

Prevalence of mastitis in smallholder dairy cattle in Pemba island, Tanzania

T.S. Suleiman¹, E.D. Karimuribo² and R.H. Mdegela²

¹Department of Veterinary Services, Ministry of Livestock and Fisheries, P.O. Box 295, Zanzibar, Tanzania. ²Department of Veterinary Medicine and Public Health, Sokoine University of Agriculture, P.O.Box 3021, Chuo Kikuu, Morogoro Tanzania.

Email: talib2001@yahoo.com

SUMMARY

A cross-sectional study was conducted from July to September 2010 to establish the prevalence of mastitis in smallholder dairy cattle in Pemba Island. The study also assessed factors contributing towards the increased occurrence of bovine mastitis in those dairy farms. Simple structured questionnaire survey, California Mastitis Test (CMT) and bacteriological culture were carried out to determine the magnitude and risk factors of clinical mastitis (CM) and subclinical mastitis (SCM) on 93 dairy households randomly selected from four districts of Pemba. A total of 643 milk samples from 163 lactating dairy cows were tested. The prevalence of clinical mastitis (CM) at farm level was 45.2% while at cow level was 31.3%. The prevalence of subclinical mastitis as defined by CMT was 66.7% at farm level, 55.8% at cow level and 34.4% at quarter level. The prevalence of intra-mammary infection based on bacterial isolation was 68.4%, 56.86% and 35.7% at farm, cow and quarter level respectively. Herd size, number of lactating cows, age of the cow, lactation stage and amount of milk produced per cow per day and number of parity were the risk factors identified to influence the prevalence of both clinical and subclinical mastitis. Mastitis pathogens isolated from 429 milk samples submitted for bacteriological culture include *Staphylococcus epidermidis* (71.5%), *Staphylococcus aureus* (7.2%), *Streptococcus* spp. (1.3%), *Klebsiella* spp. (5.2%) and *Escherichia coli* (6.5%). The findings revealed that the prevalence of both clinical and subclinical mastitis in smallholder dairy cattle in Pemba Island is high and appropriate control measures need to be devised.

Keywords: crossbred dairy cow, risk factors, smallholder dairy farmers, udder infection.

INTRODUCTION

Smallholder dairy production is the only reliable source of milk in Pemba Island. The smallholder dairy producers have taken over the business after collapse of the Government owned farms of Mtakata and Chamanangwe at the beginning of 1990s due to inefficiency caused by poor management (Mshangama and Ali, 1995). Average milk production of crossbred cows under zero grazing system is estimated to be 8 kg per cow per day while those kept under semi-intensive system is estimated to be 6 kg per cow per day (Biwi, 1987). This low level of production is attributed to many factors including diseases such as mastitis.

Mastitis which is an inflammation of mammary glands is characterized by changes in the udder and in the milk regardless of its causes (Radositits *et al.*, 2000; Shabbir *et al.*, 2009). Clinical mastitis is characterized by changes in the udder that include swelling, heat, pain and indurations that can be observed during udder palpation and changes in milk that include discolouration and presence of clots or flakes in the milk of infected quarter. Subclinical form of mastitis cannot be diagnosed during physical examination of infected udder or by visual examination of udder or milk contents (Radositits *et al.*, 2000). There are several forms of mastitis in dairy cattle. Contagious mastitis is transmitted from one infected quarter to other quarters or to another cow during milking while in environmental mastitis, the cows become infected when they come in contact with opportunistic pathogens

from contaminated environment (Kudi *et al.*, 2009). However, it is difficult to differentiate the isolated pathogens based on this classification (Haas *et al.*, 2005). Clinical Mastitis can be classified as acute, chronic or gangrenous mastitis based on the nature of inflammation (Radositits *et al.*, 2000).

The prevalence of CM in other part of Tanzania was described by Mdegela *et al.* (2004) in a study conducted in Kibaha and Morogoro where 80.2% of the farmers interviewed reported having at least one case of CM for the period of two years before the study but 22.4% of farms at Kibaha and 25% at Morogoro found to have at least one case of CM. In Tanga and Iringa, 14.2% of farmers interviewed reported CM for the period of one year before the study while 28.6% of the farmers in Iringa and 16.8% in Tanga reported the signs of CM during the study (Karimuribo *et al.*, 2006). The prevalence of subclinical mastitis in other parts of Tanzania was 90.3% in Dar es Salaam (Kivaria *et al.*, 2004), 75.9% in Tanga and Iringa (Karimuribo *et al.*, 2008), 74.5% at Kibaha and Morogoro (Mdegela *et al.*, 2004) and 68% in Unguja (Gitau *et al.*, 2003).

Different factors have been identified to increase the occurrence of both clinical and subclinical mastitis in dairy cattle. Madut *et al.* (2009) in Sudan identified cow's age, lactation stage, tick infestation and presence of teat lesions as risk factors for increased occurrence of bovine mastitis. In Ethiopia, Getahun *et al.* (2008) reported teat lesion, parity and lactation stage to have an effect on occurrence of subclinical mastitis. In

other parts of Tanzania, Kivaria *et al.* 2004 identified water scarcity, barn size, calf suckling, uses of single towel and number of labourers as risk factors that determine the occurrence of bovine mastitis, while Karimuribo *et al.* (2008) observed high milk production, breed, age, stripped milking and brought-in cow as risk factors for the increased occurrence of SCM.

Economic effects of mastitis in dairy cattle can be accumulated from losses in milk production, treatment cost, decreased milk quality, premature culling of infected cow or change in the dairy herd management system, mastitis control programme and cost of continuing extension services to dairy farmers (Hogeveen, 2005; Petrovski *et al.*, 2006). The decreased of both quality and quantity of milk produced during SCM cannot not be easily observed by farmer due to the absence of clinical manifestation of mastitis. Even during CM, farmer can observe the loss from milk discarded during the disease and treatment of infected cow but the loss continues after the cow is cured and the milk produced stay below potential for the rest of current lactation without farmers' knowledge. Due to the wide range of pathogens causing mastitis, consumption of unpasteurized milk from infected cows can cause public health hazard in human. Presence of bacterial pathogens like *Staphylococcus* spp., *Streptococcus* spp and *E. coli* from infected cows can cause disease or even outbreak in human consumed raw milk (Hameed

et al., 2006). In addition, the extensive use of antibiotics to treat CM can lead to major public health concern if proper withdrawal period is not observed. The effects can be either by causing allergic reaction to people sensitive to some antibiotics or causing resistance and failure of some antibiotics to treat common disease in human.

Since the evaluation of mastitis status in Pemba Island had never been done, this study was designed to establish baseline information of mastitis and the associated risk factors among dairy cattle in Pemba. Specifically, the study intended to; a) determine the prevalence of clinical and subclinical mastitis in dairy cattle, b) assess risk factors contributing to the occurrence of mastitis in dairy cattle and c) isolate and identify bacterial pathogens associated with mastitis in dairy cattle.

MATERIALS AND METHODS

Study area and design

A cross-sectional study was conducted between July and September 2010 to establish the prevalence of CM and SCM in dairy cattle in Pemba Island of Zanzibar in the United Republic of Tanzania. All four districts of Pemba Island which are Micheweni, Wete, Chake Chake and Mkoani were included in the study. The laboratory work was conducted at the Faculty of Veterinary Medicine Sokoine University of Agriculture (SUA), Morogoro, Tanzania.

Sampling and data collection

Questionnaire interview at household level involving 93 respondents from participating dairy farms. Physical examination of 163 lactating cows, cow side test of SCM using California mastitis test (CMT) to 643 quarters and milk sampling for bacterial isolation were also conducted. The participating farms were obtained by using two stage sampling procedure, the first stage was the selection of participating Shehias from each district, where five Shehias from each district were randomly selected from a list of all Shehia with dairy farming activities. The second stage was the selections of dairy farms, where 93 dairy farms were randomly selected based on the proportion of dairy cattle in the selected Shehias as prepared by field assistants. At each of the selected dairy farm, the owner or other family member was interviewed using a structured questionnaire in which important information regarding farm characteristics, herd management, milking procedure, cows characteristics and farmer's knowledge on both CM and SCM were collected. The information collected was compared with the current prevalence of both CM and SCM in the farm in order to establish risk factors contributed to the increased mastitis prevalence in the island.

Screening for mastitis

Each lactating cow from all selected dairy farms was subjected to mastitis

screening procedure. Physical examination of the udder and teat was done to assess malformation, presence of gangrene, blind teat or any other signs of CM. Milk consistency and milk colour were also observed. Each lactating quarter was also screened for SCM using CMT field test whereby fresh milk taken direct from each quarter were mixed with equal amount of CMT reagents in pad. The results were classified as negative (N), Trace (T), +1, +2 or +3 depending on the jelly thickness formed. After CMT screening each teat was cleaned using fresh water, dried and disinfected using a piece of cotton wool soaked in 70% alcohol as described by Quinn *et al.* (1994) and about 5 ml of milk samples was collected separately from each quarter into a sterile universal bottle and labelled. The samples were stored in a cool box with ice packs to maintain the temperature at 4-8°C and transported to Chake Chake veterinary laboratory where they were kept deep frozen until when were transported to SUA for bacteriological diagnosis.

Laboratory diagnosis

Bacterial isolation was performed by culturing a portion of each quarter milk sample on Blood and MacConkey agar media. The culture was incubated at 37°C for 24 hours using the standard procedures described by Quinn *et al.* (1994). The macro-morphology of isolated microorganisms was observed and subjected to Gram staining technique to describe their

micro-morphology characteristics. For identification of species isolated, biochemical tests were conducted as described by Sheryl and Whitlock (1999). Negative samples after 24 hours were re-incubated for 48 to 72 hours followed by macro and micro-morphological observation of organism as described above.

Data analysis

Data storage and analysis was done using Epiinfo® version 3.5.1 2008 for window (CDC, 2008) where descriptive statistic and logistic regression analysis were performed. Graphical presentations were prepared using Microsoft Excel 2007. Test for significance of categorical data was done using Chi Squared (χ^2) test. Logistic regression analysis was conducted to identify farm and animal level categorical and continuous explanatory variables which significantly influenced the outcome variable. In this analysis, an outcome variable was defined as the presence or absence (i.e. binary variable) of either CM or SCM based on positive reaction to CMT or bacteriological culture. Prevalence of CM was calculated

at farm and cow levels while the prevalence of SCM was calculated at farm, cow and quarter levels using results from CMT screening test and bacteriological isolation. Prevalence of CM and SCM was calculated using the formula described by Thrusfield (2005).

RESULTS

Screening of animals for subclinical mastitis by CMT

In this study, a total of 652 quarters were examined for soundness, 616 (94.5%) teats were found to be normal in shape and consistence, 15 teats (2.3%) were found to be hard and not producing milk, 9 teats (1.4%) were blind.

Prevalence of clinical mastitis

The prevalence of CM at farm level was 45.2% while at cow level it was 31.3%. Although the prevalence was higher in Chake Chake and Wete districts compared to Micheweni and Mkoani districts, the differences were not significant between the districts.

Factors that influenced the occurrence of clinical mastitis

Based on univariate regression analysis, factors that increased the occurrence of CM at farm and cow levels were herd

size ($P<0.01$), number of lactating cows in the farm ($P<0.01$), lactation stage ($P=0.01$), amount of milk produced per cow per day ($P<0.01$) and number of parity ($P=0.01$) as shown in Table 1.

Table 1. Factors that influenced the prevalence of clinical mastitis and subclinical mastitis based on Logistic Regression Analysis

Variable	β^*	(S.E.) [†]	95%	C.I. [‡]	P-Value
Factors that influenced the prevalence of CM					
Farmers' Age (n=93)	0.0274	0.0241	0.9803	1.0775	>0.01
Herd size (n=93)	0.3248	0.1150	1.1046	1.7334	<0.01
Number of lactating cows (n=93)	0.8088	0.2582	1.3536	3.7241	<0.01
Cows age (n=163)	0.1042	0.0572	0.9920	1.2415	>0.01
Lactation stage (months) n=163	0.1241	0.0482	1.0301	1.2442	=0.01
Milk production per day (n=163)	0.1763	0.0498	1.0819	1.3149	<0.01
Number of parturitions (n=163)	0.1359	0.0669	1.0047	1.3060	=0.01
Factors that influenced the prevalence of SCM					
Herd size	0.4369	0.1428	1.17	2.0479	<0.01
Lactating cows	1.3925	0.3982	1.8442	8.7835	=0.01
Cows age	0.2555	0.0705	1.1245	1.4824	<0.01
Lactation stage (months)	0.1003	0.0477	1.0069	1.2137	>0.01
Milk production per day	0.1109	0.045	1.023	1.2203	=0.01
Number of parturitions	0.3011	0.0824	1.1498	1.5883	<0.01

* Regression Coefficient, [†] Standard Error, [‡] Confidence Limit at 95%

Prevalence of subclinical mastitis as defined by CMT

The prevalence of SCM based on CMT screening test was as presented in Table 2. The prevalence of SCM at farm and cow levels were higher at Chake Chake and Mkoani compared to Wete and Micheweni districts, however, there was no significant difference between these four districts, $P>0.01$ for farm level and $P>0.01$ for cow level. Prevalence of subclinical

mastitis at quarter level as defined by CMT screening test was relatively lower compared to prevalence at farm and cow levels. The quarter level prevalence was significantly influenced by district (Table 2).

Based on location of the quarter screened, 40.4% of right front quarters, 33.5% of right rear quarters and 32.3% of left rear quarters screened were found to be positive (n=161) while 31.3% of left front quarter screened were found to be positive (n=160). Although it was

observed that the right front quarters were more infected compared to other quarters, the difference between them was not statistically significant.

Factors that influenced the prevalence of subclinical mastitis

Based on univariate regression analysis, factors that influenced the prevalence of SCM as defined by CMT at farm and cow levels were as presented in table 1. Herd size showed significant influence on prevalence of SCM ($P<0.01$), hence the prevalence increased as the number of cows in the farm increased. The prevalence of SCM also increased with the increased number of lactating cows in the farm ($P=0.01$), increased average milk production of cows per day ($P=0.01$), age of the lactating cows screened ($P<0.01$), stage of lactation hence it was higher in cows in third lactation stage and above compared to the first and second stage ($P=0.01$) and increased number of parity hence subclinical mastitis was higher in cows with more than five parturitions ($P<0.01$). In addition, farmers' practices together with farm and cows characteristics that were observed during the study included training in dairy management and mastitis control, study location in terms of districts, education level and gender of farmer. Others were type of housing and type of floor, availability of water supply, participation of the owner in the cattle management activity, practice done before milking, use of dry cow therapy, number of milking per day, rearing system used and restriction in suckling. All of these factors showed no influence in the prevalence of subclinical mastitis.

Prevalence of subclinical mastitis as defined by bacterial isolation

Prevalence of SCM as defined by bacterial isolation was 68.3% at farm level ($n=60$), 55.9% at cow level ($n=111$) and 35.7% at quarter level ($n=429$). The prevalence of SCM at farm and cow level was higher at Mkoani and Wete districts compared to Chake chake and Mkoani districts but the difference between localities was insignificant. Prevalence of SCM at quarter level as defined by bacteria isolation was relatively lower compared to that at farm and cow levels (Table 2). The quarter level prevalence of SCM defined by bacteria isolation was higher at Mkoani district (49.1%) followed by Chake chake (36.8%) and Wete (33.4%) while Micheweni recorded the lowest prevalence (28%). The difference between location was insignificant ($P>0.01$).

Comparison of prevalence of subclinical mastitis as defined by CMT and bacteria isolation

Comparison of prevalence of SCM as defined by both methods, CMT and bacteria isolation, was done at farm, cows and quarter levels. At farm level, only 31 farms (51.7%) out of 60 whose milk samples cultured were positive to both methods while nine farms (15%) were negative to both. No bacteria were isolated from 10 farms that were positive to CMT while bacteria were isolated from ten farms that were negative to CMT field test. At cow level, a total of 38 cows (34.2%) out of 111 whose milk samples cultured were tested positive by both methods while 20 cows (18%) were negative using

both methods. Furthermore, bacteria were isolated from 24 cows (21.6%) that were tested negative using CMT while no bacteria was isolated from 29 cows (26.1%) that tested positive by CMT. Out of 429 quarter milk samples cultured, only 75 quarter (17.5%) were positive to CMT and bacteria isolation while 198 samples (46.2%) were negative to both methods. In addition, bacteria were isolated in 78 quarter samples (18.2%) that tested negative using CMT while no bacteria were isolated in 78 quarters samples (18.2%) that tested positive using CMT. There was association between CMT positivity and bacteria isolation

at all levels (OR=2.79 at farm level, OR=1.09 at cow level and OR=2.44 at quarter level) and it has been observed that it is more likely to isolate bacteria in CMT positive quarters (RR=1.73 and P-value<0.01).

Bacteria isolation

Bacteria that were isolated during the study included *Staphylococcus epidermidis* (71.2%), *Staphylococcus aureus* (7.2%), *Streptococcus spp* (1.3%), *Klebsiella spp* (5.2%) and *Escherichia coli* (6.5%). A total of 276 (64.34%) out of 429 samples cultured did not yield any bacterial growth.

Table 2. Prevalence of subclinical mastitis as defined by CMT screening test and bacterial isolation

	Study Area				
	Micheweni	Wete	Chake	Mkoani	Total
Prevalence of subclinical mastitis as defined by CMT					
Number of farms visited	15	32	31	15	93
Number of cows tested	27	53	63	20	163
Number of Quarter tested	108	208	248	79	643
Prevalence at farm level n (%)	8 (53.3)	19 (59.4)	24 (77.4)	11 (73.3)	62 (66.7)
Prevalence at cow's level n (%)	12 (44.4)	29 (54.7)	37 (58.7)	13 (65.0)	91 (55.8)
Prevalence at quarter level n (%)	24 (22.2)	77 (37.0)	96 (38.7)	24 (30.4)	221 (34.4)
Prevalence of subclinical mastitis as defined by bacterial isolation					
Number of farms examined	11	21	19	9	60
Number of cows examined	20	37	40	14	111
Number of Quarter cultured	75	144	155	55	429
Prevalence at farm level n (%)	5 (45.5)	16 (76.2)	13 (68.4)	7 (77.8)	41 (68.3)
Prevalence at cows level n (%)	9 (45.0)	23 (62.2)	20 (50.0)	10 (71.4)	62 (55.9)
Prevalence at quarter level n (%)	21 (28.0)	48 (33.3)	57 (36.8)	27 (49.1)	153 (35.7)

DISCUSSION

In this study both CM and SCM were found to be prevalent in all farms investigated in Pemba Island. The overall prevalence of CM was higher at farm level (45.2%) compared to cow level (31.3%). The prevalence of CM for the period of one year before the study at both farm and cow levels were low compared to what have been found in SCM. The prevalence of CM was found to be higher compared to other parts of Tanzania (Karimuribo *et al.*, 2005; 2006). Factors that influenced the occurrence of CM were herd size, number of lactating cows in the farm, lactation stage, amount of milk produced per cow per day and number of parity. The findings were similar to what was recorded in other studies (Oltenacu and Ekesbo, 1994; Getahun *et al.* 2008; Madut *et al.*, 2009).

The prevalence of SCM as defined by CMT was higher at farm level (66.7%) followed by cow level (55.8%) and lower at quarter level (34.4%). This was found to be higher than what have been observed in other part of Tanzania (Karimuribo *et al.*, 2008). The prevalence of SCM at cow level as defined by CMT was lower than what has been found in other parts of Tanzania (Gitau *et al.*, 2003; Kivaria *et al.*, 2004; Mdegela *et al.*, 2005 and Karimuribo *et al.*, 2008). Factors that influenced the prevalence of SCM as defined by CMT at farm and cow levels were herd size, number of lactating cows in the farm, age of the cow, lactation stage, amount of milk produced per cow per day, number of parity and breed of cow under investigation. These findings are in line

with what has been recorded in other studies (Oltenacu and Ekesbo, 1994, Getahun *et al.* 2008; Byarugaba *et al.* 2008; Madut *et al.* 2009). It is possible that increased number of lactating cows in the farm together with the increased amount of milk produced per cow per day may lead to increased labour and improper dairy farm management in terms of cleaning, use of disinfectant and handling of lactating dairy cows leading to the observed high prevalence of mastitis in the study area.

The prevalence of SCM based on bacterial isolation was higher at farm level (68.4%) compared to cow level (56.86%) and quarter level (35.7%). The prevalence at cow and quarter level as defined by bacteria isolation was higher than what was observed in other parts of Tanzania (Karimuribo *et al.*, 2008). Isolated pathogens were mainly *Staphylococcus epidermidis*, *Staphylococcus aureus*, *Streptococcus spp*, *Klebsiella spp* and *Escherichia coli* as classically isolated in other parts of Tanzania (Mdegela *et al.*, 2004; Karimuribo *et al.*, 2005; Kivaria and Noordhuizen, 2006). The bacterial isolation focused mainly on aerobic bacteria rather than anaerobic, therefore, there was a possibility of missing anaerobic bacteria and fungi as found in other parts of Tanzania (Mdegela *et al.*, 2005).

Comparison of CMT and bacteria isolation revealed different prevalences at farm, cows and quarter levels. Bacteria were isolated from 17.5% of the quarter milk samples cultured that were positive to CMT field test. On the other hand, bacteria were isolated from 78 quarter milk samples (18.2%) that were

tested negative to CMT; this might be due to the presence of intra-mammary infection (IMI) that did not provoke immune system to produce increased amount of Somatic Cell Count (SCC). Milk samples from 78 quarters (18.2%) were tested positive using CMT but no bacteria was isolated; this might be due to the presence of other factors rather than bacterial agents that provoke the immune system to increase the amount of somatic cell count in those quarters. About 46.2% quarter milk samples were negative to both methods; these quarters were considered negative to SCM with no intra-mammary infection. These findings were in line with other findings from other parts of Tanzania (Mdegela *et al.*, 2009). Furthermore the findings describe association between CMT positivity and bacteria isolation as described in other studies (Mdegela *et al.*, 2004; Karimuribo *et al.*, 2008).

In conclusion, high level of SCM was considered to be among the causes of poor milk production in dairy cows in the study area in terms of quality and quantity. Subclinical mastitis is considered as source of infection that may develop to CM causing destruction of milk secreting cells in the mammary gland and contribute to low milk production. To improve quality and quantity of milk produced in Pemba Island some efforts should be made to increase farmers' awareness on mastitis in dairy cattle, dairy farm management and hygienic milk production. Production and distribution of extension materials together with farmers' training on mastitis control and quality milk production may reduce the problem, reduce antimicrobial use and improve both quality and quantity

of produced milk. This will increase household's income and improve livelihood of those poor dairy farmers in the studied area.

ACKNOWLEDGEMENTS

Authors would like to extend their thanks to the ASSP/ASDP-L Zanzibar Sub-Programmes for sponsoring this research work and Mr P. Mkuchu of Department of Veterinary Medicine and Public Health, Sokoine University of Agriculture, Morogoro, Tanzania for his technical assistance in laboratory sample analysis.

REFERENCES

- Biwi KM. Strategies for improving the traditional livestock sector in Zanzibar. In: *Proceedings of the 14th scientific conference of the Tanzania Society of Animal Production, Arusha International Conference Centre*, 214 – 229, 1987.
- Byarugaba DK, Nakavuma JL, Vaarst M, Laker C. Mastitis occurrence and constraints to mastitis control in smallholder dairy farming systems in Uganda. *Livest Res Rural Dev* 20: 5. 2008 [<http://www.lrrd.org/lrrd20/1/byar20005.htm>] site visited on 17/7/2010.
- CDC. Epi Info™, a database and statistics program for public health professionals. CDC, Atlanta, GA, USA, 2008.
- Getahun K, Kelay B, Bekana M, Lobago F. Bovine mastitis and antibiotic resistance patterns in Selalle smallholder dairy farms, central Ethiopia. *Trop Anim Health Prod* 40: 261 – 268, 2008.
- Gitau GK, Waridi M, Makame HA,

- Saleh M M, Muhamed RA, Mkola AP, Haji MA. Occurrence of high udder infection rates in dairy cows in Unguja Island of Zanzibar, Tanzania. *Int J Appl Res Vet M* 1: 2003.
- Haas Y, Narkema HW, Schukken YH, Veerjamp, RF. Associations between somatic cell count patterns and the incidence of clinical mastitis. *Prev Vet Med* 67: 55 – 68, 2005.
- Hameed KGA, Sender G, Kossakowska AK. Public health hazard due to mastitis in dairy cows. *Anim Sci Pap Rep* 25: 73-85, 2006.
- Hogeveen H. Mastitis is an economic problem. In: *proceedings of the British Mastitis Conference, Stoneleigh*, 1-13, 2005.
- Karimuribo ED, Fitzpatrick JL, Swai ES, Bell C, Bryant MJ, Ogden NH, Kambarage DM, French NP. Prevalence of subclinical mastitis and associated risk factors in smallholder dairy cows in Tanzania. *Vet Rec* 163: 16 – 21, 2008.
- Karimuribo ED, Fitzpatrick JL, Bell CE, Swai ES, Kambarage DM, Ogden NH, Bryant MJ, French NP. Clinical and subclinical mastitis in smallholder dairy farms in Tanzania: Risk, intervention and knowledge transfer. *Prev Vet Med* 74: 84 – 98, 2006
- Karimuribo ED, Kusiluka LJ, Mdegela RH, Kapaga AM, Sindato C, Kambarage DM. Study on mastitis, milk quality and health risks associated with consumption of milk from pastoral herds in Dodoma and Morogoro regions, Tanzania. *J Vet Sci* 6: 213 – 221, 2005.
- Kivaria FM, Noordhuizen JPT M, Kapaga AM. Risk indicators associated with subclinical mastitis in smallholder dairy cows in Tanzania. *Trop Anim Health Prod* 36: 581 – 592, 2004.
- Kivaria FM, Noordhuizen JPTM, Nielen M. Interpretation of California mastitis test scores using *Staphylococcus aureus* culture results for screening of subclinical mastitis in low yielding smallholder dairy cows in the Dar es Salaam region of Tanzania. *Prev Vet Med* 78: 274 – 285, 2007.
- Kivaria FM, Noordhuizen JPTM. A retrospective study of the aetiology and temporal distribution of bovine clinical mastitis in smallholder dairy herds in the Dar es Salaam region of Tanzania. *Vet J* 173: 617 – 622, 2006.
- Kudi AC, Bray MP, Niba AT. Mastitis causing pathogens within the dairy cattle environment. *Int J Biol* 1(1): 3 – 13, 2009
- Madut NA, Abdel-Gadir AE, El Jalii IM. Host determinants of bovine mastitis in semi-intensive production system of Khartoum state, Sudan. *J Cell Anim Biol* 3: 071 – 077, 2009.
- Mdegela RH, Kusiluka LJM, Kapaga AM, et al. Prevalence and determinants of mastitis and milk-borne zoonoses in smallholder dairy farming sector in Kibaha and Morogoro districts in Eastern Tanzania. *J Vet Med Series B* 51 (3): 123–128, 2004.
- Mdegela RH, Karimuribo ED, Kusiluka LJM, Kabula B, Manjurano A, Kapaga AM, Kambarage DM. Mastitis in smallholder dairy and pastoral cattle herds in the urban and peri-urban areas of the Dodoma municipality in Central Tanzania. *Livest Res Rural Dev* 17: 123, 2005. [<http://www.lrrd.org/lrrd17/11/mdegel17123.htm>]. Site visited on

- 17/7/2010.
- Mdegela RH, Ryoba R, Kurimuribo ED, Phiri EJ, Loken T, Reksen O, Mtengeti E, Urio NA. Prevalence of clinical and subclinical mastitis and quality of milk on smallholder dairy farms in Tanzania. *J S Afr Vet Assoc* 80: 163-168, 2009.
- Mshangama RM, Ali SO. Milk producers role, needs and response to market demands and conditions in Zanzibar. In: *Proceedings; Workshop on Strategies for Market Orientation of Small Scale Milk Producers and their Organisations*, Morogoro, Tanzania. (Edited by Henriksen, J., Aboud, A.O.O. and Kifaro, G.C.) 104-112, 1995.
- Oltenacu PA, Ekesbo I. Epidemiological study of clinical mastitis in dairy cattle. *Vet Res* 25: 208 - 212, 1994.
- Petrovski KR, Trajcev M, Buneski GA. A review of the factors affecting the costs of bovine mastitis. *J S Afr Vet Assoc* 77: 52-60, 2006.
- Quinn PJ, Carter ME, Markey B, Carter GR. *Clinical Veterinary Microbiology*. Mosby, Elsevier Limited, London, 648 pp, 1994.
- Radositits OM, Gay CC, Blood DC, Hinchcliff KW. Mastitis in: *Veterinary medicine: a text book of the disease of cattle, sheep, pigs, goats and horse*. 9th edition, W B Saunders Co. Philadelphia, USA, 603-700, 2000
- Shabbir MZ, Rabbani M, Yaqub T, Ahmad A, Akhtar F, Muhammad K, Hussain M, Ahmad M. Trend in isolation and antimicrobial susceptibility of mastitis causing pathogens of Nili Ravi buffalo. *Pak. J Zool* 9: 273 - 279, 2009
- Sheryl A, Whitlock MA. Microscopic, cultural and other techniques for bacterial identification. In: *Essentials of diagnostic microbiology*. edited by Shimeld, L. A. Delmar publishers, Albany, USA. pp 87-100, 1999.
- Thrusfield M. *Veterinary epidemiology, third edition*. Blackwell publishing, Oxford, UK. 610pp, 2005.