upper Volta; <sup>2</sup> Test Type: MRT=Milk Ring Test; SRL=Serology; <sup>3</sup> Gidel et al. (1974) Values cited from this reference are based on prevalences in different ecological zone.
<table>
<thead>
<tr>
<th>Disease &amp; Causative Agent</th>
<th>Primary Livestock Production Systems</th>
<th>Transmission/Risk factors</th>
<th>Control/Prevention Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Animals</td>
<td>Humans</td>
<td>Household</td>
</tr>
<tr>
<td><strong>Tuberculosis</strong></td>
<td><em>Mycobacterium bovis</em></td>
<td>cattle</td>
<td>Inhalation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Brucellosis</strong></td>
<td><em>Brucella abortus</em></td>
<td>cattle</td>
<td>Ingestion of contaminated milk, cream, fresh cheese</td>
</tr>
<tr>
<td><em>Brucella melitensis</em></td>
<td>sheep</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Brucella suis</em></td>
<td>goats</td>
<td>pigs</td>
<td>Direct contact with contaminated tissues/products (blood, urine)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Inhalation</td>
</tr>
<tr>
<td><strong>Anthrax</strong></td>
<td><em>Bacillus anthracis</em></td>
<td>cattle</td>
<td>Inhalation or ingestion of spore-laden dust</td>
</tr>
<tr>
<td></td>
<td>sheep</td>
<td>goats</td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
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</tbody>
</table>

31
<table>
<thead>
<tr>
<th>Disease &amp; Causative Agent</th>
<th>Primary Livestock Production Systems</th>
<th>Transmission/Risk factors</th>
<th>Control/Prevention Methods</th>
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<tbody>
<tr>
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<td></td>
<td>Animals</td>
<td>Humans</td>
</tr>
<tr>
<td>Cysticercosis</td>
<td></td>
<td>Consumption of pigs</td>
<td>Ingestion of Taenia-infected human faeces</td>
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<tr>
<td><em>Taenia solium</em></td>
<td></td>
<td>Consumption of under-cooked human faeces</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Consumption of Taenia-infected human faeces</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Consumption of Taenia-infected pig meat</td>
<td></td>
</tr>
<tr>
<td>Campylobacter</td>
<td></td>
<td>Environmental contamination</td>
<td>Consumption of raw or under-cooked meat</td>
</tr>
<tr>
<td><em>Campylobacter jejuni</em></td>
<td>pigs</td>
<td></td>
<td>Consumption of raw milk and contaminated water</td>
</tr>
<tr>
<td><em>Campylobacter coli</em></td>
<td>poultry</td>
<td></td>
<td>Faecal contamination at the time of milking</td>
</tr>
</tbody>
</table>
Figure 1. Life cycle of *Taenia solium*. Solid line: human-pig-human transfer: 1. Chain of proglottids passed in faeces; 2. Proglottids or eggs eaten with faeces; flies harbouring eggs could be eaten by pigs rooting; 3. Metacestodes eaten in raw or undercooked pig. Dashed line, human-human transfer resulting in human cystercerosis: 4. Faeco-oral transfer of eggs by contaminated hands; 5. Contamination of vegetables through use of night soil fertilization; 6. Transfer of eggs from faeces to food. 4-6 result in the accidental oral infection of people not currently infected with the adult tapeworm in addition to the ingestion by children of eggs in contaminated soil. (Lloyd, 1998)
Urban Agriculture and Zoonoses in West Africa: 
An Assessment of the Potential Impact on Public Health 
Part B: Field Research 

Assessment of Bovine Tuberculosis (*Mycobacterium bovis*) and Risk Factors of 
Transmission in the Peri-Urban Centres of Bamenda, Northwest Province (Cameroon)

1. Introduction

Demand for milk products in sub-Saharan Africa increased approximately 2.5% in the 70's and 80's (Walshe et al. in Cosivi et al. 1995). As a result, dairy production in many African countries has been intensified. Dairy systems in the form of small-holder producers and large scale farms are commonly concentrated in peri-urban and urban regions, this is particularly true in East Africa. In the sub-humid regions of West Africa (Gambia, Ghana and Nigeria) Fulani agro-pastoralists supply the majority of milk to urban centres. In Bamako (Mali, West Africa) milk is supplied to the capital by two types of producers: 1. High-input, capital-intensive, large scale dairies using cross-bred and pure bred cattle located in and around the city; and 2. Communal dairies producing milk from herds of local cattle assembled from several owners.

The basic characteristics of intensive animal production in the tropics: exotic breeds, housing, and zero grazing predispose the animals to diseases. A common disease of cattle is bovine tuberculosis, caused by *Mycobacterium bovis*. *M. bovis* is infectious to humans and can pose a serious zoonotic risk (Gallagher and Jenkins 1998). The risk is further increased in immune-suppressed and HIV positive individuals. As a result of the HIV epidemic, the crude incidence rate of human TB in sub-Saharan Africa is expected to increase to 191 cases per 100,000 from 1990 to 293 (per 100,000) presently (Cosivi et al. 1998). Most of human TB infections are due to *M. tuberculosis*. However, information on human disease due to *M. bovis* is scarce. Where African data have been available, approximately 1-5% of isolates from human cases have proved to be *M. bovis*.
Bovine tuberculosis in humans can result in either a respiratory or a gastro-intestinal infection. Herdsmen working with cattle are at high risk of acquiring pulmonary tuberculosis if the animals are infected. For the general population the risk arises from the consumption of untreated infected milk products.

As part of an investigation of zoonotic infections of public health significance in urban and peri-urban livestock production systems in West Africa, a small-scale field study was conducted in the peri-urban towns in the vicinity of Bamenda (Northwest Province) in the highlands of Cameroon. The primary objective of the study was to determine the prevalence of bovine tuberculosis in the peri-urban dairy herds and to identify potential risks to households.

2. Tuberculosis and Dairy Production in Cameroon

Information on cattle tuberculosis in Cameroon is sparse. Data of 2,492 animals tested for TB in the Northwest Province in the mid-80s indicated that 3% of animals on extensive farms and 13% of animals on ranches were infected with tuberculosis (Merlin and Tsangueu 1985). An earlier study (Tanya et al. 1983) in the Adamawa Province indicated a prevalence of TB of 1.4% in local cattle on an experimental livestock station and 2.8% in their dairy cows (Holsteins and their crosses).

Livestock production accounts for 16% of agricultural production in Cameroon. Over 90% of the 4-5 million cattle are found in 4 provinces: the Far North, the North, the Adamawa Plateau and the Northwest Province. Despite the large cattle population, the domestic milk production in Cameroon is in deficit to demand, and the difference is satisfied through imports. Teuscher et al (1992) estimated that imports of milk and milk products at 11480 tonnes. This amount represents about 50% of the adult per capita dairy consumption (estimated at 10 kg./person/year). In order to reduce imports, cross-breeding programmes were established in various regions of Cameroon. In the Northwest Province Heifer Project International (HPI) and the Institute of Agricultural Research and
Development (IRAD) are responsible for these programmes. In and around Bamenda, the capital city of the Northwest Province, Holsteins, Jerseys and their crosses with Red and White Fulani (respectively) and Gudali cows are the main producers of milk for the region.

The presence of higher producing cows (pure-breeds and cross-breeds) in the Bamenda region, has enabled Sotramilk, a modern-type milk processing plant to organize milk collection along the main axes of production. Nonetheless, informal discussions with producers and processors in November 2000 suggest that the manufacture of dairy products from fresh milk alone is still at the early stage. To maintain a constant volume of production, processors blend fresh and reconstituted imported milk.

3. Tuberculosis Testing in Bamenda Highlands Dairy Herds

3.1 Materials & Methods

Field research was conducted in November 2000 with the logistical and administrative assistance of Heifer Project International. HPI provided a sampling frame of all dairy herds within their project. The number of herds sampled to detect disease was calculated according to

\[ n = \frac{Z_{1-α/2}^2 \hat{p} \hat{q}}{L^2} \]

Where:
- \( n \) = number of herds
- \( z \) = confidence level
- \( \hat{p} \) = estimated prevalence of bovine tuberculosis in Cameroon at the herd level based on literature
- \( \hat{q} = 1 - \hat{p} \)
- \( L^2 = \) allowable error

For the purposes of this study \( z = 1.96 \) (95% confidence interval), \( \hat{p} = .15 \), and \( L = .15 \)

Intradermal tuberculin testing is the key diagnostic method of detection of bovine TB in live animals. The basis of tuberculin testing is the induction of a delayed type hypersensitivity reaction
to the intra-dermal introduction of antigenic substances derived from laboratory culture of *Mycobacterium bovis*. The reaction is manifested by erythema and induration of the injection site appearing 8-12 hours post injection and peaking 2-7 days later.

The single cervical tuberculin test was administered in accordance with the Canadian Food Inspection Agency (CFIA) field protocol. One dose of 0.1 ml of bovine Purified Protein Derivative (PPD) was injected into the neck of the bovine and the response was observed, palpated and measured 72 hours later.

A positive case of TB was deemed as any animal where there was an increase in skin thickness of greater than 10 mm, either seen, felt or measured. Tests were read as negative or positive. For those animals that tested positive, HPI was advised to retest animals with a comparative cervical test 60 days after the initial test in order to rule out false positives reactors due to *Mycobacterium avium* or *Mycobacterium paratuberculosis*.

In addition to cervical testing, individual health and demographic data on cows tested were collected from herd records and interviews with the primary animal caretaker. Herdsmen and household heads were interviewed to glean information on household milk consumption (ie. preparation) and the destination of milk in the event of surplus. Households were also surveyed to identify any cases of human tuberculosis.

### 3.2 Statistical Analysis

Data were submitted to a descriptive analysis to identify distribution of variables, and to logistic regression to determine risk factors potentially associated with tuberculosis in animals and herds. The logistic regression was performed using the General Equalizing Equations in Proc Genmod in SAS (Statistical Analysis Systems) in order to adjust the coefficients and standard errors to account for the underdispersion detected at the farm/herd level. Relative risks, associated confidence intervals and probabilities on the relative risks were calculated using DISTRIB programme.
Attributable fractions were calculated according to: 

\[(RR-1)/RR\], where the RR is the relative risk.

4. Results

4.1 Descriptive Analysis

Of the 166 animals in 66 household herds available for testing in the peri-urban towns and villages of Bamenda, 69 animals in 23 herds across 9 villages/towns were tested for bovine TB. Owners of herds within villages and towns were members of local cooperatives or dairy groups. Except for the 2 herds owned and managed by the Sisters of Emmanuel and SAJOCAH Dairy Farm with 20 and 37 animals respectively, all other herds were family run and relatively small ranging from 1 to 7 animals with a mean of 4 animals per herd. Overall, the age of individual animals ranged from 2 to 144 months (mean=41 months; s.d.= 33 months).

Forty-eight percent of the animals were pure breeds, either Holstein or Jerseys. Native breeds, Gudali, Borana and Red and White Fulani cows, constituted approximately 28% of animals within the dairy herds. The remaining 20% were Gudali-Holstein, Fulani-Jersey and Holstein-Borana crosses (Figure 1). As would be expected in dairy production the majority of animals, 73%, were female animals. Overall, at the individual animal level, the prevalence of tuberculosis in the sampled dairy herds was 26%. That is, 26% of all animals read positive for the cervical test (95% CI = 11-41%). However, at the herd level, 56% of all herds tested had at least one animal that tested positive to the tuberculosis test.

Amongst the dairy farmers in the study, three different production systems were common. Of the 23 herds surveyed, 17% of them were ranced (or extensively farmed); 43% were maintained in a semi-intensive system, and 39% were kept intensively (Figure 2). Ranched animals are pastured
and generally not provided with any additional feed. Cows kept under semi-intensive conditions are stalled, but often pastured to supplement feeding. Intensively kept animals are stalled for their entire life and depending on the means of the farmer are fed kitchen waste, crop residues, home grown crops and occasionally purchased concentrate.

Only exotic animals were kept under intensive conditions and comprised 23% and 54% in extensive and semi-intensive systems respectively. Of the 19 crossbred animals, approximately 28% were maintained in an extensive systems and the others were kept semi-intensively (Figure 3).

4.2. Tuberculosis Risk Factors in Dairy Cows

In a univariate analysis, animals greater than 18 months of age were approximately 4 times more likely to test positive for TB than younger cattle (Relative Risk = 3.79; CI = 2.4-5.2); p<0.05). However, after controlling for age in this study of dairy herds, only breed and production systems were significant risk factors for tuberculosis. Of the 18 positive animals, 61% were of exotic breed, 39% were crosses of local breeds and exotic (primarily Holstein and Goudali) animals. Not a single individual of native breeds reacted to the cervical test.

The prevalence of TB-positive animals was approximately 31% in the extensive systems and 23% under both the semi-intensive and intensive conditions (Table 1). Breeds behaved differently within production systems. Under both management systems under which local breeds were maintained, extensive and semi-intensive, not a single of these individuals tested positive to the cervical test. The prevalence of TB positivity in exotics ranged between 23.5% in intensive systems up to 35.7% in semi-intensive systems. The highest prevalence (60%) was detected in hybrid animals under extensive conditions (Table 1). The prevalence of TB-positive tests in crossbred animals was lowest in the semi-intensive systems (11%).

Being of a local breed was clearly a protective factor with respect to tuberculosis. Compared to local breeds in an extensive system, hybrids were almost 12 times more likely to test positive
Ninety one percent of the positive test results are attributable to being exotic hybrid under an extensive system (Table 2). Within the same production systems a similar trend appeared in the exotic group. Imported breeds were 7 times more likely (.624-112.9) to test positive than their local counterparts (p=.1428). The risk of TB in exotic animals kept under intensive production and exotics under an extensive system appeared to be the same (RR= 1.6; CI = .500-5.24; p=.5198). Although not statistically significant (p=.2560), exotic animals in intensive systems were 5 times more likely (CI = (.519-73.6) to be positive on a cervical test than local animals kept under extensive management. Similarly, exotic cows under semi-intensive housing had a 7.3 times greater risk (CI = .811-102.2;p=.0960) of testing positive for TB compared to local breeds managed extensively. Crossbred animals in extensive systems were close to 4 times at greater risk (CI=.957-19.4;p=.0600) of testing positive than hybrids maintained in semi-intensive conditions.

4.3. Household Dairy Processing

The majority of households (67%) consumed the milk and sold a certain proportion to the processing plant, Sotramilk. Except for the Sisters of Emmanuel, none of the other producers had the means to store milk (refrigeration). Therefore, milk from the evening milking would be consumed by household members and the morning milk would be sold to Sotramilk. Eleven percent of households, in addition to consuming their own milk, and selling to Sotramilk also sold/gave it away to their neighbours. One dairy farm, that of the Sisters of Emmanuel was distinctive from the other farmers. In addition to production of milk, the sisters processed the raw milk into pasteurized milk, cheese and yoghurt and marketed the products.

Eighty-eight percent of households indicated that they boiled the milk before drinking it and 11% either boiled it or consumed it raw or fermented. Not a single case of human tuberculosis was identified among the households surveyed.
5. Discussion

In light of the intensification of dairy production in urban/peri-urban regions of the tropics and the resurgence in the incidence of tuberculosis in humans, particularly in immunocompromised humans, there is a renewed interest in the zoonotic importance of \textit{M. bovis}. The aim of this investigation was to identify risk factors potentially linked to transmission or infection of \textit{M. bovis} to humans in the Bamenda region of Northwest Cameroon. The prevalence of reactors to the cervical test suggest that 26\% of animals are infected. However, tuberculous cattle go through a period of desensitization before and after calving and as many as 30\% give false negative reactions returning to a positive status 4-6 weeks later (Radostits 2000). In this survey, only one cow had given birth within 2 months prior to the survey, and she tested positive for TB.

Data from this study indicated that breed and production systems are significantly associated with a positive cervical test. Although cattle of all ages are susceptible to TB, the probability of becoming infected generally increases with age as the time exposed increases. An analysis of meat inspection and tuberculin testing reports from Great Britain showed that on average the incidence of TB in cattle increased uniformly by 7.5\% for every year of life, reaching 40\% at 5-6 years old. Calves which are exposed to cows are exposed to constant risk of infection by the aerogenous route, but when calves are not housed with cows about 90\% of them reach maturity (2 years) without being infected. In cattle grazing in the open range or in feral cattle, the prevalence of tuberculosis is about 1-5\%, whereas in dairy cows the rate of infection range from 25-50\%. This difference is attributable to the difference in housing, with dairy cows housed or penned in small paddocks and their longer average life span (O’Reilly and Daborn 1995).

Native breeds were the least likely to test positive for TB in this study. There is some
evidence that the East African Zebu (*Bos indicus*) cattle are more resistant to tuberculosis than European breeds. Experimental and epidemiological studies in East Africa showed the short-horned, humped zebu cattle to be more resistant to bovine TB than the local ankole cattle, or any of the European breeds. Meat inspection figures on ankole and zebu cattle kept under similar conditions in Uganda were 16% and 0.93% respectively and on tuberculin testing 54.9% and 4.6% respectively (O’Reilly and Daborn 1995). Similarly, the zebu-type White and Red Fulani, and Gudali of West Africa may have an adapted tolerance to infection.

Unlike most pastured dairy systems, data from this survey indicated that extensive production systems had the highest prevalence of TB-positive animals. Generally, intensive livestock systems facilitate close contact between animals and favour the transmission of respiratory diseases, including tuberculosis (Wagner 1993). However, even under extensive pastoral conditions, husbandry factors such as congregation at watering points or gathering together of animals in enclosures overnight may lead to increased spread of infection, and individual herds with high prevalences may be encountered (Radostits 2000). Nonetheless, since all the positive tests were from exotic and exotic hybrids, and the relative risks of testing positive to TB did not differ significantly between the 2 breed types (exotics and hybrids), it is possible that these animals, particularly in extensive systems where the environmental stresses are greater, are more susceptible to TB under the tropical conditions compared to local breeds. This was evidenced by the fact that hybrids in extensive systems were almost 4 times more likely than their counterparts in semi-intensive systems of testing positive to TB (CI=.957-19.4; p=.0600). Constant exposure to the external environment also increases the probability of contact and infection with *Mycobacterium avium*. Infection with this agent would also give rise to a positive test.

Overall only hybrid animals were at a significantly greater risk of testing positive for TB (compared to local breeds). From a biological perspective we would expect to observe exotic animals
equally, if not more susceptible than hybrid cows. The high relative risks and wide confidence intervals for exotic animals in intensive systems compared to locals in extensive systems and exotics in semi-intensive systems also compared to locals is indicative that the sample size may not have been large enough to demonstrate a significant statistical difference between the breeds and systems. To assess whether the original sample size was too small to identify significant differences, the power* for the present data was determined. The power was less than 50%, suggesting that given larger sample sizes, the true differences would have been detected.

6. Herd Immunity

The ability of groups of animals to resist becoming infected or to minimize the extent of infection (i.e., the number and/or the severity of cases) is referred to as herd immunity (Martin et al. 1987). The ability of an animal to resist infection may be either innate (genetic origin) or acquired (e.g., active or passive immunity as a result of previous contact with an infectious agent). Transmission of the infectious agent depends on the susceptibility of individual animals as well as the rate of contact between members of the population. Local breeds, with their apparent resistance to infection with tuberculosis may actually serve to minimize the transmission of TB amongst other members of a mixed-breed herd.

7. Transmission of M. bovis to Humans

The risk of transmission of *M. bovis* to humans through the consumption of contaminated milk and eventual establishment of infection depends on the right permutation of numerous factors: 1. *M. bovis* must be present in the udder of the cow at time of milking. This occurs only when the disease is at an advanced stage and has disseminated throughout the animals body. However, this is probably

*Power= the probability of rejecting the null hypothesis when it is false*
a rare occurrence even where tuberculosis is still present. At a time when tuberculosis was prevalent in European dairy cows, only 1% of udders of slaughtered tuberculous animals had visceral lesions (O’Reilly and Daborn 1995). (Tuberculous human milkers can transmit the disease to cows through handling). 2. Treatment (pasteurization, boiling, fermenting,) through a commercial system or at home, affects the bacterial composition of the milk product. Therefore, improper or complete absence of processing commercially and domestically increases the probability of transmission; 3. Infection is dependant on the dose of *M. bovis* bacteria being shed by the animal (generally a large inoculum is required to establish infection (O’Reilly and Daborn 1995) and a smaller infecting dose of tubercle bacilli often results in a protective immunity). This in turn rests upon a variety of physiological conditions in the animal, and finally; 4. The establishment of infection in the consumers depends on their immune status.

In the Bamenda region, over 50% of the herds had at least one positive animal in the herd. Therefore over half of the households owning dairy cows have at least one infected animals that could potentially contaminate the pooled milk of the herd. However, the majority of respondents indicated that milk was boiled before consumption. As long as the milk is boiled and not just warmed, the risk of transmission of *M. bovis* (via milk consumption) to household members is reduced. The practice of blending fresh and reconstituted milk at the processing plant may decrease the risk of contamination further, unless pasteurization of the fresh milk is inadequate.

Undoubtedly, exotic animals and their hybrids are at the highest risk of being infected and in turn infecting others of the same breeds. In general, exotic dairy cows are often more susceptible to disease and environmental vicissitudes in tropical climes than the more rigorous indigenous breeds. Furthermore, their nutritional requirements and greater need for water increase their susceptibility when management practices are not adequate. Although crossbreeds appeared to be equally susceptible to TB under extensive condition as the exotic breeds, the data indicated that housing them
in a shed/barn and intermittently pasturing them may decrease the risk of their becoming infected with a *Mycobacterium* species. Though not as high producing as exotic animals (assuming proper management), in the Bamenda Highlands of Cameroon, crossbreed animals under controlled housing may be a more prudent investment given their possible greater resistance to a debilitating and fatal disease.

**Part B. Tables and Figures**

**Table 1. Comparison of Prevalence of Bovine TB**

<table>
<thead>
<tr>
<th></th>
<th>Extensive</th>
<th>Semi-Intensive</th>
<th>Intensive</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exotics</strong></td>
<td>33.3 (6.3 - 72.9)</td>
<td>35.7 (15.3 - 62.9)</td>
<td>23.5 (8.4 - 48.8)</td>
</tr>
<tr>
<td><strong>Locals</strong></td>
<td>0 (0 - 25.9)</td>
<td>0 (0 - 63.1)</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Crosses</strong></td>
<td>60.0 (26.2 - 87.8)</td>
<td>11.1 (.05 - 44.3)</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>30.7 (15.4 - 50.5)</td>
<td>10.5 (42.2)</td>
<td>23.5 (8.5 - 48.8)</td>
</tr>
</tbody>
</table>

1. As determined by the cervical test
2. Numbers in brackets indicate confidence interval (%) on the prevalence point estimate
3. n/a = no animals in these systems
### Table 2. Relative Risks of Tuberculosis between Breeds and Production Systems

**Comparison of Relative Risks within and between Breeds and Productions Systems**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Relative Risk (CI)</th>
<th>p-value</th>
<th>Attributable %</th>
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</thead>
<tbody>
<tr>
<td><strong>Extensive System</strong></td>
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</tr>
<tr>
<td>Exotic vs Local</td>
<td>6.9 (.624 - 112.9)</td>
<td>.1428</td>
<td>85.4</td>
</tr>
<tr>
<td>Crosses vs Exotics</td>
<td>1.7 (.588 - 5.5)</td>
<td>.4505</td>
<td>40.4</td>
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<tr>
<td>Crosses vs Local</td>
<td><strong>11.9</strong> (1.4 - 154.4)</td>
<td><strong>.0119</strong></td>
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<tr>
<td><strong>Semi-Intensive System</strong></td>
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<tr>
<td>Exotic vs Local</td>
<td>2.8 (.373 - 36.6)</td>
<td>.6258</td>
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<tr>
<td>Exotic vs Crosses</td>
<td>2.4 (.548 - 13.0)</td>
<td>.3280</td>
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<td>Crosses vs Local</td>
<td>1.2 (.084 - 22.0)</td>
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<td><em><em>Intensive</em> vs Extensive</em>*</td>
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<td>Exotics vs Exotics</td>
<td>1.6 (.500 - 5.24)</td>
<td>.5198</td>
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<td>Exotics vs Locals</td>
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<td><strong>.0770</strong></td>
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<tr>
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<td>.4900</td>
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<td>.9221</td>
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<td>Exotics vs Cross Breeds</td>
<td>1.7 (.345 - 9.47)</td>
<td>.6738</td>
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<td>Exotics vs Exotics</td>
<td>1.0 (.329 - 3.74)</td>
<td>.8903</td>
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<td>Exotics vs Locals</td>
<td><strong>7.3</strong> (.811 - 102.2)</td>
<td><strong>.0960</strong></td>
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<td>Extensive Systems</td>
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<tr>
<td>Exotic vs Crosses</td>
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<td>.3746</td>
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<td>Crosses vs Locals</td>
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<td>.5341</td>
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<tr>
<td>Crosses vs Crosses(^1)</td>
<td><strong>3.9</strong> (.957 - 19.4)</td>
<td><strong>.0600</strong></td>
<td><strong>74.3</strong></td>
</tr>
</tbody>
</table>

*All animals maintained intensively are exotic breeds

\(^1\)Crosses in extensive systems vs. crosses in semi-intensive systems
Figures 1 - 3

Figure 1. Breeds of Dairy Cows

Figure 2. Production Systems in Study

Figure 3. Proportion of Breed Types in Production Systems
References


Medina, M. T.; Rosas E.; Rubiodonnadieu F.; Sotelo J. 1990. Neurocysticercosis as the main cause of late onset epilepsy in Mexico. Archives of Internal Medicine, 150, 325-327.


Moda, G; Daborn, D.J.; Grange, J.M.; Cosivi, O. 1996. The zoonotic importance of Mycobacterium bovis. Tubercle and Lung Disease, 77, 103-108.


Glossary

Anthrax  a bacterial disease caused by the organism *Bacillus anthracis*

Brucellosis  a generalized infection of humans involving the reticuloendothelial system, caused by a species of *Brucella* derived from contact with goats, cattle, and pigs

Cysticercosis  in humans it is an infection with the larval forms (*Cysticercus cellulosae*) of *Taenia solium*, which penetrate the intestinal wall and invade tissues of the brain, eye, muscle, heart, liver, lung, and peritoneum. Brain involvement may result in epilepsy

Enteritis  inflammation of the intestine, particularly the small intestine

Enzootic  present in an animal community, but occurring in only small numbers of cases

Epidemiology  the study and distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problems

*Escherichia coli*  a species of coliform bacteria normally present in the intestinal tract of humans and other animals, and common in water, soil and food; it can be pathogenic, causing urinary-tract infections, food poisoning and septicaemia.

Etiology  the cause(s) or origin of a disease

Haemorrhagic exudate  fluid, cells, or cellular debris, in this case mixed with blood, which has escaped from blood vessels and has been deposited in tissues or on tissue surfaces, usually as a result of inflammation

Obligate pathogen  characterized by the ability to survive only in a disease- producing role

Pathogenic  giving origin to disease or morbid symptoms

Saprophyte  any organism living upon dead or decaying organic matter

Septicaemia  systemic disease associated with the presence of pathogenic microorganisms or their toxins in the blood; also known as blood poisoning

Toxoplasmosis  a protozoan disease of humans caused by *Toxoplasma gondii* and is characterized by lesions of the central nervous system

Tuberculosis  an infectious disease of man and animals caused by species of
Mycobacterium and characterized by the formation of tubercules and caseous necrosis in the tissues

Urban Agriculture: the growing of plants and raising of animals for food and other uses; processing and marketing of resultant products within urban and at the periphery (peri-urban) of cities

Zoonoses: diseases of animals that may be transmitted to humans (and vice versa) under natural conditions