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Brucellosis in West and Central Africa: A review of the current situation in a changing landscape of dairy cattle systems

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Abstract

Brucellosis is a neglected endemic zoonosis in West and Central Africa. In this narrative review, evidence of livestock and human infection is presented along with details of past and current control strategies in 14 selected countries. Data from available literature is combined with expert opinion elicited during a regional workshop on brucellosis diagnostics. Demographic changes that affect both the epidemiology of brucellosis and the success of control or surveillance are also considered. The evidence suggests that brucellosis prevalence in emerging peri-urban dairy cattle systems may be higher than that found in traditional transhumant extensive systems. Accurate microbiological and epidemiological evidence across the region is lacking but it appears there is inherent interest in controlling the disease. There are many data gaps which require collaborative future research to evaluate fully the social and economic impact of the disease in an evolving livestock sector heavily influenced by high rates of urbanisation and regional population growth.

1. Introduction

The dairy sector in West and Central Africa is evolving. Demand for dairy products is growing and consumer preferences and behaviours are changing; in order to capitalise on the opportunities, the sector must adapt and develop. The growth of the dairy industry in the region is undoubtedly positive in terms of increased nutrition and diversity in the diets of consumers, as a driving force for poverty alleviation amongst farmers and as an avenue for national and regional economic growth (Mathias and Mundy, 2010). However, this burgeoning demand is not without inherent risks in terms of the spread of zoonotic diseases and exposure to food borne pathogens. Of these risks, brucellosis is perhaps one of the most significant threats due to the potential impact on both human health and animal health and productivity (Moreno, 2014).

Brucellosis is a zoonotic disease caused by gram negative coccobacilli bacteria belonging to the *Brucella* genus. Four of the eleven *Brucella* species are recognised human zoonoses, these being *B. abortus, B. melitensis, B. suis and B. canis* (Corbel, 2006). As one of the world's most widespread zoonosis, brucellosis is responsible for a vast global burden imposed on poor people through disease, disability and impaired livestock productivity (J. McDermott et al., 2013; WHO, 2005). However, brucellosis is rarely prioritized by decision makers within health systems and the World Health Organisation (WHO) includes it as one of its seven neglected endemic zoonoses (WHO, 2005). In humans, brucellosis causes flu-like symptoms and chronic debilitating illness. It often manifests as recurrent bouts of fever, which can be misdiagnosed as drug-resistant malaria and lead to underestimation of its incidence (Chabasse et al., 1983). The main routes for human infection are consumption of contaminated dairy products and contact with infected ruminants (Charters, 1980). In livestock, brucellosis decreases productivity by causing abortions, reducing fertility and decreasing milk yield (Corbel, 1988). In many western European countries, elimination of *B. abortus* in cattle has been achieved by stringent test and slaughter regimes and continued surveillance such as those practiced in the UK leading to 'brucellosis free' status being granted in the 1980's (Young and Corbel, 1989). In other areas, reduced human incidence has come through pasteurization of dairy products alongside mass livestock vaccination programmes.

Globally, WHO reported foodborne disability-adjusted life years (DALYs) due to brucellosis to be 124,884 (95% C.I. 43,153 - 2,910,416) in 2010, acknowledging that in resource-scarce settings at least as many DALYs could be due to the non-foodborne route (WHO, 2015). However, the estimation of the DALYs for brucellosis is criticised due to under reporting of the non-specific symptoms often associated with *Brucella* infection in humans. As a neglected endemic zoonosis, accurate epidemiological data are often scarce; consequently meaningful estimates of the economic and/or social burden are mostly unavailable. Across the African continent, while there are examples of research studies investigating the prevalence of brucellosis (Akakpo and Bornarel, 1987; Ducrotoy et al., 2015; J. J. McDermott et al., 2013), there is very limited if any consistent surveillance data in humans, domestic or wild animals. The limited available literature mostly considers seroprevalence and often lacks evidence of epidemiological rigour in the study design and presentation of results. Spread widely over time and geographical landscapes, the literature does not offer a full interpretation of the specific epidemiology of brucellosis across the continent, which it seems, may differ considerably to other continents. Of the four zoonotic *Brucella* species, *B. melitensis* and *B. abortus* are globally considered the predominant species of importance due to the impact on human health and animal productivity. Generally, *B. abortus* is associated with cattle while *B. melitensis* is associated with small ruminants and a higher pathogenicity in humans (Young and Corbel, 1989). Despite the host predilection of the *Brucella* species, there is evidence of cross infectivity as shown by infection of sheep with *B. abortus* in the absence of *B. melitensis* (Allsup, 1969; Luchsinger and Anderson, 1979; Shaw, 1976). This may be relevant in the case of sub Saharan Africa where little evidence of *B. melitensis* has been found and mixed farming systems are common. More work is needed however, to establish the epidemiological situation before using these assumptions to inform control policy decisions. To date, the limited number of studies isolating bacterial species have given preference to sampling cattle rather than small ruminants or humans (Akakpo and Bornarel, 1987; Domenech et al., 1982; Pilo-Moron et al., 1979; Sacquet, 1955).

The West African region spans an area of approximately 5 million square kilometres with diverse geographical and cultural characteristics. It has many disparities in food requirements and production (Dixon et al., 2001). Migration of people, livestock and wildlife across the region has long been commonplace. Many initiatives have been established at various times to combine forces politically and economically in order to take advantage of economies of scale and the opportunities the diversity of states brings. Initiatives such as the Economic Community of West African States (ECOWAS) Regional Agricultural Policy (ECOWAP) and the Comprehensive Africa Agriculture Development Programme (CAADP) over the past decade have shown the renewed interest and emphasis on the role and importance agriculture has on the economic development and growth of the region. While there have undoubtedly been many benefits and positive outcomes of such initiatives there are unsurprisingly varying levels of success in different member states. In many instances priority setting is affected by food crisis such as those seen after the financial crash in 2008 or following numerous civil wars and unrest in many countries.

Economies of scale are important when the region's dairy industry faces fierce international competition from imports of dried milk powder from Europe. Such regional cooperation can facilitate procurement of vaccines, medicines and diagnostic capacity for diseases that reduce productivity and pose risks to human health. In conjunction with animal health policy and interventions, market strengthening in terms of improved logistics, processing and distribution are key to putting regional production on a more even playing field with cheap imports of milk powder into the region (Ndamb et al., 2007).

The predominant driver for an increase in demand for dairy products is population growth. Levels of population growth are amongst the highest in Africa and specifically in the West African region where the population has more than doubled over the last thirty years, growing by 2.7% annually with a projection of 736 million people by 2050 (UNDESA, 2015). In conjunction with population growth, urbanisation and changes in consumer preference have a big influence on overall demand for dairy products and types of products purchased. Urbanisation is also transforming where and how products are bought. Urbanisation rates in West Africa are rapid even when compared to other African regions.

In many countries, the burgeoning dairy potential is recognised and there have been various attempts to capitalise on it. Many governments in countries such as Senegal and Ivory Coast have implemented breed enhancement programmes often utilising imported European breeds with higher milk yields since 1990-2000. These programmes often see limited success due to disease susceptibility amongst such breeds. Concurrently, there has been an increase in commercial closed dairy farms utilising modern dairy milking machines and housing onsite processing plants. Such processing plants have also had limited success due to the inability to produce adequate quantities of milk from single herds and the difficulties in forming milk co-operatives due to poor cold chain and transport logistics.

There is serological evidence of widespread brucellosis infection of cattle in the West and Central African region (Akakpo and Ndour, 2013). There is consistent correlation between abortion levels and seropositive herds as well as carpal hygroma being a quasi-pathognomonic sign of brucellosis in cattle (Domenech et al., 1980). Hygromas are often considered the main symptom of brucellosis in cattle besides abortion in sub-Saharan Africa (SSA) as cattle are often kept within a herd for the entirety of their natural lives allowing for persistence of chronically infected animals. In central Africa a linear correlation between abortion rate and carpal hygroma prevalence has been shown; it has been suggested this can be used as a proxy to establish whether a brucellosis control programme is necessary when other diagnostic methods are not available (Domenech et al., 1982, 1980) .

To date there is no published review of West Africa collating brucellosis data in animals and people for the region and the magnitude of the disease burden is unclear. Without such baseline data it is impossible to conduct epidemiological and economic assessments on mitigation strategies (Rushton et al., 1999) for brucellosis and/or for policy makers to make informed decisions on disease management (Mclnerney, 1996). Therefore, in this review, we aimed to present currently available data and information on the brucellosis situation and a description of key demographic drivers in 14 francophone West and Central African countries, namely Benin, Burkina Faso, Cameroon, Central African Republic, Côte d'Ivoire, Gabon, Ghana, Mali, Mauritania, Niger, Rwanda, Senegal, Chad & Togo.

The objectives were to 1) collate data on prevalence of brucellosis in cattle, humans and small ruminants; 2) provide an overview of existing control strategies and policies; and 3) describe the demographic evolution of human and cattle populations and the impact this has on the dairy sector structure now and in the future.

2. Methods

2.1 Overview

A narrative literature review, a method suitable to illustrate current knowledge and gaps on a topic where scarce evidence exists (Baumeister and Leary, 1997), was conducted by integrating data from open source population statistics databases and scientific literature. Moreover, expert opinion was collated to complement the secondary data available.

2.2 Literature search and review

2.2.1 Literature search

Three scientific databases (Google scholar, Pubmed, Science direct) were searched for relevant articles using the following search terms: (brucellosis OR brucella OR dairy zoonosis) AND (Africa OR West Africa OR Central Africa OR *individual country names*), with a publication limitation of 1950 to the 30 June 2016. The searches were conducted in both French and English. All databases were searched using title and abstract search. Duplicate entries were identified and removed before selection of articles was begun.

2.2.2 Selection process

The articles were sorted by two reviewers with a combined fluency in English and French.

All reports were classified into one of two categories, based on their abstracts: Category 1: Relevant – articles related to human/cattle or small ruminant brucellosis in relation to brucellosis infection in populations (i.e. disease frequency) or articles related to diagnostic capacity or disease control methods; Category 2: Irrelevant - articles related to non-brucellosis dairy zoonosis; articles addressing topics not related to the current review, such as genetics or experimental laboratory animal studies.

The abstracts of papers belonging to Category 1 and meeting the following criteria were retained: published between 1950 and 30 June 2016, prevalence or incidence data included, and containing information relating to diagnostic tests, *Brucella* species isolation results or evaluation of social or economic impact of disease in livestock or human populations.

The selected papers were reviewed in full by both reviewers and information on study area, study population, seroprevalence estimates and bacterial isolation as well as diagnostic tests utilised and discussion of control methods or surveillance were tabulated.

2.3 Collection of expert opinion

Expert opinion was elicited in order to supplement the scientific literature. A regional workshop by a joint research project established between the Royal Veterinary College (RVC) the Ecole Inter-Etats des Sciences et Médecine Vétérinaires de Dakar (EISMV), London School of Hygiene and Tropical Medicine (LSHTM), Animal and Plant Health Agency (APHA) and GALVMED, under the Zoonosis in Emerging Livestock Systems (ZELS) initiative was run in Dakar in June 2015. In attendance were 28 participants from 14 countries with the majority of those invited working in teaching, government or diagnostic institutions (see appendix 1 for list of delegates' countries and institutions). A snowballing sampling of experts was conducted to identify participants through the alumni and contact network of EISMV. During the workshop, delegates were divided into three groups of 9-10 people. Semi-structured group interviews were carried out with each group covering three main topics; namely 1) Current knowledge of brucellosis situation and its impact; 2) Brucellosis control programmes; and 3) Brucellosis diagnostic capacity (see Appendix/supplementary materials for the question guide).

Free discussion in French was encouraged by a facilitator who took notes. At the end of the discussion, participants were given questionnaires to fill in to summarise their opinion on the topic that had been discussed (see appendix 2/3/4 for questions). Data were analysed by means of collating, translating and tabulating questionnaire responses and coding of discussion notes to highlight common themes and opinions on the topics discussed.

2.4 Extraction of information from databases

Data on livestock parameters were obtained from the FAOSTAT database (FAO, n.d.). Human demographic data were obtained through the open source Health Nutrition and Population Statistics database of the World Bank for each of the countries. Data sets were downloaded in excel format, relevant data was extrapolated to formulate graphical representations concerning trends in populations and dairy production.

3. Results

3.1 Literature review

A total of 68 publications, chapters or theses were included in the review. Of these 48 were written in French and 20 in English. They spanned from the 1950s to 2015, with only three studies being carried out within the last five years. As data was relatively limited older pieces were not excluded and as such included two publications from the 1950's, one from the 1960's, seven from the 1970's, 21 from the 1980's, five from the 1990's and 17 from the 2000's.

3.2 Brucellosis Impact

3.2.1 General overview

Tables 1 and 2 show the literature findings in cattle and human populations. A more detailed summary of individual countries can be found in the supplementary material (appendix 5). The highest number of publications was from Ivory Coast, Mali, Niger and Senegal with a large proportion dating back over two decades ago. Across all 14 countries, there were numerous national surveys in the 1970's and 80's, in contrast more recent studies tend to concentrate on particular geographic areas. On occasion, it appears there are conflicting findings in the same areas such as in Benin and Burkina Faso, however in the case of Burkina Faso there were long time gaps between studies and they may not be directly comparable (Table 1). Only few papers were found that outline in full the farming systems within the studies. Seroprevalence estimates ranged from 0% to 55.2% ±11.9%. Numerous high seroprevalence estimates were reported in peri-urban areas of Burkina Faso, extensive systems in Cameroon, Chad, Niger and Togo in the late 1970's and early 80's. The recent highest seroprevalence estimate was reported for peri-urban farms around Dakar in Senegal 2012 (Table 1).

Ten of the 14 countries had literature on studies in humans (Table 2). Most of the studies were carried out in at risk groups such as farmers or abattoir workers or those presenting at health facilities with fever or abortions. There was no evidence of seropositivity in a none-exposed group in Benin or in any groups of a small sample of 77 people in a study in Ghana.

A lack of agreement in results was identified between the Rose Bengal and ELISA techniques in Benin, Cameroon and Chad (Table 1).

In many cases, a situation of low individual seroprevalence and moderate to high herd seroprevalence is reported (Akakpo, 1987; McDermott and Arimi, 2002) suggesting a state of endemicity with relatively low transmission rates. Factors such as low reproductive rates as well as environmental conditions of transhumant herds moving in dry and hot conditions have been hypothesised as explanations for

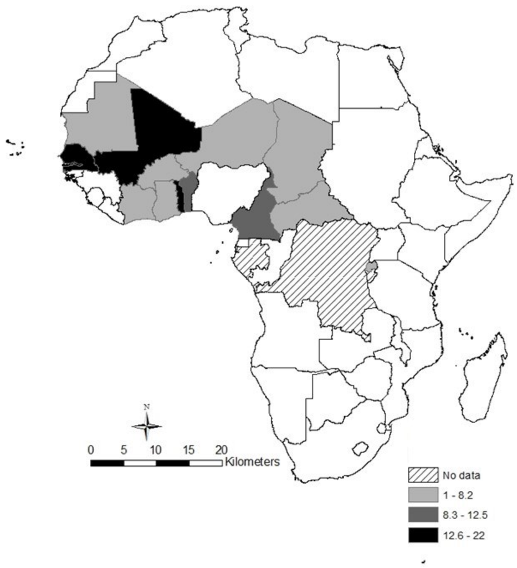

Figure 1 Literature estimates of cattle herd seroprevalence for Brucella spp.in West and Central Africa

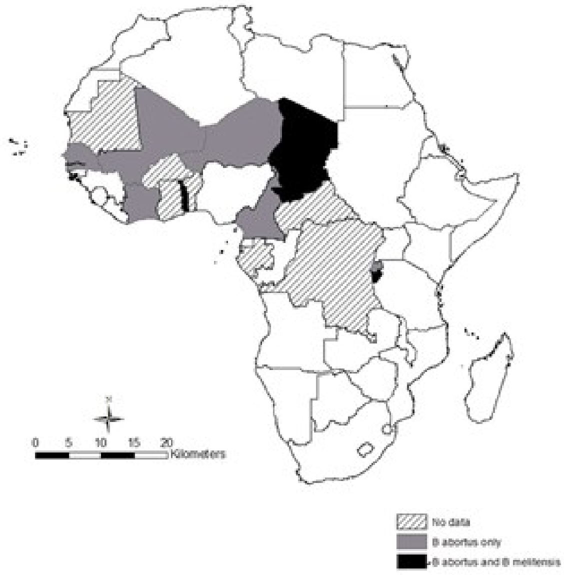

Figure 2 Brucella isolates in West and Central Africa listed in literature from 1955 to 2011.

the low transmission rates (Ducrotoy et al., 2015). These findings however are in sharp contrast to recent studies in peri-urban farming systems (Mugizi et al., 2015; Tialla et al., 2014), where reports of both high individual and herd seroprevalence estimates suggest a different epidemiological picture to that outlined above. These farming systems are often more intensive with little transhumance which may account for the more favourable transmission conditions and therefore a greater burden of brucellosis in these emerging farming systems. In personal communication with an author of the study in Senegal it was noted that the affected farms are 'renewed by transhumant animals especially the males but the females remained within the herd for extended periods, sometimes up to 10 years. In some farms visited, there are females with hygromas. After, our visit, most of the farmers slaughtered positive animals.' In a report in 2012 by the International Livestock Research Institute (ILRI, 2012), they highlighted a higher risk of brucellosis in intensive systems and list Togo, Mali, Ivory Coast, Niger, Cameroon and Burundi amongst the top hot spots for the disease globally.

These findings contradict those found in a review in East Africa (Njeru et al., 2016), where a lower seroprevalence in large urban centres such as Nairobi was noted in comparison to extensive pastoralist systems. There are numerous things to consider when hypothesising the reasons behind these differing findings, perhaps different climate, production systems or the mixing of extensively managed herds with a plethora of wildlife in East Africa which is far less common in West Africa.

Table 1 Country demographics and literature findings for brucella spp. in cattle in West and Central Africa

Year	Sampling	Diagnostic Test	Outcome *Brucella spp* prevalence/species isolation *(plus confidence intervals or standard errors where given)*	Area / system /subpopulation sampled and additional findings	Reference
BENIN: 114.8 thousand Sq.km, neighbouring Nigeria on the southern coast of the region. 10.88 million people; urban growth rate 3.6%, 2.2 m cattle, of which 12% dairy cattle					
1980-81	Non-probabilistic	TFC, TRB	10.4% ± 1.97%	National survey. Traditional farming	(Akakpo A.J., Bornarel P., 1984)
2001	Risk based, probabilistic	TRB	6.2% ± 1.8%	Bétécoucou, Kpinnou, Okpara and Samiondji (southern half of the country)	(Koutinhouin et al., 2003)
		ELISA	15.2% ± 2.6%		
2000-03	Specific population, all tested	TFC, iELISA, TRB	1.91% ± 0.25%	State farms of Okpara, Bétécoucou and Samiondji	(Adehan et al., 2003)
BURKINA FASO: A medium sized land locked country in the middle of the region, having five direct land borders with other countries it is well positioned for regional trade. 18.11 million people; urban growth rate 5.7%, 9 m cattle, of which 15% dairy cattle					
1970-73	Non-probabilistic	SAW, TFC	8.1% ± 3.3%	Gaoua and Markoye	(Gidel et al., 1974)
		RT	11.5% ± 1.7%	Banfora, Dori	
1981-82	Unknown	TRB, TFC	12.3% ± 1.8%	7 regions out of 11, traditional farming	(Bessin, 1982)
		TRB, TFC	55.2% ±11.9%	Ouagadougou, urban area	
2001-02	Non-probabilistic	TRB	13.1% ± 3.9%	Hamdallaye borough of Ouagadougou. Potential risk factors: concentration of animals and manure accumulation near household	(Traore et al., 2004)
2004-05	Unknown	TRB, iELISA	8.2% ± 2.8%.	Rural extensive — Dairy farm survey in and around Bobo-Dioulasso	(Boussini et al., 2012)
			8.1% ± 2.9%.	Intra-urban extensive	
			0.31% ± 0.35%	(Semi-) intensive	

2012	Probabilistic	TRB and iELISA	7.3% (95% C.I. 3.5%-14.7%)	Transhumant herds from Burkina Faso in the Northern Savannah region of Togo	(Dean et al., 2013)
Cameroon: Cameroon has a relatively large land mass bordering Nigeria with a small coastal border within Central Africa. 23.34 million people; urban growth rate 3.5%, 6 m cattle, of which 5% dairy cattle					
1976-80	Unknown	TRB	30.8% ± 1.0 %	Breeding females in extensive farming systems (sedentary and transhumant)	(Domenech et al., 1982)
1980	Unknown	TFC, TRB	22.2% ± 6.3%	Region of Diamaré	(Akakpo, 1987)
			19.7% ± 4.5%	Region of Bénoué	
			4.8% ± 1.9%	Region of Adamaoua	
			12.5% ± 2.1%	National survey	
2002-03	Non-probabilistic	iELISA	9.64%	Abattoir of Dschang (West Cameroon)	(Shey-Njila et al., 2005)
		TRB	4.88%		
2009	Unknown	iELISA	8.4% *No CI given*	21 villages in Cameroon, Holstein cattle	(Bayemi et al., 2009)
2015	Unknown	iELISA	5.2% *No CI given*	North-West region of Cameroon	(Bayemi et al., 2015)
Central African Republic: Central African Republic (CAR) is a sizeable landlocked country in Central Africa bordering Cameroon on its westerly side. Despite its size, the total population in 2015 was only 4.9 million. Civil war and displacement in the country have hindered development and consequently CAR ranks as one of the world's top 10 most poor countries. urban growth rate 2.7%, 4.35 m cattle, of which 5% dairy cattle					
2004	Unknown	TRB	3.3%		(Nakoun, 2004)
Chad: Chad is one of the large inland countries of central Africa, neighbouring Niger, CAR and Cameroon. 14 million people; urban growth rate 3.8%, 8 m cattle, of which 10% dairy cattle					
1955	Unknown		*B.abortus* isolated from infected cattle		(Sacquet, 1955)
		SAW	12%.	National Survey Regional variations: from 7.4% in Fianga to 23.8% in Massakori	
1976-80	Unknown	TRB	31.9% ± 1.1 %	Breeding females in extensive farming (sedentary and transhumant) Prevalence of clinical signs in females 13% (abortion, hygroma or arthritis)	(Domenech et al., 1982)
			B. abortus biotypes 3, 6 and intermediate 3/6 isolated from cattle samples.		
1999-2000	Non-probabilistic	TRB	7.3 % [0.9-17.0]	Chari-Baguirmi and Kanem regions	(Schelling et al., 2004)

2000	Probabilistic	TRB, TFC	2.6% ± 1.2%	Sedentary herds in Abéché peri-urban area, producing milk for local market.	(Delafosse et al., 2002)
2008-09	Unknown		7%	National level reported in OIE questionnaire	(Akakpo et al., 2009)
2014	Unknown	TRB	5.7% (95% C.I.: 3.8-7.6%)	South-eastern shore of Chad (only the islands, not the mainland)	(Abakar et al., 2014)
		iELISA	11.9% (95% C.I.: 9.3%-14.6%)		
Gabon: Gabon is one of the smaller countries included in the study, the majority of this population are urban dwellers (almost 90%). Gabon is the most southerly of the countries and has a substantial coastal border. 1.73 million people; urban growth rate 2.5%, 38 thousand cattle, of which 30% dairy cattle.					
Ghana: Ghana is a medium size land mass along the south coast of the region, despite its moderate size it has a large population with over half of the population reported as urban dwellers. In contrast, Ghana has amongst the lower population of cattle in the region, reporting just under 1.7 million head of cattle in 2014 27 million people; urban growth rate 3.5%, 1.7 m cattle, of which 20% dairy cattle					
1992	Unknown	RBT	9.3%	Coastal savannah area	(Turkson and Boadu, 1992)
2000	Unknown	RBT	6.6%	Akwapin-South district	(Kubuafor et al., 2000)
2012	Probabilistic	RBT	2.93%	Dormaa and Kintampo districts, Brong Ahafo region.	(Folitse et al., 2014)
Ivory Coast: The Ivory Coast neighbours Ghana on the southern coast of the region. Slightly larger in land area it has a smaller total population than Ghana but a similar proportion (55%) of citizens residing in urban areas. 22 million people; urban growth rate 3.7%, 1.6 m cattle, of which 20% dairy cattle					
1970-73	Non-probabilistic	RT	42.9% ± 2.7%	Bouaké, Korogho, Man and Odienne	(Gidel et al., 1974)
		SAW, TFC	15.5% ± 2.6%		
1975-77	Non-probabilistic	TRB, SAW, TFC	10.0% ± 0.5%.	National survey Herd prevalence 75 %. 38% of cows with abortions are seropositive. Important regional variations, from 1.1 to 40%	(Pilo-Moron et al., 1979)
			B.abortus biovar 1 and 6 isolated from infected cattle		
1976-78	Unknown	TRB	28.3%	North region Herd prevalence: 41% (RT), 75% (TRB). In positive herds: higher abortion rate, reduced fertility, higher mortality in calves.	(Camus, 1980)
1984	Unknown	TRB, SAW	5.4% (centre) to 19.5% (north)	North and Centre regions Overestimates true prevalence because some vaccination is practised	(Angba et al., 1987)

2004	Unknown	Bayesian analysis of the results of TRB, iELISA, SAW and TFC	3.6%	Dairy farms (training and private farms)	Peri-urban forest area around Abidjan. Farms providing milk products for Abidjan	(Thys E., Yahaya M.A., Walravens K., Baudoux C., Bagayoko I., Berkvens D., 2005)
			4.3%	Traditional farms		
2005	Probabilistic	Bayesian analysis of the results of TRB, iELISA and SAW.	8.8 % [5.0-16.4]	Nzi, Comoé and Lake regions		(Sanogo et al., 2008)
2012	Non-probabilistic, high risk groups	TRB and iELISA	10.3% (95% C.I.: 8.4%-12.4%).	Savannah-forest region of Ivory Coast		(Sanogo et al., 2012)
			B. abortus biovar 3	UNPUBLISHED*		
Mali: Mali is one of the largest inland countries in the region, landlocked it shares borders with many other countries. Mali reports the second largest national herd of cattle and the largest dairy herd of the study countries. 17.6 million people; urban growth rate 4.9%, 10 m cattle, of which 20% dairy cattle						
1991	Unknown	ELISA	23.3% ± 2.5%	National survey. Reported prevalence from 11 to 20%, in previous unpublished surveys. West Mali more affected (subhumid area): herd prevalence up to 87% in Koulikouro, 74% in Kayes. Tombouctou area is less affected (arid climate)		(Tounkara et al., 1994)
			B. abortus.			
1998-01	Risk based	TRB	Prevalence among suspect cases rose from 8.7 to 19.5% during study period	Central Veterinary Laboratory, suspect cases (mostly abortions and pre-sale check-up). Herd prevalence rose from 31.4 to 65%.		(Bonfoh et al., 2003)
2008-09	Unknown		22%	National level reported in OIE questionnaire		(Akakpo et al., 2009)
2011	Unknown	TRB	1%	Cinzana region 2 of 204 cattle tested positive to TRB; neither were positive to iELISA.		(Sow et al., n.d.)
		ELISA	0%			
Mauritania: Mauritania is another large country in the North of the region neighbouring Mali but also having an expanse of coastal border in the West. In contrast to Mali, it has a much smaller human and cattle population.4 million people; urban growth rate 3.5%, 1.9 m cattle, of which 20% dairy cattle						

Niger: Niger, like Mali is a large landlocked country in the northern edge of the region. With a population of nearly 20 million in 2015 it has a very high urban population growth rate of 5.4% annually but currently less than 20% of its population reported to be urban dwellers. Niger has the largest national herd of cattle. 3.5%, 11.4 m cattle, of which 13% dairy cattle					
1970-73	Non-probabilistic	RT	21.2% ± 5.1%	Niamey area	(Gidel et al., 1974)
		SAW, TFC	2.4% ± 4.6%		
1980-81	Unknown	TRB, FC	35.3% ± 3.6%	Niamey (more humid than Zinder) Prevalence in other species: 6.6% ovine, 2.0% caprine, 8.6% camels.	(Saley, 1983)
		TRB, FC	12.1% ± 5.1%.	Zinder	
1980-81	Unknown	TFC, TRB	30.9% ± 3.2%	National survey. Traditional farming, Most affected area in Niger is the department of Niamey	(Akakpo, 1987)
			B. abortus 3 or 3/6		
1989-90	Probabilistic	TRB	1.4% ± 0.4%	National level survey. Endemicity in all cattle rearing areas	(Bloch and Diallo, 1991)
2013	Probabilistic	iELISA	1.3% (95% C.I.: 0.9% - 1.8%)	Niamey	(Boukary et al., 2013)
Rwanda: Rwanda is a small landlocked country in the East of Africa but is included in this work due to the links and interest of ministerial vets there and their participation in the regional workshop. Despite its small geographical size compared to other countries, it has a total population of over.11 million people; urban growth rate 5.8%, 1.1 m cattle, of which 20% dairy cattle					
1982-83	Unknown	TFC, TRB	34.9% ± 3.7%	National survey, traditional farming	(Akakpo, 1987)
			B. abortus 3 or 3/6		
2008-2009	Unknown		1.7%	National level, reported in OIE questionnaire	(Akakpo et al., 2009)
Senegal: Senegal is a medium sized country with a large proportion of its border being coastal on the region's western coast. 15 million people; urban growth rate 3.8%, 3.5 m cattle, of which 20% dairy cattle					
1960-62	Unknown	SAW	13% ± 2.1%.	National survey. Casamance and Thies are infected. Diourbel seems free. Prevalence of clinical signs 8.5% (abortion, hygroma)	(Chambron, 1965)
			B. abortus and *B. intermedia* isolated from infected cattle		
1974-75	Probabilistic	SAW	12.0% ± 1.9 %	Dakar's abattoir (cattle from northern half of Senegal) 17.2% of sera are positive at least once in SAW, TFC, Coombs or TRB	(Chantal and Thomas, 1976)
1976	Unknown	TRB	14.4% ± 3.5%		(Fensterbank et al., 1977)
		Skin test	8.5% ± 2.8%		

			B. abortus isolated from infected cattle	1 village in Basse-Casamance. All animals with hygromas (except 1) are seropositive.	
1979	Non-probabilistic		180 *B. abortus* biovar 3/6 and 1 *B. abortus* biovar 1	181 strains isolated from cattle arthritis samples	(Verger et al., 1979)
1984	Non-probabilistic		*B. abortus* 1 and 3/6		(Verger and Grayon, 1984)
1987	Non-probabilistic		*B. abortus* 3 or 3/6	Casamance region	(Akakpo, 1987)
2001-03	Probabilistic	RBT and TFC	0.6% (95% C.I. 0% -1.3%)	Bassin Arachidier region	(Unger et al., 2003)
2007-08	Unknown	Competition ELISA, TRB	1.5% ± 2.1%	Dairy farms in Thiès region	(Kouamo et al., 2010)
2008-09	Unknown		20 %	National level. Reported in OIE questionnaire	(Akakpo et al., 2009)
2012	Probabilistic	TFC, TRB	25.0% ± 4.9%	Peri-urbane dairy farms around Dakar. Supply Dakar with unpasteurized milk and milk products. Correlation of seropositivity with age, breed, abortion and hygroma. Herd prevalence >95%.	(Tialla et al., 2014)
Togo: Togo is a relatively small country sitting between Ghana and Benin on the southern coast of the region, although Togo only has a small coastal border. 7.3 million people; urban growth rate 3.9%, 520 thousand cattle, of which 15% dairy cattle					
1977	Unknown	TFC, TRB	40.9% ± 3.0%	National survey, traditional farming. Lomé and Avetonou are the regions most affected by brucellosis	(Akakpo, 1987)
			B. abortus 3 or 3/6		
1977-79	Non-probabilistic	TRB, SAW	41.2% ± 2.9%	National survey. Regional variations: increase from North to South. Some seropositive among livestock keepers	(Sonhaye, 1980)
1984	Non-probabilistic		*B. abortus* 3/6		(Verger and Grayon, 1984)
1990	Non-probabilistic	TRB, TFC	16.6% ± 3.3%	National survey (but small sample) Higher prevalence in Maritime and Plateaux regions (but vaccination in the latter)	(Kponmassi, 1991)
2011	Probabilistic	TRB and iELISA	9.2%, (95% CI: 4.3-18.6%)	Northern Savannah region of Togo	(Dean et al., 2013)
			B. abortus	isolated from 3 bovine hygroma samples	

				Northern Savannah region of Togo – sample also includes transhumant herds from Burkina Faso (approx. 1/3 herds)	

*Supplementary work referred to within the paper but unpublished itself

***TFC* Complement fixation, *TRB* Rose Bengal test, *ELISA* Enzyme linked immunosorbent assay, *SAW* Sero agglutination of Wright, *RT* Ring test, *iELISA* Indirect enzyme linked immunosorbent assay, *RBT* Rose Bengal test, *IFI* Indirect immunofluorescence, *C.I* confidence interval

Table 2 Literature findings in humans for brucella spp. in West and Central Africa

Country	**Population**	**Test**	**Outcome**	**Comment**	**Reference**
Benin	1. Livestock keepers 2. Slaughterhouse employees	TRB, IFI	17.7% ± 6.4 %	*Gouka and Cotonou area. No positive among non-exposed persons*	(Audurier A., Fayomi B., Laudat P., 1987)
	3. Non-exposed group		0		
Burkina Faso	Village surveys	SAW, TFC	2.5%	*Banfora, Dori, Gaoua and Markoye Correlation with livestock keeping, esp. in pastoralists*	(Gidel et al., 1974)
Chad	Livestock keepers	TRB	1.8 %	*Chari-Baguirmi and Kanem regions Risky behaviours reported (assistance with calving, contact with abortion material, consumption of non-pasteurized milk)*	(Schelling et al., 2004)
Ghana	High risk groups	RBT	0	*No evidence of human brucellosis was detected by antibody screening in selected risk groups (6 veterinarians, 6 butchers, 21 herdsmen and 12 environmental health inspectors) nor in the control group of 30 people*	(Kubuafor et al., 2000)
Ivory Coast	Village surveys	SAW, TFC	0.45%	*Bouaké, Korogho, Man and Odienne No positive in Tabou (no cattle in that area). Correlation with cattle keeping, esp. in pastoralists*	(Gidel et al., 1974)
		Not specified		*Known human focal outbreaks in these areas Odienne, Korogho and Bouaké*	(Armand, 2001)
Mali		TRB, IFI	0.5%	*Fourou, Mostly agriculture, few contacts with livestock*	(Tasei et al., 1982)

			24.4%	*Gourma, Pastoralists, raw milk consumption*	
	Unknown	RBT	24.4%	*Rural areas*	(Bonfoh et al., 2003)
			4.6%	*Bamako*	
	Mopti town. Survey among febrile patients	SAW	67%	*Significant risk factors: proximity of ruminants and consumption of non-pasteurized milk.*	(Dao et al., 2009)
	Village surveys	TRB	0.9% (2/213)	Cinzana region	(Sow et al., n.d.)
		iELISA	0.04% (1/213)		
Niger	Village surveys	SAW, TFC	1.4 %	*Niamey area, Correlation with cattle keeping, esp. in pastoralists*	(Gidel et al., 1974)
			8.6%.	*90% of households consume raw milk, 77% manipulate abortion materials.*	(Adamou, 2014)
Rwanda	Prevalence of positive serology in women presenting with abortion and/or stillbirth	TRB	25% 15/60 women were positive		(Rujeni and Mbanzamihigo, 2014)
Senegal	Abattoir workers in Dakar	TRB	8.6%		(Diop, 1975)
Togo	Village surveys- Fulani ethnicity	TRB and iELISA	2.4% (95% C.I.: 1.0-5.6%)	*Northern savannah region of Togo*	(Dean et al., 2013)
	Village surveys- Non-Fulani ethnicity		0.2% (95% C.I.: 0-1.6%).		

***TFC* Complement fixation, *TRB* Rose Bengal test, *ELISA* Enzyme linked immunosorbent assay, *SAW* Sero agglutination of Wright, *RT* Ring test, *iELISA* Indirect enzyme linked immunosorbent assay, *RBT* Rose Bengal test, *IFI* Indirect immunofluorescence, *C.I* confidence interval

3.3 Brucellosis control

3.3.1 Vaccination & surveillance –Workshop findings

During workshop discussions, the consensus was that there are minimal surveillance and control activities for brucellosis taking place across the region. No participant reported extensive countrywide surveillance. Four delegates reported that vaccines were available in their country (Table 3), but none of these countries had a structured vaccination programme in place, all reporting voluntary vaccination with the onus falling on the farmer.

Table 3 Vaccines currently available in study countries according to workshop delegates

Country	Vaccines available
Gabon	S19, RB51
Ghana	S19, RB51
Ivory Coast	S19, Rev1
Rwanda	RB51

There was also consensus that cattle vaccines were needed, but opinions were mixed on whether vaccination in small ruminants was necessary.

Five countries reported control activities, namely Chad, Gabon, Rwanda, Mali and Niger.

Chad reported there to be a written policy for brucellosis in the country but no actual implementation or activity. The delegate believed that there was interest in control programmes in some government managed farms and in the peri-urban farms emerging which are often owned by wealthy people from the cities.

Gabon has only recently (2014) begun any animal health service activities as animal production is very minimal in the country. There is reportedly test and slaughter carried out by a large cattle producer in the south of the country. There is no national programme and it is down to farmers to utilize private veterinarians for advice and buying vaccines.

While there is no government run control in Mali, serum samples have been taken through a private breed improvement programme but have not been tested as there was a lack of reagents available. The delegate believed that vaccination should be implemented nationwide as government services do not have money to compensate farmers for test and slaughter methods.

In Niger, there is routine testing of workers in the central veterinary laboratory and in cattle breeding centers, but no reported testing in the general population of animals.

Rwanda has the most extensive control activities. Large dairy farms are routinely tested once per year; smaller farms only being tested if there are cases of abortions. Samples are also collected twice yearly at vaccination drives where vaccines for various diseases are disseminated and samples are collected simultaneously. There is a government initiative of giving either a cow or small ruminant to poor families, all animals used in this programme are tested and slaughtered if found to be positive. Animals found to be positive on farm are sent to abattoirs so the farmer receives only the normal going rate and no additional compensation to cover the difference in market value of a dairy animal and its slaughter price. The delegate from Rwanda hypothesized that although not routinely tested, small farms could have high levels of brucellosis. He described a case where a bull from a large farm was being used to serve cows on small local farms who then introduced the disease onto the large farm. It seems likely given that there is no compensation paid, farmers on the smaller farms would be less likely to report abortions and risk losing valuable dairy animals. Approximately 5000 vaccines per year are administered mainly in the Kigali and Gishwati dairy areas. The vaccine costs the farmer 3500Frw per dose (approx. 4.25 USD). The vaccines are produced by MSD in South Africa and imported.

Senegal and Ghana reported historical control programmes that are no longer in existence.

3.3.2 Vaccination & surveillance – Literature findings

In literature only two papers were found that detailed any structured control activities in the past, these being from Burkina Faso and Ivory Coast. In Burkina Faso, Bessin (1982) highlights in his thesis the detection and slaughter of positive animals as well as vaccination in large peri-urban herds. There is no further evidence of this after the early 1980's.

In Ivory Coast, Angba et al (1987), Camus (1995) , Chambron (1965), Armand (2001) and Thys et al (2005) all described vaccine control implemented in the north of the country from 1978 and described a decrease in abortion rate of 37% after the first year of the campaign. By the early 1990's however there is no further evidence in the literature of the continuation of any control activity.

3.3.3 Diagnostic capacity

During workshop discussions on the diagnostic methods for detecting brucellosis all countries reported having the capacity to carry out Rose Bengal tests and ELISA, however many countries did not have the access to reagents required to utilise these methods. While those working in the animal health sector were generally reasonably familiar with the diagnostic techniques available for *Brucella* testing, those working in the human health sector were not and none had heard of any testing for brucellosis within routine healthcare screening of patients. Many alluded to fever profiles utilised for febrile patients and expressed interest in being able to incorporate *Brucella* testing within this profile. However, considering recent findings in East Africa (de Glanville et al., 2017) in regards to misdiagnosis by the commonly used febrile antigen *Brucella* agglutination test (FBAT), careful consideration would be required before implementing routine testing in the West African setting.

While discussing constraints in *Brucella* diagnostics, the most frequent reason noted in animal diagnostics was the lack of minor equipment such as reagents, while in human diagnostics major equipment lacking was considered the most frequently cited constraint.

Most countries were said to have the capacity to carry out PCR if they were provided with protocols, primers and controls. However, many participants expressed apprehensions about having the appropriate expertise to do so.

There was no relevant literature that detailed diagnostic capacity within the countries that were reviewed.

3.4 Evolution of human and animal demographics

The combined human population of the study countries in 2015 according to World Bank statistics was 198.7 million people. This ranged from Ghana with the largest population (27.4 million) to Gabon with a population of 1.7 million (Fig 3).

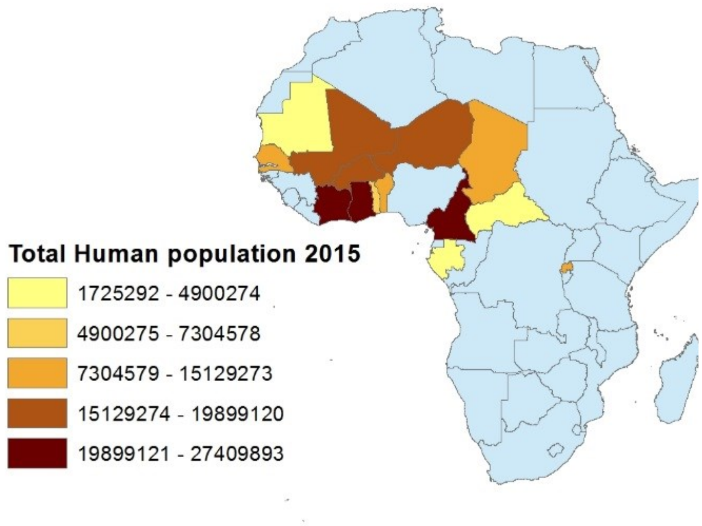

Figure 3 Country wide human population statistics extrapolated from World Bank Database

Urban population growth was 4.5% annually, whereas rural population growth was 1.8%. This trend is predicted to continue into 2050 with urban population growth projected to be 3.7% per annum compared to only 0.5% in rural areas (UNDESA, 2015). The majority of countries now have over 40% of their population as urban dwellers with Gabon now nearing 90% of its population living in urban areas.

Countries across the region vary strongly in their sizes and agricultural potentials. Figure 4 shows the larger inland countries having the largest cattle populations. While the smaller coastal countries have the lowest cattle populations

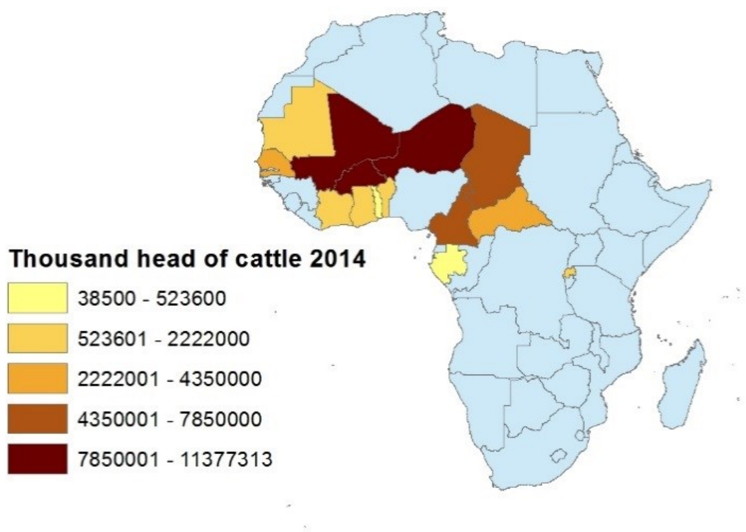

Figure 4 Cattle population statistics extrapolated from FAOSTAT

but generally the highest human urban populations in the region. In all countries, steady increases in overall cattle populations have been occurring over the last decades. While there is ambiguity over reporting of specifically dairy cattle, Figure 5 shows the percentage increases over the 2003-2013 period and the preceding 10-years. Burkina Faso, Gabon, Niger, Ghana, Togo and Benin all had much higher percentage increase in

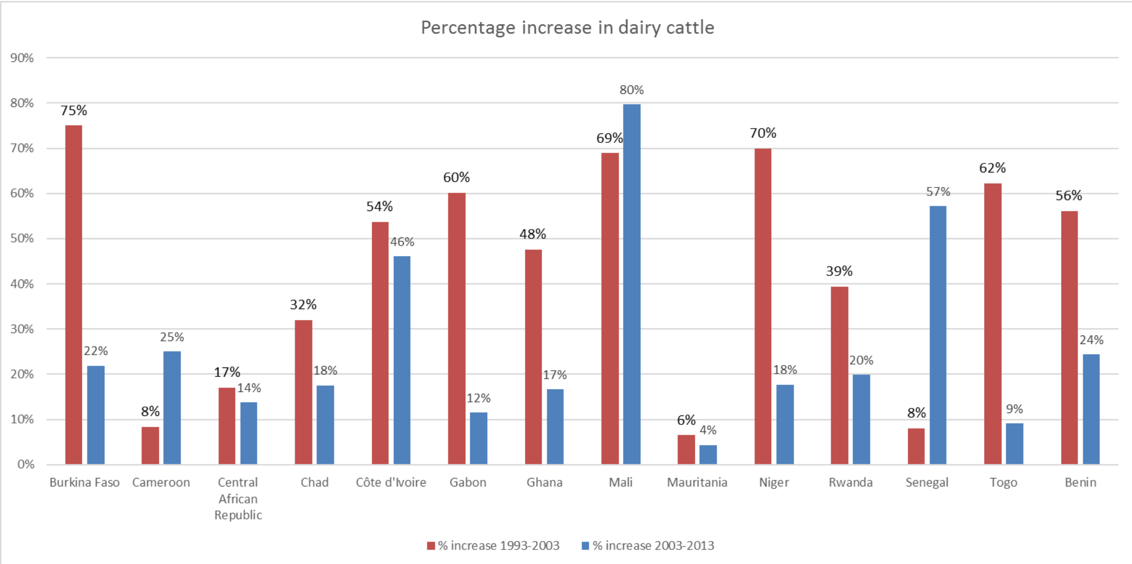

Figure 5 Percentage increases in dairy cattle numbers by country extrapolated from FAOSTAT

dairy cattle numbers during the 1993-2003 period than the period from 2003-2013. Conversely, Senegal has seen dramatic growth of 57% in the last 10 years compared to only 8% in the 10-year period preceding. Similarly, Mali and Cameroon have both also seen relatively higher growths more recently than during the previous period. Both Mauritania and Central African Republic have seen smaller and more consistent growth over both the time periods.

Despite the relative increases in dairy cattle and milk production across the countries, consumer demand is not met by local production as shown by the import figures for dry milk powder in Figure 6. All countries have seen increasing value of dry milk imports since the turn of the century with marked fluctuation during the financial crisis of 2008; this highlights the vulnerability of countries heavily reliant on imports.

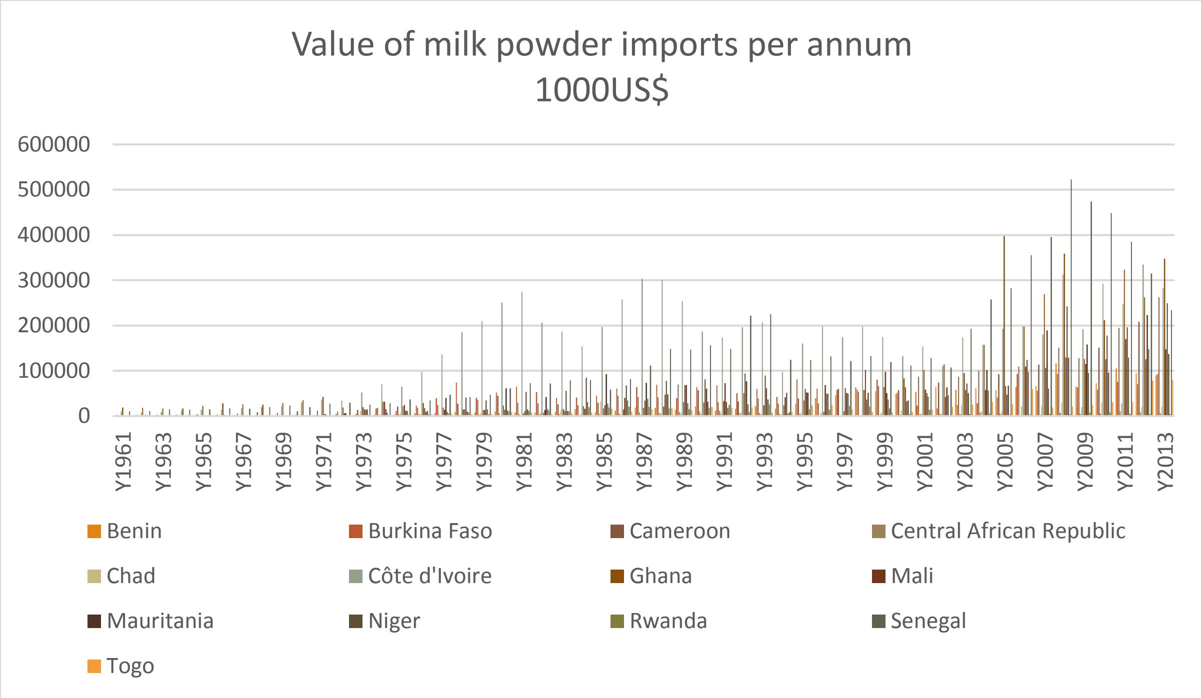

Figure 6 extrapolated from FAOSTAT

4. Discussion

It is evident that although variable and scarce, available literature suggests a reasonably high burden of brucellosis in the cattle populations of the 14 study countries. There is insufficient data to conclude any meaningful estimates of the burden however in small ruminant or human populations.

Although the literature is scarce for the region, the high seroprevalence estimates seen in developing systems such as those reported in Dakar, Senegal (Tialla et al., 2014) are concerning. This evolving brucellosis epidemiological picture may be true in many of the study countries that are witnessing the same changes in production styles as a result of urbanisation. Dakar in particular represents one of West Africa's most developed cities and is most likely a good indicator of future directions of other major cities in the region.

With the highest rates of urbanisation, the West African cattle sector is far more likely to have higher proportions of emerging farming systems around urban centres that, as suggested previously, may have a much higher burden of brucellosis and different epidemiological picture to the extensive systems predominantly seen elsewhere.

This review, in line with others (Ducrotoy et al., 2015) highlights the degree of the lack of reliable and up to date data on the epidemiological picture of brucellosis within West and Central Africa. With no up to date bacterial isolation in any species and very limited human and small ruminant studies it is paramount that microbiological research establishes the detail in a region where mixed farming systems, informal food markets and migration of people and animals are commonplace.

The brucellosis prevalence estimates obtained from the literature in this review must be viewed with caution. Most data reviewed was at least five years old in countries where the farming systems and brucellosis prevalence show changing patterns within a setting experiencing rapid rates of urbanization (Unger et al., 2003). Many of the studies were carried out in particular geographic or industry specific settings and are not generalizable to the entire population as suggested. Others have not been sampled in a probabilistic manner and are not representative therefore of an accurate estimate. Likewise, the human and cattle population data utilised in this review gives some good preliminary information and indicators for the region's trends over the last decades, but the accuracy and consistency of the data portrayed is uncertain. Both FAOSTAT and the World Bank databases rely on many different sources to compile datasets, some being household surveys while others coming from countries own reporting and estimations by different organisations.

With an obvious scarcity of literature from the human health field there is a need for further research to assess the burden of the disease on humans within this setting. Although human health workshop delegates felt they lacked knowledge of brucellosis presentation and diagnostics, they were very encouraged by spending time with colleagues from the animal health sector discussing the issues surrounding the disease.

Although diagnostic techniques for *Brucella* are not routinely used in most countries, the capacity is largely there and small stumbling blocks could be overcome with regional co-operation. As was demonstrated at diagnostic training sessions during the workshop, delegates were comfortable with the techniques and quickly adapted to new concepts brought forward for alterations in field testing protocols.

It is clear that the study countries while all experiencing urbanisation, population growth and changing consumer demands, vary a lot in their size, capacity and progression through structural adjustments on the path to development. While the in land countries are generally much larger geographically they all so have more favourable livestock rearing conditions. The smaller coastal countries however are often much more densely populated with very large urban populations and high demand for dairy and value added products in general. We have only examined the francophone countries of the region and must not forget the likely influence that Nigeria has over regional affairs given its sheer size and dominance of both population and economy in the region.

In all countries, urbanisation is associated with changes in employment patterns and an increase in the 'middle classes' with higher disposable incomes. Increasingly both sexes are working outside of the home often with long commutes across large cities. There is therefore less time available to people for shopping, processing and preparing food. In turn, this is driving trends for convenient processed food that can be purchased and often consumed away from the home. As predicted by Bennett's Law (BENNETT, 1954) there is a strong relationship between increasing incomes and a disproportionate rise in the share of non-staple foods in the overall food budget of a household. This is most notably seen in increased demand for high protein products such as meat and dairy. Historically raising GDP of a country was linked with increased consumption of animal fats and proteins. However, more recent food balance sheets from the FAO seem to show that this link is less pronounced, with increased consumption of animal products even in those countries with low GDP and high levels of urbanisation. This suggests that drivers besides those purely economic influence consumption patterns within modern urban settings. Explanation could come in the form of modern retailing within most African countries and the high penetration of internet technologies in this setting. Most large urban areas in West Africa have a myriad of international and national supermarket chains, which utilise mass media advertising and offer a more luxurious shopping experience for the growing middle classes. As well as targeting the higher income population, many supermarkets recognise the large proportions of low-income residents in urban dwellings and offer small package low cost items. As is evident in many developed countries, the supermarket's influence over agricultural policy can be very powerful. As they take over a larger market share, their ability to dictate market prices and place demands in terms of food safety and value addition shapes the direction of many sectors. The influence of such players in West Africa over agricultural policy and knock on effects for animal health implications in the future is not be overlooked.

Despite the rise in number and popularity of supermarkets within West Africa little data is available regionally outlining the market coverage of the sector at this time and the relative amounts of locally produced versus imported goods sold by supermarkets in the region.

Companies such as Arla and Nestle have established processing plants in West Africa and import large quantities of European milk powder for reconstitution in the region before widespread distribution. Locally produced milk cannot compete with the cheap imports due the inconsistent supply over different seasons and the logistical difficulties with the transport and storage of short shelf life fresh produce. This reliance on imported goods reduces the potential for development of the regional dairy industry. When the increasing consumer demand is being supplied by imports, there is less impetus for policy change and development to strengthen the sector.

None the less there is clear indication of a vast interest, effort and need for further development of the dairy sector in the region. There are many issues that the countries face in developing the dairy sector in order to compete on a more level playing field with cheap European imports of dry milk powder. However, there are great drivers to do so not only for regional economic growth but also to alleviate poverty and to enhance nutrition in line with the sustainable development goals. One of the most important areas in the development of the dairy sector is animal health, due not only to the productivity limiting nature of endemic diseases but also the human health risks associated with many.

From review of the literature and workshop discussions, it would appear that the largest and most difficult gap to overcome in terms of animal health and particularly brucellosis control is the lack of policy or legislation. This ultimately requires reliable research in to the current epidemiological picture in the emerging peri-urban systems and assessment of the economic impacts of disease and benefits of control.

5. Conclusion

At present, the true social and economic burden of brucellosis in West and Central Africa is unknown. Scarce and aged data would suggest that the epidemiological picture is evolving as demographic changes occur at varying levels across the region. In order to assess the impact and evaluate control methods, systematic research is required to investigate seroprevalence in emerging livestock systems and in human populations. Only then can meaningful impact evaluations inform policy decisions as to appropriate and sustainable control and surveillance strategies for the future.

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