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Economic Implications and Management of Bovine Tuberculosis in Fiji: Promoting Decent Work and Economic Growth

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Abstract

Fiji is one of the Pacific countries highly affected by Bovine Tuberculosis. Bovine Tuberculosis (bTB) is globally critical because of its effects on animal production. A Brucellosis and Tuberculosis Eradication and Control (BTEC) program was initiated in Fiji during the 1980s and has since been supported by government financing and industry participation. Bovine Tuberculosis is a persistent bacterial illness of animals and people caused by Mycobacterium bovis. In many nations, bovine Tuberculosis is a significant irresistible illness among cows, other domestic animals, and specific natural life populaces. Bovine Tuberculosis in Fiji leads to reduced opportunities for local trades and a lower production system because of ill animals and pre-mature cull of potential production stock. The bTB conditions in Fiji have become a rising concern for the stakeholders of livestock industries as the stock culling further teases lower milk production in the nation. The Biosecurity Authority of Fiji also implemented and raised awareness for farmers to consider BTEC program strategies to reduce the risk of bTB. The plan was further finalized and refined by the Ministry of Agriculture in early 2018. The proposal of this strategy involved recommendations and reviews on the hygiene of meat, control methods of bTB and selection of diagnostic tests to encourage and strengthen BTEC program strategies in Fiji.

Keywords: *Bovine Tuberculosis, Fiji, BTEC Program.*

Introduction

Fiji is one of the Pacific countries with hot heat and humidity all year, with a normal of 25 degrees Celsius, dropping to 18 degrees in the cold weather months and transcending 30 degrees in the late spring season. The stormy season extends from November to April, with the bigger islands getting more downpours or rains than the more modest islands. Agriculture is one of the most critical aspects of Fiji, both in livestock and crops (Heidi Fradette, 2020) Livestock plays a significant part in the existence of individuals in the Pacific Island people group in terms of jobs and food security. As per the Secretariat of the Pacific Community, Livestock is a significant piece of agribusiness that upholds food and wholesome security and employment for the rustic networks and ought to be improved to help people in the future (SPC, 2011). However, Fiji's livestock sector is highly affected by many diseases, such as zoonotic diseases involving Leptospirosis and Brucellosis, but this review will focus on Bovine Tuberculosis (Heidi Fradette, 2020). These diseases are also caused and spread by environmental changes (Igbal, 2022). Climatic changes bring more extensive changes to the environment, causing substantial economic and production in livestock production (Igbal et al., 2022).

According to (OIE, 2018), bTB or Bovine Tuberculosis is a persistent bacterial illness of animals and people caused by *Mycobacterium bovis*. In many nations, bovine Tuberculosis is a significant irresistible illness among cows, other domestic animals, and specific natural life populaces. Transmission to people comprises a general medical condition. Bovine Tuberculosis causes severe losses in the economy of the livestock industry due to confiscation of the carcass, animal disposal, pre maturing of culling, production loss and poor performance of the reproductive system (Canto Alarcon et al., 2013). Bovine Tuberculosis in Fiji leads to reduced opportunities for local trades and a lower production system because of ill animals and pre-mature cull of potential production stock. The bTB conditions in Fiji have become a rising concern for the

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stakeholders of livestock industries as the stock culling further teases lower milk production in the nation (Borja et al., 2018).

According to (Borja et al., 2018), it is most likely that the bTB was introduced in Fiji through cows/cattle brought in by European settlers during the 1830s. This information was derived from (Papakura, N.Z.: R. McMillan, 1984) During their publishing of a review named [The Cyclopedia of Fiji – A Complete Historical and Commercial Review of Fiji]. In the 1970s, the detrimental effects of Tuberculosis and brucellosis were recognized in local cattle/cow farms and establishing a national program to control the impacts was recommended (FVPL, Public Sector Investment Program, 2014-2016). Afterwards, the MOA (Ministry of Agriculture) established and began the program to eradicate Tuberculosis and brucellosis in Fiji and named the program "Fiji Bovine Brucellosis and Tuberculosis eradication and control (BTEC) program". This commencement was done in the early 1980s with the guidance and support from the Government of Australia (Tukana et al., 2015), organizing registration of dairy farms, monitoring the cattle movements and compulsory Btb testing on cattle and ear tagging on those who have been tested, as well as inspection of carcass at abattoir with compensation payments for damnation at slaughter (Borja et al., 2018).

This review will eventually determine the possibilities of Bovine Tuberculosis in Fiji, its detection method, management of the disease, and government intervention programs to eradicate bTB from the Fiji Islands.

Discussion

Geographical Distribution of Bovine Tuberculosis

Due to high mortality and morbidity, bovine Tuberculosis has been a global concern in several developing countries. Likewise, cattle and other animals' movement between regions has made it easier to transmit and spread bovine Tuberculosis and antibiotic resistant (newly evolved) strains (El-Sayed et al., 2016; Sechi et al, 2001). In addition, reservoir animals like wild boars, badgers, and deer are also endowed with bovine tuberculosis geographical distribution through their natural movements (Naaz, 2018). According to (Pal and Boru, 2012), bovine Tuberculosis was once found globally; however, control methods and strategies have eradicated/nearly eradicated bovine Tuberculosis from domestic animals in several nations. Yet, wild specie animals that act as a crucial reservoir of tubercle bacilli may pose a deliberate threat in elimination and control programs. Countries classified as Tuberculosis – free involve Iceland, Australia, Sweden, Denmark, Finland, Norway, Switzerland, Austria, Latvia, Luxembourg, Lituania, Latvia, Estonia, Canada, The Czech Republic, Jamaica, Singapore, Isreal and Bar-bados. In addition, elimination strategies have been in progress in other European nations (Sharma et al., 2010).

The preponderance of bovine Tuberculosis within a nation alters with the dissemination of animals. Larger cities with comprehensive farming and dairy productions possess higher levels of tuberculosis infestation (Naaz, 2018). According to (Corner, 2006), bovine Tuberculosis has a widespread effect in nations like the Middle East, Africa, and Asia. Figure 1 demonstrates the World Health Organization (WHO) Report showing an estimated worldwide Btb incidence rate in 2011 (Pal et al., 2014).

Figure 1: WHO Report on Estimated Global Bovine Tuberculosis Incidence Rates in 2011

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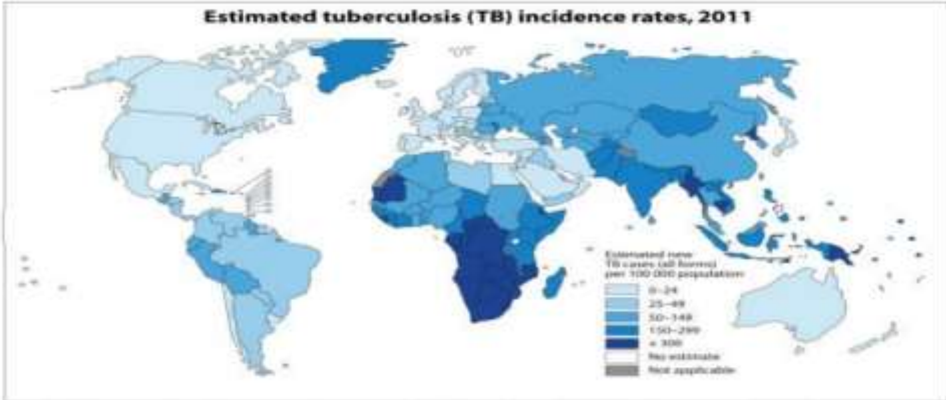

Source: (Pal et al., 2014), *Microbes and Health.*

Overview of Tuberculosis in the Dairy Industry

Dairy farming is mainly concentrated in Fiji's Central division, which has the most significant number of dairy farmers and has dominated the dairy industry since 1991 (Igbal, 2021). Cattles have been identified as the primary host of bovine Tuberculosis. Yet, several other mammalian species are vulnerable to bovine Tuberculosis (De Lisle et al., 2001). An animal that has been infected shed bovine Tuberculosis in various ways, such as; through milk, discharging lesion, saliva, faeces and urine (Phillips et al., 2003; Neill et al., 2005; Jha et al., 2007). The data obtained in the year 2014 stated that cattle that were sent to slaughter after having a conclusive test on the skin represented that one in three activators (animals possessing a positive single intradermal test) had epitomized Tuberculosis, and 85 per cent had some gross lesions of TB during the examination of post-mortem period. Therefore, the Fijian Government perceives the acknowledged elimination of bovine Tuberculosis. It could be beneficial to each cattle farmer and the nation regarding trading and human health. However, this disease had its most brutal hit in the dairy sector, which has endured the most loss of cattle numbers (AH&P. BTEC Strategic Plan, 2018).

In Fiji, historical documents and data have been scarce; thus, a case study was conducted by (Borja et al., 2018) to further elaborate on the BTEC (Fiji Bovine Brucellosis and Tuberculosis eradication and control program) born in Fiji to eliminate Tuberculosis from the country. Table 1 shows the Budget evaluated for Fiji's BTEC Program with the number of cattle's and farms tested for bTB from 1999 – to 2014.

Table 1. BTEC Program-Budget for Btb Test On-Farm and Cattle in Fiji (1999-2014)

Year	BTEC Budget (USD)	Number of		Number and Percentage with Positive Results			
		Farms Tested	Animals Tested	Farms		Animals	
				No.	%	No.	%
1999	36,450	373	38,870	56	15	220	1
2000	36,450	245	29,303	37	15	230	1
2001	72,900	299	26,277	50	17	293	1
2002	72,900	228	30,880	31	14	183	1
2003	72,900	170	27,506	26	15	121	0
2004	72,900	105	19,323	22	21	180	1
2005	72,900	438	41,591	34	8	192	0
2006	72,900	96	7,552	27	28	186	2
2007	114,079	98	9,569	23	23	61	1
2008	85,335	377	43,516	43	11	212	0
2009	718,065	417	32,160	11	3	39	0

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2010	96,228	113	14,967	7	6	17	0
2011	437,400	136	14,916	14	10	60	0
2012	370,641	303	27,618	15	5	47	0
2013	364,500	324	17,439	11	3	61	0
2014	729,000	401	29,597	32	8	721	2
TOTAL	**3,425,548**	**4,123**	**411,084**	**439**	**439**	**2823**	

Source: (Borja et al., 2018), A retrospective study on bovine Tuberculosis in cattle on Fiji: Study findings and stakeholder responses.

This information was also not included in the Animal Health Survey published in 1999 by the Secretariat of the Pacific Community (Martin et al., 1999). Reports and documents about Btb in Fiji from 1999 have been limited to the reports and records in government books and the data given to the World Health Organization for Animal Health (OIE) since Fiji inclined into a member in 2007. Cattle growing areas of all kinds (beef and dairy farms of school farms, villages, government stations, middlemen and individual farms) were involved in the BTEC program. Participation was compulsory even though the farmers did not accede (Borja et al., 2018).

Farm Types – Tested for Bovine Tuberculosis

In the BTEC Program, an equate of 168 dairy cows (median: 172.5, average: 168, range: 16-717) were espied as positive every year for the last 16 years in comparison to beef cattle's (average: 3, median: 3, range: 0-18). 99% (2,685 of 2,690) of dairy animals detected positive from 1999 to 2014 belonged to Central Division. A limited capacity of dairy cows was detected positive each year (range 0.1–4.2%), from beef cattle tested positive 0.1 to 1.5% in 8 of 16 years. Less than 1 per cent of cattle from other farm types tested positive in 10 of 16 years (Table 2). In the Western Division, decreased proportions of positively tested cattle were detected in 4 of 14 years that beef cattle were tested, in 3 of the 13 years that dairy cattle were tested, and in 2 of the 15 years that cattle from other farms were tested (Table 2), (Borja et al., 2018).

Table 2. Number of Cattle Tested and bTB Cattle's Tested Positive by Different Farm Types in Central and Western Division (1999-2014)

Year	**Central Division**							**Western Division**						
	% of positive animals			Number of animals tested				% of positive animals			Number of animals tested			
	Beef	Dairy	Other[a]	Beef	Dairy	Other[a]	Total	Beef	Dairy	Other[a]	Beef	Dairy	Other[a]	Total
1999	0.2	0.7	0.3	919	23,598	7,195	31,712	0	0.5	0.1	982	396	3,515	4,893
2000	0	0.9	0.5	1,218	23,414	3,525	28,157	0	0	0	0	184	864	1048
2001	0.5	1.3	0.4	366	21,459	4,154	25,979	1.2	0	0	82	216	0	298
2002	0	0.8	0.3	662	23,064	1,935	25,661	0.1	0	0	4900	0	319	5219
2003	0	0.7	0.1	347	16,386	1,709	18,442	0.1	0.5	0	8699	186	179	9064
2004	0	1.4	0.9	387	12,110	214	12,711	0.2	0	0	1029	17	3363	4409
2005	0.1	0.6	0	1583	29,990	3,382	34,955	0	0	0	3517	132	2427	6076
2006	1.5	4.2	0	197	4,341	163	4,701	0	0.5	0	2609	183	59	2851

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2007	0	0.7	0.4	304	7,662	1,308	9,274	0	0	0	0	0	73	73
2008	0.2	0.8	0	1261	27,038	1,561	29,860	0	0	0	1006	323	2130	3459
2009	0	0.2	0	904	24,559	716	26,179	0	0	0	1695	4134	97	5926
2010	0	0.1	0.2	106	13,356	531	13,993	0	0	0	483	41	275	799
2011	0	0.5	0	453	12,776	263	13,492	0	0	0	1102	0	322	1424
2012	0.1	0.2	0.8	1171	22,987	384	24,542	0	0	0	941	1030	332	2305
2013	0.5	0.4	0	560	15,173	286	16,019	0	0	0	122	1037	68	1227
2014	0.1	3.1	0.1	1509	22,856	1,356	25,721	0.1	0	0	2301	72	1410	3783

The [(a)] shown below represents dairy cattle and beef farms that include school farms, settlements/villages, middlemen, and government stations.

Source: (Borja et al., 2018), A retrospective study on bovine Tuberculosis in cattle on Fiji: Study findings and stakeholder responses.

Risk Factors Contributing to The Spread of The Disease

Inhaling Mycobacterium Bovis is regarded as the most apparent and fundamental pathway to bovine infection, and it is **aided by close, protracted intercourse between a healthy and infected animal**. Likewise, M. bovis being directly ingested from infected animals or pastures, utensils, or water is also a common route of infection in some countries and regions (Neill et al., 2001). Risk Factors of Bovine Tuberculosis are reft into herd-level and animal-level risk factors. Age, body condition, breed, immune status, and automatic contamination conditions are considered the risk factors regarding animal level. While, bovine tuberculosis outbreak history, herd size, and lack of performance in the diagnostic test are herd-level risk factors (Humblet et al., 2009).

Animal Level Risk

Age

Bovine tuberculosis risk rises with the Age of the animal. It increases with declined conditions of the body. Still, sex, the status of the reproductive system and quality of lactation in the body were not related to bovine tuberculosis status, which demonstrates that the prevalence of bovine Tuberculosis rises with the Age of the animal as the period of exposure to the agent boosts with poor body conditions and Age and thus, the lower immune system is more acceptable to the development of infection with Mycobacterium Bovis (Sintayehu, 2017). According to (Pollock and Neill, 2002), the mycobacteria possess the ability to endure in a latent state for more extended periods before their reactivation during old Age. In (Pollock and Neill, 2002) review, they demonstrated the possible significance of cattle exposed to Mycobacterium Bovis, as outlined in (Figure 2).

Figure 2. Diagram Demonstrating The Likely Outcomes of Cattle When Exposed To M. Bovis.

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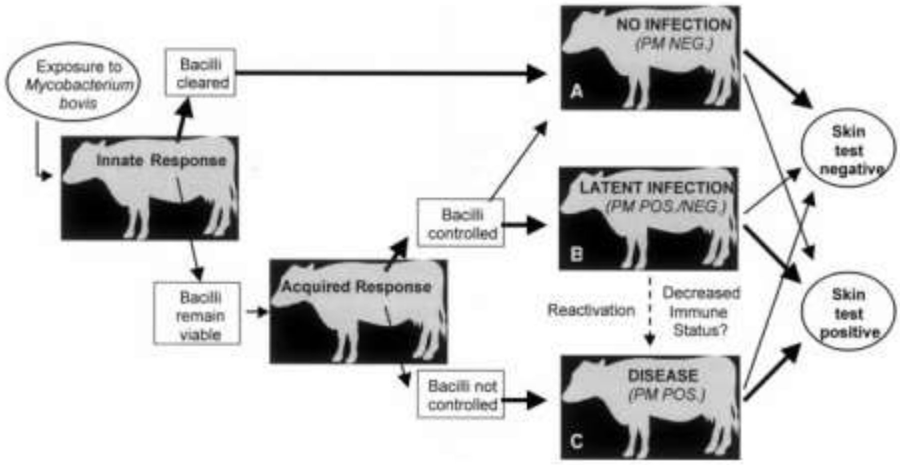

Source: (Pollock and Neill, 2002), Mycobacterium bovis infection and Tuberculosis in cattle. In *Veterinary Journal*.

The above Figure shows that when there is a possibility of two events, the thicker arrow shows (arbitrarily) the route regarded to be the most common. 'PM POS./NEG'. illustrates negative or positive findings at experiments done in the lab and gross post-mortem. Under these circumstances, part of the cattle herd (A in Figure 2) can resist infestation from M.bovis exposure, which may be due to their strong immune responses. In most situations, these animals will negatively result in the skin test during the tuberculin testing period. Yet, despite having resistance capability, few of these cattle may display responses at skin testing because of successful T-cell response development. Cattles showed (C in Figure 2) when exposed to M. Bovis, became infected, and displayed the disease. Such cattle are usually positive when tested. However, some animals might be anergic and not responsive during tuberculin testing. Likewise, it is possible that other cattle (B in Figure 2), when exposed to Mycobacterium bovine, progress an immune response that is effective and is associated with latent mycobacteria and may not or may be biformed with major changes pathologically.

Breed

According to (Redi, 2003), the breed is the other major factor in which Brahman breed of cattle are assumed to be more resistant to bovine Tuberculosis than the European breeds as the effects of bTB on Brahman cattle are less severe. Yet, under specific feedyard situations, a rate of 60 per cent morbidity and a weight gain due to depression can be observed in the Zebu (Brahman) cattle (Redi, 2003).

Immune Status

Suppression of the immune system is an inclined factor for many diseases. Therefore, being infected with M. bovis rises, even though it has not been scientifically illustrated in cattle (Menzies and Neill, 2000). The susceptibility toward M. bovis might also become enhanced in cattle already affected by other immunosuppressive viruses such as; bovine diarrhoea or immunodeficiency viruses (De la Rua-Domenech et al., 2006).

Auto-contamination

According to (Phillips et al., 2003), during rumination, a cattle being infected through oral routes can further release aerosols that are contaminated. These contaminated aerosols may be inhaled by cattle and lead to respiratory infection.

Herd – Level

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The size of the herd is one risk factor as there is more animal on a ranch, the more prominent the likelihood that one of them will gain the contamination. In addition, enormous herds usually graze on a more extensive area, with a higher chance of more coterminous herds, expanding the risk of spread (Sintayehu, 2017). One of the other risk factors contributing to the spread of bovine Tuberculosis is introducing an infected animal to a non-infected zone or area. This highly helps the disease to spread more around the herds (Sintayehu et al., 2017); the vogue of bovine Tuberculosis is more in agro-pastoral than in the production system pastoral, which may be due to closer contact that happens between cattle and humid situations in agro-pastoral systems (Faye et al., 2005).

According to (Sintayehu, 2017), host movement has also been identified as one of the herd risk factors for transmission of bovine Tuberculosis. The disease can impact more when animals are moved from an infected area to a free bovine tuberculosis zone. When the herd of cattle moves, the capacity of sharing grazed areas and water supplies with other animals that are already infected increases accordingly. Thus, it boosts the probability of a close contact between animals infected by bTB. Wildlife maintenance hosts also play a crucial role in transmitting bovine Tuberculosis to other animals (de Garine-Wichatitsky et al., 2013). Changes in land use and associated ecosystem alterations have been identified as on the casual route in the emerging and re-emerging infectious diseases. Usage of land can result in the overture of invasive species, which may influence the prevalence of bovine Tuberculosis through direct effects on the composition of the host community, densities of the host and contact networks of the host (Sintayehu, 2017).

History of Btb Outbreak in the Herd And Human Antecedent of Tuberculosis in the Household

A cross-sectional study was carried out in 1996 (Ireland) involving over 2,000 individuals (accounting for 200 herds) failed to illustrate that endured source of bovine tuberculosis infection was a significant herd-level risk factor; yet, this study involved enterprises of beef and store, which was important as well (Griffin et al., 1996). According to (Olea-Popelka et al., 2004), this factor was probably pre-historic in herds of dairy cows, where animals used to remain in the same herd for many years. The austerity of bovine tuberculosis outbreak was demonstrated in 2004, so it helps assume the future outbreak rates in Ireland for a herd with a history of bovine Tuberculosis, as recommended by a retrospective study involving 6,757 bovine tuberculosis -exposed and 10,926 non-exposed herds. The tables below show the traits of Bovine Tuberculosis exposure severity groups and frequency and severity of bTB herd breakdowns done by (Olea-Popelka et al., 2004).

Table 3. Btb -Exposure- Austerity Group Characteristics, Based on the Btb Episode Extent In 1995 in Ireland

Severity category	**Exposure in 1995**	**No. herds in category**	**BTB history[a]**	**Number of cattle in herd[b]**			**Median no. of cows**	**BTB prevalence in DED[c] (%)**
				Q1	Q2	Q3		
0	No reactor	10705	1816	13	28	59	8	5
1	0 standard reactor	577	179	25	49	82	17	10
2	1 standard reactor	2922	896	25	50	91	14	10.5
3	2–3 standard reactors	1463	509	32	64	111	19	12
4	4–8 standard reactors	910	316	38	68	116	21	13.4

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5	>8 standard reactors	503	183	61	93	151	32	14.3
Total herds		17080						

Source: (Olea-Popelka et al., 2004), Breakdown severity during a bovine tuberculosis episode as a predictor of future herd breakdowns in Ireland

The (a) shows the history of previous herd BTB breakdown in 1990–1994.

(b) Q1, Q2, Q3: quartiles 1, 2, 3.

(c) District Electoral Division

Table 4. Frequency and Austerity of Btb Herd Breakdowns in Ireland During 1996-2000 By Bovine Tuberculosis Exposure Category In 1995

Severity category	**Exposure category in 1995**	**Total breakdown per cent**	**0**		**1**		**2-3**		**≥4**	
			No. of herds[a]	%[b]	No. of herds[a]	%	No. of herds[a]	%	No. of herds[a]	%
0	No reactor	18.1	172	1.6	820	7.7	487	4.6	459	4.3
1	0 standard reactor	26.9	15	2.6	52	9.0	42	7.3	46	8.0
2	1 standard reactor	28.0	71	2.4	328	11.2	212	7.3	208	7.1
3	2-3 standard reactors	32.3	25	1.7	174	11.9	130	8.9	144	9.8
4	4-8 standard reactors	36.4	23	2.5	109	12.0	79	8.7	117	12.9
5	>8 standard reactors	38.6	17	3.4	47	9.3	46	9.2	84	16.7

Source: (Olea-Popelka et al., 2004), Breakdown severity during a bovine tuberculosis episode as a predictor of future herd breakdowns in Ireland

0, 1, 2–3 and ≥4 depicts the number of standard reactors in Bovine Tuberculosis breakdowns, 1996–2000. (a) The number of herds in each exposure category with a specified number of standard reactors in the future breakdown. (b) Percentage of herds in each exposure category with a specified number of standard reactors in the future breakdown

Herd Size

The more cattle on the farm, the greater the probability of one of the cattle getting the infection. Generally, more extensive herds pasture on a large area, having a higher probability of having more contiguous herds, therefore, boosting the cattle-to-cattle spreading risk, as recommended by a study carried out in 1999. In addition, due to imperfection of skin test specificity, if the size of the herd increases, the false-positive reactor probability will be more (De la Rua-Domenech et al., 2006).

Lack of Diagnostic Test Performance

The SICCT and the Single Intradermal Tuberculin Test are still the international methods of field diagnosis of bTB (De la Rua-Domenech et al., 2006). Even if regulated, the testing of the skin has not always been processed as suggested due to the conditions of the management making it hard to progress. The test identified as IFN-c, the other widely used bTB diagnosis test, lacks perfect sensitivity and specificity (Whelan et al., 2006). According to the testing area, the specificity and sensitivity of the skin test vary widely (De la Rua-Domenech et al., 2006; Whelan et al., 2006).

Clinical signs of Bovine Tuberculosis

When an animal is contaminated with M.bovis, the pace of progress of the disease is subject to various elements, including the irresistible, infectious portion and the resistant status of the host. The signs and severity of the illness fluctuate depending on the body framework most impacted; however, clinical indications of infection in cattle often show in enhanced cases and might be vague. This makes clinical instances of TB hard to detect. The signs include weakness, swelling of various lymph nodes, respiratory distress and persistent cough, and loss of condition and appetite. Involvement of the udder is rare; however, the infection can lead to progressive hardening of the affected quarter and enhancement of the top of the udder lymph nodes. In these cases, the cattle may be detected in the milk samples (Scottish Government, 2018). According to (Neill et al., 2001), individual cattle infected by Tuberculosis can vary markedly in pathology and clinical presentation. The infection is generally a chronic disease; however, it can occasionally be acute and rapidly progressive (Wadhwa et al., 2006).

The environmental situations of the animal that is already affected may cause more pronounced clinical effects. Stressful conditions like post-calving and malnutrition can boost the probability of clinical signs. Clinical signs differ according to the location site; it can be situated either in liver, lungs, spleen and bones, yet it has a subclinical, more extended period, ranging from some months to many years. Likewise, its signs are often asymptomatic (Dlamini, 2013). According to (Renwick et al., 2007), it can take years to develop clinical symptoms and spread of M. Bovis within the animal, especially in ruminants. The specificity of the clinical signs depends on the organ/tissue localization of the dissemination of post-primary infection. Organs and tissues usually affected include the digestive system, respiratory tract, udder, and others (Dlamini, 2013).

PCR Intervention

PCR, or Polymerase chain reaction method is one of the fast and most sensitive detection tools that can be utilized to diagnose the agents in clinical samples within 48 hours; however, the inhibitors present in the sample can restrict its performance (Haddad et al., 2004). On the other hand, Tuberculosis has benefited from numerous major implementations in diagnosis, immunopathology, vaccination and treatments; thus, this progress will promptly enhance and improve diagnostic treatments (Brady et al., 2008).

Detecting Bovine TB

Identification of the Agent

In animals like cattle, evidence of Tuberculosis clinically is usually lacking unless very pervasive lesions have been developed. Due to this, the diagnosis for each animal and its elimination program was impossible before the tuberculin development by Koch in 1890. A concentrated sterile culture filtrate named Tuberculin of tubercle bacilli developed on beef broth that has been glycerinated and on a synthetic media provides a solution for detecting the disease. Immunological acknowledgements of the infectious M. Bovis in cattle continue to be premeditated to establish alternative and improved methods of diagnosis, as testing

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of the skin method sometimes has practical disadvantages (OIE, 2018). The gamma interferon test has been used as a blood diagnostic test for cattle infected by Tuberculosis and other animals such as buffalo and goats. This test is also commercially available (Buddle et al., 2001). Examining stained smears or sections of tissues may illustrate the presence of M. Bovis in post-mortem and clinical specimens, which can be clarified by the cultivation of organisms on media of primary isolation. The collected containers must be sterilized to prevent contamination which can fail to identify M. Bovis (Cousins and Florisson, 2005).

Microscopic Examination

According to (OIE, 2018), M. Bovis could be detected microscopically on smears from clinical samples and on prepared materials of tissues. The Ziehl–Neelsen stain usually is used to determine the acid fastness of M. Bovis; however, a fluorescent acid-fast stain can also be used to detect the fastness. In addition, the probable mycobacteriosis diagnosis may be made if there are histological lesion characteristics in the tissues. However, lesions being often paucibacillary, acid-fast organism presence in the histology sections may not be detected, even though M. Bovis can be isolated in culture.

Nucleic Acid Recognition Methods

According to (Huard et al., 2003; Niemann et al., 2000; Parsons et al., 2002), "accelerated determination of isolates to the alignment of M. Tuberculosis complex could be built by the complexity of Gen-Probe TB DNA probe or polymerase chain reaction (PCR) targeting 16S–23S rRNA, the insertion sequences IS6110 and IS1081, and genes coding for M.-tuberculosis-complex-specific proteins, such as MPB70 and the 38 kDa antigen b have been used. In addition, specific identification of an isolate as M. bovis can be made using PCR targeting a mutation at nucleotide positions 285 in the oxyR gene, 169 in the pncA gene, 675/756/1311/1410 and 1450 of the gyrB gene and presence/absence of RDs (Regions of Difference)".

The test used for Bovine TB Detection in Fiji

Shambled monitoring subsists in inspecting the carcass for tubercle lesions by meat inspectors indulged by the Government at the two significant abattoirs of FMIB (Fiji Meat Industry Board) situated in Nasinu, Central Division and Vuda, Western Division (FVPL, 2010). As a result, organs that have been affected or the whole carcasses are convicted based on tubercle lesions' location and severity (AH&P, 2015).

Testing of Intradermal Tuberculin

According to (Thoen et al., 2008), effective and reliable diagnosis is a significant concern among several veterinarians. TST (Tuberculin skin test) or Intradermal tuberculin test strategy is established by purified protein derivative (PPD) injection in smaller amounts and aligning the swelling of the dermal three days after the injection. Culture filtrate of M. Bovis in the medium of synthetic liquid by the precipitation with trichloroacetic acid or ammonium sulfate is used to prepare for PPD. The antigen is injected into the neck area since it is more prostrate to hypersensitive reaction related to Tuberculin (Schiller et al., 2010). Due to its affordability, the intradermal test is mainly used. (Ramos et al., 2015; Schiller et al., 2010). However, this test is identified to be lacking in specificity and sensitivity. According to (Mishra et al., 2005), host-related extrinsic and intrinsic factors like tuberculin quality, weak immunity of cattle, and the diagnosis technique being used can lead to false-positive results, giving unnecessary culling of cattle that are healthy and thus, leading to economic loss.

Post-Mortem Diagnosis

Diagnosis of Bovine Tuberculosis through post-mortem or pathologic diagnosis is accomplished during carcasses sanitary inspection in a slaughterhouse. Examination of carcasses is done to confirm M. Bovis infection, which has eventually become a regular diagnosis to control disease transmission for human-related cases, mainly due to infectious meat consumption (Sa'idu et al., 2015). The trait formation of granulomas, which is yellowish in color (Figure 3) in mycobacteria, is utilized for bovine tuberculosis diagnosis (Sa'idu et al., 2015). According to (De Kantor and Ritacco, 2006), the tubercles usually occur in

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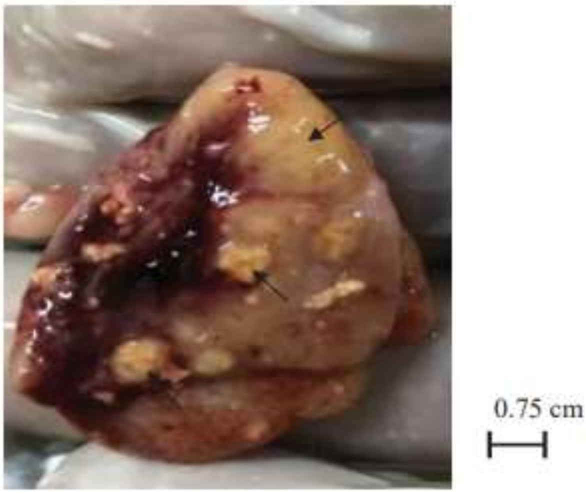
the lymph nodes around the cattle head and thorax area. Likewise, they are found in the spleen, liver, lungs, and body cavity surfaces. Figure 3 shows the tuberculosis lesions in lymph node tissue samples of cattle that have been infected, collected from an abattoir in Fiji, at the post-mortem examination of cattle that illustrated positiveness when the tuberculin skin test was used.

Figure 3. Tuberculosis Lesions in Lymph Node Tissue Sample



Source: Zafiar Tasmeen Naaz. (2018). Standardization and Application of a Polymerase Chain Reaction (PCR) for Determining the Occurrence of Bovine Tuberculosis in Raw Milk Samples.

Bacterial Culture

M. Bovis identification from culture depends traditionally on the morphology of the colony followed by a series of biochemical testing (Kubica *et al.*, 2006). The two types of media that most labs recommend for primary isolation are either agar-based or egg-based (Adams, 2001). It is crucial to ensure that the use of the chemicals for decontamination assists in growth prevention of other bacteria but should have minimum of toxic effects to M. Bovis to retain bacteria of interest at the maximum rate. (Dundee *et al.*, 2001) said, "Quaternary ammonium compounds, sulfuric acid, sodium hydroxide (Petroff method), oxalic acid and hexadecylpyridiumchloride (HPC) can be used at various concentrations for decontamination since they have reliable sensitivity and specificity depending on the type of specimen being investigated".

Microscopy Histo-pathology

Ziehl-Neelsen (ZN) staining technique (Riello et al., 2016) is utilized for mycobacteria detection in a sample, hounded by fluorescence microscopy and light microscopy examination. (Marais et al. 2008).' s research proposed that auramine O staining is more specific and sensitive when compared to the ZN staining technique. However, despite its low cost and simplicity, there are many disadvantages of implementing this method, as it fails to determine or detect mycobacteria reliably at all phases of infection because of cell wall modification in persistent mycobacteria (Strohl et al., 2001). Therefore, ZN is primarily used for presumptive tests because non-viable and viable cells cannot be varied (Thoen et al., 2008).

Economic Implications

Bovine Tuberculosis acts as a crucial burden in the economic sector to the societies, which is mainly linked with lower productivity of infected animals, international trade of animals and

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restrictions in animal products, and eradication and control programs (Ayele et al., 2004). According to (Thoen et al., 2006), reduced milk and meat production are significant productivity losses in cattle. The milk production is less compared to those animals that are un-affected. Failure in meat production is split into losses in beef processing caused by illness slaughtering, negligence in processing caused by average slaughter, and a decrease in meat production. (Thoen et al., 2006). The disease has a vast detrimental effect on the development of the socio-economy, which also influences the national economy (Senedu et al., 2008).

There are relatively no control programs implemented in most developing countries. Bovine Tuberculosis causes extreme economic losses, generally in peri-urban and urban cross breed dairy cattle because of mortality, lower productivity, carcass condemnation, and international trade restrictions (Amanfu, 2006). In addition, in some locations, the disease may pose a severe threat to endangered wildlife species (OIE, 2006). In industrialized nations, Bovine tuberculosis regulatory programs are based on the inspection of the meat combined with testing of skin and slaughtering of positive animals (Reviriego-Gordejo and Vermeersch, 2006). According to (Reviriego-Gordejo and Vermeersch, 2006; Schiller et al., 2011), these programs' economic implications are relatively high, yet, they are justified regarding public health and safety of food products, and Bovine tuberculosis elimination is treated as a crucial objective that needs to be achieved.

Management of Bovine TB in Fiji and Government Intervention

A retrospective study was carried out in Fiji on Bovine Tuberculosis in cattle (Borja et al., 2018). This review provided a case study on the control of bTB in an infected cattle population. In addition, it outlines the methods and results of a retrospective study of the Bovine tuberculosis control program (BTEC) in Fiji from 1999 to 2014. With Australian Government support, dairy farm registration, monitoring of cattle movement, and necessary bTB testing were implemented with ear tagging of tested cattle. These actions identified the property, tagged animals, and vigilance programs in the United Kingdom (European Union, 2014) and Australia (More and Good, 2015). Yet, the annual cattle farm registration requirement is space for dairy farms as the basis for the legal sale of raw milk and milk products, with only a few herds of beef being registered voluntarily. Therefore, testing on the field was done annually even though there was inconsistency between farms (Borja et al., 2018).

According to (Borja et al., 2018), the SID (Single Intradermal Test) using protein derivative antigen that is already purified from M. Bois is commanded at the caudal fold of the tail (CFT) with the outcome that was read three days after administration. Up till September 2014, a positive conclusion was determined by a wheal presence not less than 4mm in diameter. The Ministry of Agriculture in Fiji logged all books and handwritten data collected in a government stock room. Thus, there wasn't any protocol being written for standard data management and analysis, and no data were systematically analyzed to enhance the progression of bTB control over time. Instead, annual and quarterly reports were adapted based on the manual record counts. Appointed responsibility for the bTB program conduction was at the alignment of the division offices from 1999-to 2010 to boost surveillance coverage. This was eventually constitutional to the national office in 2011 to improve the quality of testing and monitoring (AH&P. BTEC Strategic Plan, 2018). The Figure below shows the total number of cattle being tested at each division in Fiji to evaluate and improve bTB control strategies.

Figure 4. Total Number of Cattle Tested and Number of Btb Tests Positive by Each Division in Fiji (1999-2014)

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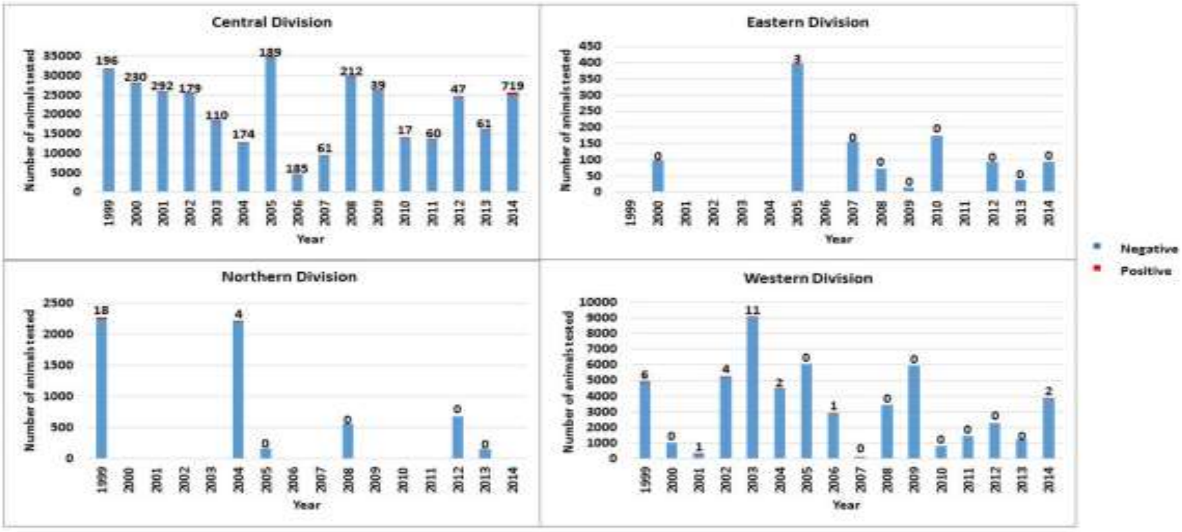

Source: (Borja et al., 2018), A retrospective study on bovine Tuberculosis in cattle on Fiji: Study findings and stakeholder responses.

The Biosecurity Authority of Fiji also implemented and raised awareness for farmers to consider BTEC program strategies to reduce the risk of bTB. For better management, they suggested practising culling of older and non-productive cattle that are unhealthy as chronic TB infections or old age cattle with a weak immune system do not always react to the testing of TB. Removing these cattle from a farm will assist in declining the risk of TB spreading to cattle that is healthy. Likewise, selling, culling non-bred bulls, or castrating will also help. The ratio of bull to cow must be 1 to 30. This assists in decreasing the breaking out/straying to neighbouring herds of bulls. The biosecurity also suggested that if farmers keep bull/steers that are non-breeding, they should be managed separately from milking heifers and herds to improve their management plans and allow a safer, more effective place for tuberculosis testing (Biosecurity Authority of Fiji, 2020).

Fiji's BTEC Program Coverage

The population numbers of cattle reported to the OIE and FAO recommended estimating the coverage of the population by the BTEC program were regarded unreliable before the year 2011 due to the procedure used to calculate the reported numbers that were not documented (OIE, 2015). The population of cattle reported to the OIE from 2011 to 2014 was based on collated data by a government veterinarian that ranged between 40,008 and 44,388 cattle. Thus, the cattle testing percentage ranged between 33.6 and 74.0%, with variation between years that usually arises from alterations in the number of tested cattle. The total cattle tested was marked low in 2004, 2006, 2007, 2010, 2011 and 2013, and for 2010 this levelled with a reduced budget compared to the previous year (Borja et al., 2018).

Regulation of Cattle Movement

There was an implementation of post-cyclone Winston disaster response done by the Biosecurity Authority of Fiji on 3 March 2016, whereby the live animals were implemented to discourage movement of livestock without former approval from the BAF (Biosecurity Authority of Fiji) or the Fiji National Disaster Management Office (BAF, 2016). On 13 January 2017, under Biosecurity Act 2008 section 77, the whole nation was defined as an emergency area of biosecurity for bTB (Government of Fiji, 2017).

Documentation on the Strategy of Fiji Brucellosis and Tuberculosis Eradication

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This strategy was further finalized and refined by the Ministry of Agriculture in early 2018. The proposal of this strategy involved recommendations and reviews on the hygiene of meat, control methods of bTB and selection of diagnostic tests by a technical team under the Government of Chile funded project called "Strengthening the institutions responsible for the inspection and certification of agricultural products, and the coordination of the national system of food safety in Fiji" (MOA, 2017). The BTEC Strategy of Fiji aims to eliminate bTB and brucellosis by 2037 (Borja et al., 2018). Table (5) predicts the requirements that need to -be implemented to encourage and strengthen BTEC program strategies in Fiji.

Table 5. Factors Contributing to This Situation and Recommendations to Strengthen the BTEC Program in Fiji

Factor	Related to	Main recommendations
Insufficient consistency in the number and location of farms tested between years	Changes between years in the government budget for the BTEC program, e.g. reduction in 2006–2007 following the political crisis in 2005/2006. Changes between years in budget allocation for bTB in the BTEC program, e.g. reduction in 2009–2010 due to response to brucellosis detection after 13-years of the absence of detections (7). An insufficient number of BTEC field staff to conduct SID testing. No interrogation of BTEC records to inform plans for on-farm testing.	Ensure a consistent, adequate annual budget allocation for the BTEC program and the bTB component. Ensure an adequate number of BTEC field staff. Implement a planning process for the BTEC program based on regular interrogation of bTB records with veterinary oversight. Establish a national database for data storage, manipulation and reporting.
Standard operating procedure for reading of SID test	Negative designation for any reaction at the injection site <4 mm across all farms irrespective of status (unknown, infected, clear) will have led to a false-negative result for some infected animals, such as cattle with chronic infection subsequently identified with tubercule lesions at abattoir carcass inspection and have impeded clearance of disease from infected farms.	Review of the SOP for reading of SID test, particularly for known infected farms.
Inconsistent application of SOP for SID testing	Inadequate training and supervision of BTEC field staff.	Provide adequate training for BTEC field staff. Ensure adequate veterinarians in the BTEC program to supervise field staff.
Inconsistent application of SOP for test and cull, and	Inadequate training and supervision of BTEC field staff.	Provide adequate training for BTEC field staff. Ensure adequate veterinarians in the BTEC program to supervise field staff.

quarantine on infected farms		
Unregulated cattle movements	Inadequate specification and implementation of cattle movement regulations.	Review of regulations on cattle movement administered by Biosecurity Authority of Fiji. Improve implementation of rules by the Biosecurity Authority of Fiji and consider the involvement of harmonization with the Ministry of Agriculture in implementation.
Stray cattle	Presence of stray cattle (untethered owned and unowned cattle are grazing freely on public land and intruding on private land) acting to maintain infection in known infected areas.	Review of regulations on stray cattle administered by Biosecurity Authority of Fiji. Improve implementation of regulations by the Biosecurity Authority of Fiji.

Source: (Borja et al., 2018), A retrospective study on bovine Tuberculosis in cattle on Fiji: Study findings and stakeholder responses

Way Forward

According to (Heidi Fradette, 2020), incrementing voluntary screening in Fiji will assist since an unknown issue cannot be solved. Currently, Fiji has a screening program (BTEC); however, it doesn't include minor herd inspection. Thereby, farmers with a smaller herd of animals are left out, and their operations are at high risk of zoonotic disease. The BTEC program uses the Caudal Fold Test (CFT), whereby injection of Tuberculin is placed under the tail. After 72 hours, the animals are checked to notice if they are swelling. If so, this illustrates the positivity of the infection on the animal; thus, they are sent to slaughter. The CFT test likewise requires two days of chute work which is when the animals must be contained and run through a chute to conduct the test. Therefore, this is unideal for most Fijian farmers who do not possess chutes. It is not affordable, and it works for accurate testing.

With the advancement of field testing and control in the cattle movement, contingency for Along with improvements to field testing and cattle movement control, opportunities for synchronously enhancing the capacity of laboratory diagnosis for Bovine tuberculosis early determination and other necessary diagnoses have been seen (Borja et al., 2018). To support diagnostic testing capacity in Fiji, several BTEC managers and veterinarians have implemented a lab network with India, New Zealand, Thailand, and Australia. Furthermore, under discussion, the OIE (World Health for Animal Health) is providing funds for a lab twinning program between the (QIA) – Animal and Plant Quarantine Korea and FVPL for proficient testing and training for laboratory management (OIE, 2015). Furthermore, the rising issues of the potential contribution of zoonotic Tuberculosis to the human tuberculosis burden in the nation, the Ministry of Agriculture associated with the Fiji Ministry of Health and Medical Services and the University of Sydney adjourned by the Institute of Marie Bashir will begin analyzing the geospatial of human tuberculosis cases and infected cattle farms, conduct surveillance of TB of livelihoods in determining high-risk locations for Bovine tuberculosis exposure, and sending samples from extra-pulmonary cases of humans and cattle issues for determination of species (WHO, 2016).

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According to (Lyon et al., 2004), managing farm sanitation will help control the spread of diseases such as bTB. Transmission of infection will be higher if M. Bovis is ingested through contaminated feeds or water. Several health issues arise from poor sanitation. Most of the farms in Fiji do not possess clean drinking water for cattle, and also some farms have a sharing procedure from the same water tank by all farm animals, which later on leads to increased transmission of the Disease (Humblet et al., 2009). According to (Fine *et al.*, 2011; Waters & Palmer, 2015), feed storage is one of the most crucial factors that needs to be considered. Bovine Tuberculosis and many other diseases can spread quickly due to contamination. Feeds that contact wet floors or rain may also be contaminated with a high level of bacteria. Some storage barns in Fiji are under the same shade as the milking shelter; thus, when the milking shed is washed, there is a probability that faeces and urine can get carried out into the storage barn, which eventually boosts the risk of contamination as well. Therefore, it is crucial to follow proper sanitation procedures to protect animals from being infected by the disease.

Conclusion

bTB remains a major in Fiji with both economic and financial effects. The understanding of the disease has been improved among farmers, yet there has not been much advancement in detecting bTB. Now, farmers are attentive to the occurrence of the disease and the harm it may do to their farms. Intensification of practices in the agricultural sector, like the presence of more dairy farms in Naitasiri and Tailevu compared to other areas of Vitilevu, could be significant factors for the inevitable rise in the infection in those areas. Thus, the Ministry of Agriculture and Biosecurity Authority of Fiji combine to eliminate Bovine Tuberculosis. In 2016, after the strike of Winston, BAF stopped the movement of cattle and calves to assist in preventing the spread of the disease. Test betterments and more consistent tests are mandatory to identify the affected farms and reduce the risk of transmission in Fiji. Fiji possesses a well-advancement method of test detection that has been used for decades. Yet, the disease is still emerging on farms, which illustrates that this detection method is insufficient. Thereby, it is a need to enhance the detection process, perform proper sanitation practices and monitor the movement of animals to help the nation eradicate the disease

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