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Småskalig mjölkproduktion i Zambia

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SUMMARY

Milk yield levels in dairy cows are influenced by many factors such as nutrition, breed, health status, management and environment. This study was conducted among small scale farmers in Zambia, where the climate can be dry for up to six months per year and cause a lack of green pasture for livestock and on-farm produced feed.

The purpose of this study was to identify management factors that can influence milk yield at small scale dairy farms in Zambia, and present advice that could improve productivity, without the need of expensive investments.

The study included semi-structured questionnaires presented to the farmers (n=29) including questions about cattle management and milk production. Testing of somatic cell count (SCC) with DCC (DeLaval Cell Counter) from herd milk samples (n=56) and observation of housing and animal body condition on-farm was also made.

The farms in this study had a mean milk yield of 6.9 liter per cow and day. A higher milk yield was found for farmers that in addition to grazing, supplemented their cows with forage and concentrates, especially if fed all year around and not only in the dry season. A majority of the herd milk tests (n=56) had a high SCC (64 % over 200 000 cell/ml) which indicate that udder infection were common.

The results indicate that an improvement in feeding (both energy and protein, as well as an improvement in udder health can improve milk yield for the herds in the present study

SAMMANFATTNING

Mjölkproduktionen hos mjölkkor påverkas av flera faktorer så som nutrition, ras, hälsostatus, skötsel och miljö. Denna studie utfördes i Zambia där klimatet kan vara torrt i upp till 6 månader per år, vilket orsakar brist på grönt bete för boskapen och även brist på foder som produceras på gårdarna.

Syftet med studien var att identifiera faktorer som kunde påverka mjölkproduktionen för småskaliga bönder i Zambia, och även ta fram rekommendationer på hur den kan förbättras utan dyra investeringar.

Studien utfördes med hjälp av semi-strukturerade enkäter där frågor om boskapsskötsel och mjölkproduktion ställdes till bönderna (n=29). Somatiskt celltal i besättningsmjölk testades också med DeLaval celltalsräknare (n=56) och observationer av djuren och inhysningssystem gjordes vid besök på gårdarna.

Resultatet visade en mjölkproduktion på 6.9 liter i medeltal i besättningarna. En högre mjölkproduktion sågs för bönder som utöver bete utfodrade sina kor med grovfoder och kraftfoder, i synnerhet om de utfodrade djuren året om och inte enbart i torrsäsong. En majoritet av mjölkproverna från besättningsproverna hade ett högt somatiskt celltal (64 % låg över 200 000 celler/ml) vilket indikerar att juverinfektioner var vanligt förekommande.

Sammanfattningsvis kan en förbättring av utfodringsrutinerna (både i energi och protein) såväl som en förbättring av juverhälsan på besättningsnivå öka mjölkproduktionen för besättningarna som ingick i denna studie.

CONTENTS

INTRODUCTION

Many factors influence milk yield levels in dairy cows e.g. nutrition, breed, health status, management and environment. Indigenous breeds that traditionally have been kept in sub-Saharan Africa, can cope well with the climate but does not give a high milk yield (Petersen *et al.*, 2003; Grimaud *et al.*, 2007; Hatungumukama *et al.*, 2007; Galukande, 2010; Kugonza *et al.*, 2011). The common indigenous breeds used in Zambia are Angoni, Barotse and Tonga (FAO & IAEA, 2015), yielding up to 5.3 liter/day (Mwenya, 2015). Crossing exotic breed with indigenous gives higher milk yield (Galukande, 2010) but both indigenous breeds and crosses demand sufficient management and feeding.

The climate in Zambia influences access to on-farm produced feed, water and pasture. The year is divided into three seasons; May to August is dry and relatively cold, September to November is characterized by dry and hot weather. The last season, December – April, is rainy and warm and can last up to six months per year (Utrikespolitiska institutet, 2011). This makes the climate dry for up to six months which means a lack of green pasture for livestock. The milk yield from grazing cows in countries with a long dry season, as Zambia, declines during that period together with a decline in body condition (Okello *et al.*, 2005; Johansson, 2013).

Small scale farmers in Zambia often start their dairy farming with the help of micro loans. The loans enable them to buy a small number of cattle and offer a way out of poverty. Still, the monthly income from milk is relatively low, in median 300 ZMK (Ndandula, 2011), that is comparable to 350 SEK (Ostermiller, 2014). Low income for farmers in poor agricultural communities puts focus on the need for low external-input technologies that do not demand capital input (Moser & Barret, 2003). Improvement in milk production at small scale farms may increase the farmers´ profits as well as animal health and nutritional status. For a higher milk production level to be obtained, animal health status, in particular udder health, as well as nutritional status and management need to be at a satisfactory level, which also can contribute to increased animal welfare. Therefore, the purpose of this study was to identify management factors that can influence milk yield at small scale dairy farms in Zambia, and present advice that could improve productivity, without the need of expensive investments. The study included semi-structured questionnaires presented to the farmers, testing of somatic cell count (SCC) from herd milk samples and observation of housing and animal body condition on-farm.

LITERATURE REVIEW

Factors that influence cattle milk yield

Feed

Cattle in sub-Saharan Africa are either held in free grazing, semi-grazing or zero grazing systems. In free grazing systems, cattle graze without any supplementing feed. In zero grazing, cattle are fed and kept in a confined space. Semi-grazing systems are a combination of free and zero grazing systems with grazing during daytime, and supplementing feeding in a confined space at a night. Free or semi-grazing systems are mostly used by small scale farmers, especially by those of lower wealth class (Rufino *et al.,* 2007). In semi-grazing systems, supplementing feed may be given and mainly consists of grass, hay (Rufino *et al.,* 2007) and other crop residues available (Ngongoni *et al.,* 2006) on the farm such as maize stovers, cowpea straw and soya bean straw. Concentrates given are for example maize bran, molasses (mixed with other feed), sunflowerseed cake and cottonseed cake (Pandey & Voskuil, 2011). These are often expensive and therefore inconsistently used, so protein and energy levels in the feed are often too low for lactating cows (Moran, 2005) because it is difficult to cover energy and protein requirements with grazing only. A lactating cow need 10-18 % crude protein depending on lactation stage (Moran, 2005), but natural Zambian veld (savannah) only give 11 % crude protein in the wet season and 3 % in the dry season. For maintenance needs, natural veld need to provide crude protein levels of 7 % (FAO, 1979) This makes natural veld at the dry season not even sufficient to provide the maintenance need of cattle (FAO, 1979). Concentrates can improve energy and protein levels in feed. Nutrient values of common concentrates are presented in table 1.

Table 1. *Nutritional values of common concentrates used by small scale farmers (Heuzé et al., 2015; Sauvant et al., 2015) in Zambia.*

Product	Dry matter (DM) (% as fed)	Energy (MJ/kg DM)	Crude protein (%)
Sugarcane molasses	73	14.7	5.5
Suflowerseed cake	89	19.4	32.4
Cottonseed cake	92.2	21.2	45
Maize bran	88.7	18.5	11.9

The energy requirements of cows depend on live weight, activity, pregnancy and milk production. Energy need to produce one liter milk is 4.5 -7.1 MJ of metabolizable energy (ME). For example, a 550 kg cow, 6 months pregnant, producing 13 liter milk, the daily energy need is 113 MJ (Moran, 2005). Natural veld in Zambia is low in energy, especially in the dry season (table 2), making it hard to cover energy needs with grazing only.

Table 2. *Dry matter and MJ energy in natural veld in Zambia in rainy and dry season (Simbaya, 2000)*

Natural veld in Zambia	Dry matter (%)	Energy (MJ/kg DM)	Crude protein (% DM)
Rainy season (nov-apr.)	25-39	16.5-9.4	8-4.2
Dry season (may-sept.)	51-73	3.8-2	2.1-1.5

Water intake and microbiological hygiene

Dehydration causes a decrease in milk yield (up to 30 - 40 % the first 48 hours, Silanikove *et al.,* 2000; Senn *et al.,* 1996) and also immediately reduce feed intake (Senn *et al.,* 1996) followed by a reduction in body weight (Little *et al.,* 1984). An acceptable microbiological quality of water is also important to avoid infectious diseases that influence feed intake and milk production levels, but the quality is seldom controlled at the farm and potential pathogens may spread due to fecal contamination of the water (Van Eenige *et al.,* 2013). Sufficient water intake also prevents dehydration, especially when cattle are exposed to heat stress (common in the subtropical climate of Zambia), where an increased respiration rate and sweating cause a loss of body fluid. Compared to other countries in southern Africa, Zambia has good access to ground and surface water (that covers 20 % of the country's surface) and cattle are watered at rivers, streams, dams and boreholes (Aregheore, 2009: Pandey & Voskuil, 2011).

Breed

The cattle breeds used in Zambia for milk production differs in milk yield. In one previous study made in the same geographical area as this study, the breeds used by small scale farmers were the indigenous (Angoni, Barotse and Tonga), exotic (Friesian, Holstein and Jersey) and crosses between these breeds (Olofsson, 2013). The indigenous breeds in Zambia are low yielding ranging from 1.9 – 5.3 kg/day and are seldom fed to maximize the production that their genetic potential could result in (Olofsson, 2013; Kaluba, 2015; Aregheore, 2009). Exotic crosses on the other hand can produce around 10 kg milk per day (Olofsson, 2013; Kaluba, 2015; Aregheore, 2009) but are in warm climates zones usually only receiving 45 – 60 % of the feed needed to maximize their genetic potential. In these areas, a combination of 50 % exotic and 50 % indigenous breed is the most economic profitable considering milk production (McDowell *et al.,* 1996) if the cattle is fed properly. Some characteristics of indigenous Zambian breeds are presented in table 3.

Table 3. *Some characteristics of indigenous Zambian breeds (FAO & IAEA, 2015)*

Breed	Angoni	Tonga	Barotse
Milk yield/lactation (kg)	990	850	1160
Weight at 3 years age (kg)	283	210	255
Geographical distribution	Eastern province	Southern province	Western province
Traditional usage	Cultural, draught power	Meat, draught power	Meat, milk, draught power

The benefits of indigenous breed in warm climates are higher resistance to heat stress (McDowell *et al.,* 1996), better udder health (Olofsson, 2013) and a lower tick burden (Wambura *et al.,* 1998) and thereby tick related diseases (Jonsson *et al.,* 2008). Ticks may cause a production loss as they irritate the animals and cause anemia. They may also spread diseases such as East coast fever (Makala *et al.,* 2003) that also lowers milk yield (Onono *et al.,* 2013). The tick load on cattle in Zambia is commonly suppressed by dipping or spraying the cattle (Makala *et al.,* 2003).

Effect of calf management on milk yield

Having the calf partially separated from the cow can increase milk production level by 15- 30 % (Little *et al.*, 1991; Mejia *et al.*, 1998) compared to systems where the cow and calf are completely separated. When suckling periods of three, four and five months were compared, a five month period gave the highest total milk yield from the cows (Sidibé-Anago *et al.*, 2008). Partly separated calves have also been found to grow quicker (Little *et al.*, 1991; Grøndahl *et al.*, 2007) than if completely separated.

Mastitis

Mastitis is an inflammation (infectious or not) in the mammary glands of one or more udder quarters. It can be either clinical with visible symptoms or subclinical with no clinical symptoms. Subclinical mastitis can only be diagnosed by analyzing the milk for inflammatory indicators. It is generally accepted that mastitis most commonly is caused by an infection with bacteria that is spread from the environment or from other cows. Clinical mastitis prevalence in sub-Saharan Africa has found to be 5 - 22 % (Mdegela *et al.*, 2009; Katsande, 2013) and subclinical 16-86 % (Karimuribo *et al.*, 2008; Mdegela *et al.*, 2009; Katsande, 2013; Abrahmsén *et al.*, 2014).

Mastitis causes a decreased milk production (Neitz, 1995; Nielsen, 2009) up to 11 % (Nielsen, 2009). Acute clinical mastitis causes the highest decline in production but subclinical mastitis can have bigger impact on the herd production if it's more prevalent and less detected (Nielsen, 2009). The decline in milk yield may start 2-4 weeks before clinical mastitis is found and continue the rest of the lactation (Nielsen, 2009).

Milk somatic cell count as indicator of mastitis

To measure inflammation in the udder, somatic cell count (SCC) is the most widely used indicator. Somatic cells measured in milk are mainly leukocytes from the blood and an increased level in milk is a response to inflammation. A high SCC can also indicate that the gland is recovering from infection (Eberhart *et al.*, 1982: see Smith *et al.*, 2001; Harmon, 1994) or that colostrum is still present (Jensen & Eberhart, 1981; Maunsell *et al.*, 1998). Normal milk should not have more than 100 000 cells/ml and the range between 100 000 and 200 000 can be difficult to make any conclusions from (Eberhart *et al.*, 1982: see Smith *et al.*, 2001; Harmon, 1994). A SCC over 200 000 cells in a herd milk sample do indicate that 15 % of the herd has at least one inflamed udder quarter (Eberhart *et al.*, 1982: see Smith *et al.*, 2001). For each 100 000 cell increase, 8- 10 % more cows are affected.

Milk SCC can be measured with direct or indirect methods. With direct methods, somatic cells are counted either manually (with microscope) or automatically with cell counters such as DeLaval cell counter (DCC) (Kawai *et al.*, 2013). DeLaval cell counter works by staining cell nucleus in somatic cells with a DNA fluorescent reagent. A digital camera then takes a picture of the sample and the cell nuclei are counted (DeLaval, 2003). Indirect methods are for example California Mastitis Test where a reagent reacting with DNA is used. The reaction increase the viscosity of the liquid and a higher viscosity indicate high levels of somatic cells (Schalm & Noorlander, 1957).

Breed and lactation number and mastitis

The prevalence of mastitis has been shown to be higher in pure exotic and crosses between exotic and local breeds, than local indigenous breeds (Eriksson, 2013; Olofsson, 2013; Katsande *et al.,* 2013). The cause of this could be that local indigenous breeds are better adapted to local environmental stress factors and has a more resistant udder and teat morphology (Katsande *et al.,* 2013). There may also be a genetic predisposition to develop high SCC and mastitis in exotic breeds (Kehrli & Shuster, 1994) why this should influence breeding programs. A higher parity number and age of the cow also increase the risk of developing mastitis, therefor older cows are at higher risk (Katsande *et al.,* 2013). There may also be a higher risk for mastitis in cows with a genetic merit for high yield (Koeck *et al.,* 2014).

Milking practice and mastitis

When mastitis occurs, frequent milking can help by removing bacteria, toxins and cellular debris from the udder (Thirapatsakun, 1999). Frequent milking can also lower SCC (Berglund *et al*., 2002) and prevent mastitis from developing by removing bacteria before they cause infection (Hillerton, 1991: see Berglund *et al.,* 2002). Milking frequency also influences milk production levels. Cows that are being milked one time per day produce 28-38 % less daily than cows milked two times per day (Stelwagen & Knight, 1997; O´Brien *et al.,* 2002). However, too frequent milking can cause injuries to the udder and should be avoided.

Among small scale farmers in Zambia it is most common to hand milk all animals (Olofsson, 2013) and hand hygiene routines during milking may affect spreading of mastitis causing pathogens between cows (Lam, 2008). Bacteria transmitted from and via hands can colonize the teat canal or teat skin and can then cause an infection. Disinfection of hands before milking and between cows, or using gloves, reduces the number of bacteria that comes in contact with the teat and therefor lowers the risk of mastitis (Lam, 2008). Teat dipping after milking also effectively reduces the amount of bacteria on the teat skin and lowers the risk for an infection to be established (Lam, 2008). Udder cloths used to wipe of the udder during milking can also be a source of bacterial transmission (Lam, 2008) if not changed between each cow.

Bedding

The material that the animals rest on should have a low bacterial load and also have properties that do not promote bacterial growth (Lam, 2008). Using soil as bedding can benefit bacterial growth because factors necessary for bacterial growth are normally available in soil. These include moisture (carrying nutrients to and waste from bacteria), organic matter (providing nutrients such as carbohydrates, proteins and fatty acids) and temperature (normal soil mostly benefits mesophilic bacteria) (Manahan, 1992).

Effects of calf management on mastitis prevalence

If calves are kept unseparated from the cows, the risk of mastitis decreases (Mejia *et al.,* 1998) because the calves remove residual milk (Ugarte, 1991) from the udder. But they can also contribute to spreading of bacteria between mastitis affected cows. Heifer calves may be at increased risk to get mastitis during the first lactation (Johnson, 1947; Schalm, 1942) if they are being fed with mastitis affected milk (in separated or unseparated systems).

MATERIAL AND METHODS

Study area and farms

The study was conducted in four areas in Zambia where small scale farmers had access to a milk collection center. Two areas (Mapepe and Palabana) are located within one hour driving from the capital city, Lusaka. The other areas (Choma and Batoka) are located more south. All four areas are marked in the map below (figure 1). The study was conducted in June to July when the weather is cold (mean temperature 8 -24 °C (night- daytime)) and dry.

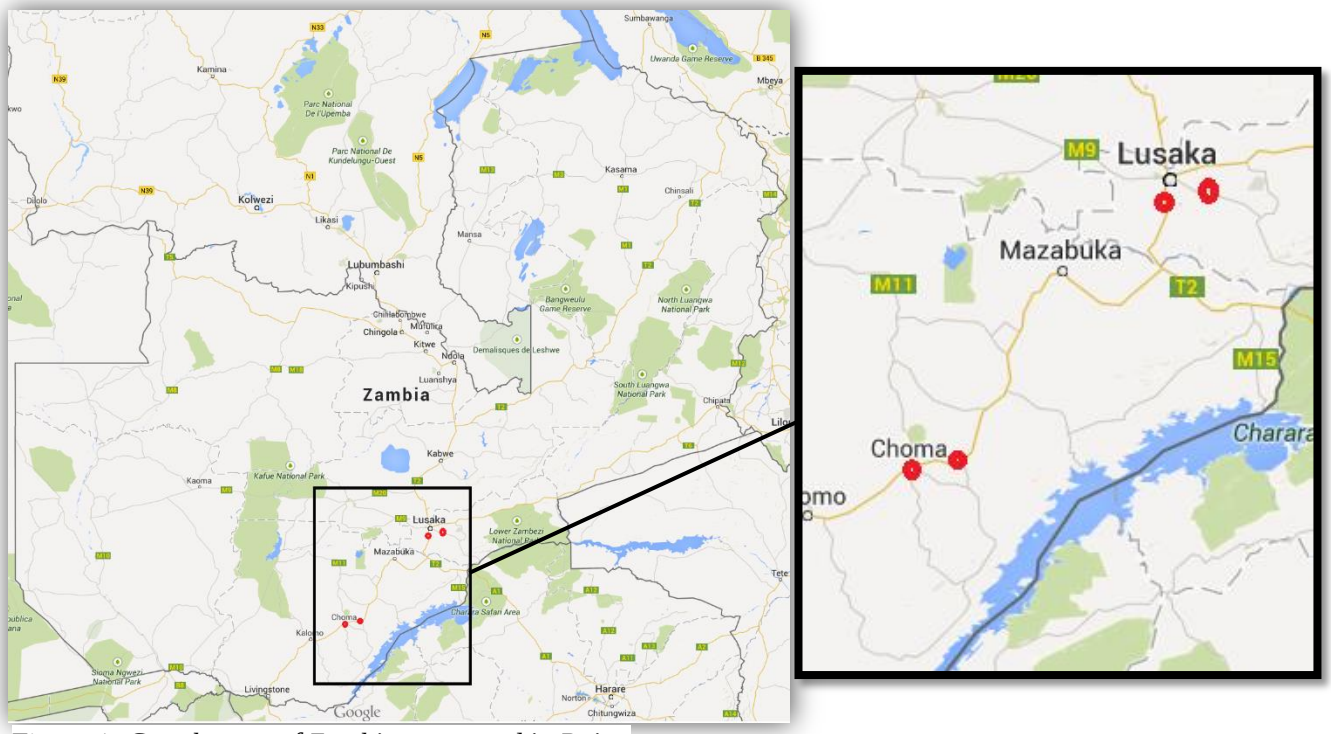

Figure 1. *Google map of Zambia processed in Paint.*

For inclusion in the "small scale"- category of the study, the total number of cows at each farm was set to a maximum of 25 cows. This did not include bulls, calves or heifer. All farmers were selected based on these criteria by help from staff at the four milk collection centers, Mapepe, Palabana, Choma and Batoka (described earlier). In total 29 farmers were included in the study (table 4).

Study design

A semi – structured questionnaire (presented in appendix 1) was used. In brief; farmers were asked questions about herd size and composition, milking routines and yield, feed and water access, housing, animal health and reproduction. Open questions were chosen because they enable farmers to highlight what they experience to be their main problems (Wärneryd, 1993), in this case regarding the dairy farming.

Milk SCC was tested in herd milk for the herd of each farmer that was interviewed and also from herds belonging to farmers not interviewed but qualified (according to the criteria) to participate in the study. All farmers were selected by help from staff at the four milk collection centers because workers delivering the milk generally had insufficient knowledge in English and could not answer questions on how many dairy cows their farm had unless asked in their native language. All workers that delivered during time of collection were asked by the staff and therefore no bias in farmer selection due to favoring of specific farmers by staff were considered. The samples, 56 in total, (table 1), were taken and analyzed immediately with DeLaval Cell counter (DeLaval, 2003) from milk churns when delivered in the morning or afternoon to the milk collection centers in each area. The milk was tested after the churns were emptied into buckets.

Observations of animal body conditions (body condition score), animal housing and feed storage was documented with photos and notes to complement the information given by farmers. Animal body condition score was graded on a scale from 1 to 5 where score 1 represented a very thin animal and score 5 an obese animal.

Statistical analyses

The interviews were recorded and answers categorized before being processed with Microsoft Office Excel. For example categories for reproductive method (own bull, neighbor bull, AI only, AI/neighbor bull and AI/own bull) was identified in this way. Correlation analysis between SCC and milk yield as well as unpaired t-tests for management factors and SCC/milk yield was then calculated in Microsoft Office Excel. The SCC data was not normal distributed and was therefore transformed to a Log10 scale before the statistical analyses was made. All information except SCC is accordingly to farmers´ own statements.

Table 4. *Numbers of farmers for which interviews were held and total numbers of farms from which milk was tested for SCC, divided by area*

Area	Interviewed farmers	Milk tests
Mapepe	8	14
Palabana	11	18
Batoka	5	11
Choma	5	12
Total	29	56

RESULTS

Farm characteristics

The 29 farms included in the study had an average of 11 dairy cows with 60 % lactating. The most common breed in all areas was crossbreed that represented 70 – 100 % of the herd. Exotic milk breeds were less common and ranged from 5 – 25 % of the herd. Cows were either milked in a milking parlor (70 %), corral (10 %) or freely in a paddock (20 %) as shown below (figure 2).

Figure 2. *Milking freely (upper left), in corral (lower) or with a parlor (upper right).*

Almost all (93 %) herds were herded all year around (semi or free grazing systems) and all were kept in paddocks at night without any weather protection and standing on soil ground. The calves were either completely separated (70 %) and kept in shelters/paddocks or partly separated, usually from night until completed milking at noon.

Most farmers did not milk the cows themselves but had workers that both milked and delivered the milk to the milk collection center (MCC). The most common way to deliver was by bike (figure 3) which in average took 25 minutes one way. All farmers delivered the milk immediately after milking. A majority of the farmers (90 %) did also consume some milk themselves (table 5).

Table 5. *Treatment of milk before consumption, for farmers that consumed milk from their own cows. Because more than one treatment was used for some farmers, the table sum up to more than 100 %*

Treatment of milk	Number of farmers
Fresh boiled	48 %
Sour	48 %
Fresh not boiled	34 %

Figure 3. *Workers delivering milk to the milk collection center.*

Staff at the MCC checked the milk for signs of mastitis by strip cup or California Mastitis Test (CMT) and gave advice on what to do with ill cattle, sold cattle medications and concentrate to the farmers connected to the center.

The farmers had access to governmental veterinarians that were free of charge and who regularly vaccinated the animals. However, when mastitis occurred, veterinarians were never taken to the farm as that service was provided at the MCC.

Milk yield

Seasonal impact on milk volume was experienced by all farmers in all areas studied. Milk production level was in mean 6.7 ($\pm$ 4.27) liters per cow and day at time of interview (dry season). In the rainy season, farmers estimated mean production to be 9.7 ($\pm$ 6.19) liter.

Farmers milking two times per day (22 farmers) had a significant higher milk yield (mean 8.5 $\pm$ 3.56 liter) than those milking only one time per day (1.9 $\pm$ 1.30 liter) ($p < .001$) and those separating their calves (18 farmers) had a significant ($p < .05$) higher milk production level (8.3 $\pm$ 2.76) than those with partly separated calves (3.7 $\pm$ 5.50).

Feeding routines were compared to milk volume (table 8). A significantly higher milk yield was found for farmers that gave forage to their cattle as complement to grazing (mean 7.6 $\pm$ 3.41) compared to not forage at all (2.8 $\pm$ 3.35). Forage year around also gave higher yield (9.0 $\pm$ 2.49) compared to only in the dry season (5.3 $\pm$ 3.68). Those who could give concentrate to their animals had a significant higher milk yield (7.6 $\pm$ 2.62) compared to those not giving any concentrate at all (2.5 $\pm$ 3.33), especially if extra was given in early lactation, (9.5 $\pm$ 3.04) , as presented in table 8 below. 45 % of the farmers stated to have a lack of feed for their animals. The animals were at time of visit in generally good body condition (table 6) and only one farmer had thin animals.

Table 6. *Percentage of estimated animal body condition scores observations (as herd average) in 29 herds. Score 1 represents a very thin animal and score 5 an obese animal*

Animal body condition score	Percentage of herds (%)
1	3 %
2	0 %
3	72 %
4	12 %
5	3 %
animals not at farm	10 %

All forage provided on – farm was produced from crop residues from farm production. None of the farmers produced their own concentrate and feed was according to farmers controlled before feeding at 65 % of the farms, but a majority had no criteria to follow on how and what to check when assessing feed quality. Type of forage and concentrate given are presented in table 7.

Table 7. *Type of feed, both forage and concentrate, in percent, given to the cows at 29 farms, as stated by the farmers. As farmers used several types of feed simultaneously and the sum exceeds 100 %*

Type of feed	Percentage of farmers (%)
Maize bran	62
Molasses	10
Sunflowerseed cake	21
Cottonseed cake	14
Soy	14
Dairy premix	14
DCP (dicalcium phosphate)	28
No concentrate at all	24
Grass	24
Maize stovers	45
Hay	55
Molasses sprinkled on other forage	62
No forage at all	17

Table 8. *Statistic correlation in milk yield between food and water parameters on 29 farms, as stated by the farmers, based on their answers of a questionnaire*

Parameter 1	Parameter 2	P-value
Farmers experiencing a sufficient access of feed to the cows (n=16)	Farmers experiencing a lack of feed to the cows (n=13)	NS
Farmer giving some forage (n=24)	Farmer not giving any forage (n=5)	.0087
Farmer giving forage only in dry season (n=8)	Farmer giving forage year around (n=16)	.0111
No concentrate at all (n=7)	Concentrate given (n=22)	.0007
Concentrate given, same amount to all (n=10)	Concentrate given, individually (n=12)	NS
Extra concentrate given to cows in early lactation (n=6)	No extra concentrate given to cows in early lactation (n=16)	.0463
Farmers experiencing a lack of water to the cows (n=3)	Farmers experiencing sufficient access of water to the cows (n=26)	NS
Water from pond/river (n=7)	Water from well (n=3)	NS
Water from pond/river (n=7)	Water from borehole (n=19)	NS
Water from well (n=3)	Water from borehole (n=19)	NS

Somatic cell count and factors influencing mastitis prevalence

56 samples of herd milk were tested for SCC and the result is presented in figure 4. The total median value was 446 000 cells/ml and only 20 farms had a SCC under 200 000 cells. No farmer stated to have mastitis at time of visit.

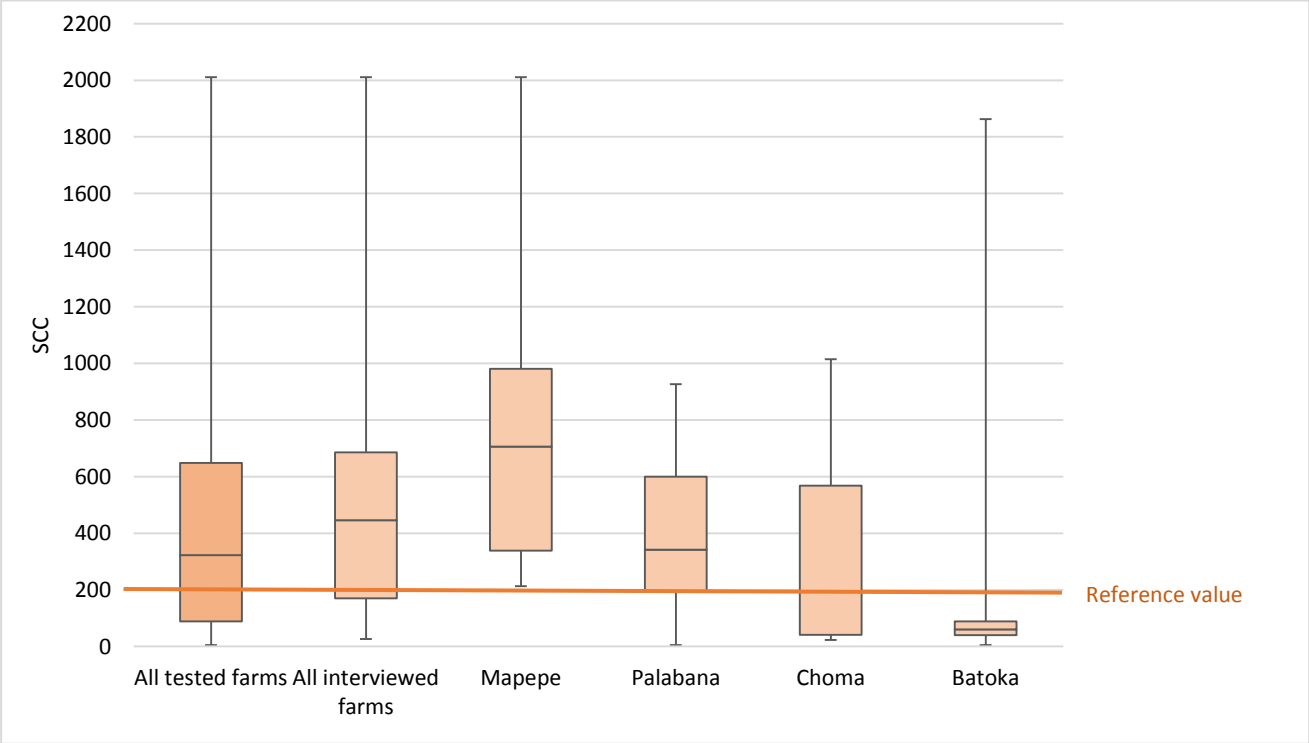

Figure 4. *Somatic cell count (cells/µl) for all milk tests (n=56) and divided to area. Reference value (Harmon, 1994) is marked with a line in the figure and represents the upper limit (200 cells/ µl) for normal herd milk.*

The current milk production levels (per cow/day/farm) was compared with SCC but the result showed no correlation between milk yield and SCC (correlation coefficient; 0.23) and also no significant difference between farms that had a SCC over or under 200 000 cells/ml (*p > .05)*

Farmers milking one time per day (n=7) had a lower SCC in the study group (*p < .01)* than those milking two times per day, median value presented in table 9. For milking, milking parlor, corral or free milking in paddock was used, but type of milking place did not affect SCC (table 11). A few farmers had their paddock on a slope or divided it for rotation to keep it dryer, but SCC was not lower for these farmers (*p* >.05). Use of hygiene routines are presented in table 10. No single farmer used all the hygiene routines presented in table 10, therefor no comparison between SCC and farmers stating to use all milking hygiene routines below, was made.

Table 9. *Median value of SCC in herd milk sample from farms (n=29) where cows was milked either one or two times per day, and used different types of milking places*

Milking routine	SCC median (cells/ml)
Milking one time per day (n=7)	75 000
Milking two times per day (n=22)	600 000
Milking parlor (n=17)	425 000
Corral (n=7)	102 000
Paddock (n=5)	60 000

Table 10. *Hygiene routines during milking and number of farmers (total 29) that use the routines*

	Use this routine	Does not use this routine
Hand cleaning before milking	7	22
Hand cleaning between cows	0	29
Separate cloth for each animal	0	29
Teat dip after milking	4	25
Udder cleaning before milking	28	1
Use of soap/udder wash for udder cleaning	7	22

Table 11. *Statistic correlation of SCC vs different management parameters, as stated by the farmers, on 29 farms, and SCC testing of herd milk samples from each farm*

Parameter 1	Parameter 2	P-value
Milking parlor (n=17)	Corral or in paddock (n=12)	NS
Milking one time per day (n=7)	Milking two times per day (n=22)	.0085
Calves held separately (n=18)	Partly separated calves (n=11)	.0407
Paddock on slope/rotation (n=3)	Normal paddock (n=26)	NS

In herds were calves where completely separated (at 17 farms) SCC was higher (*p < .05)* than in herds were calves partly had access to the cow (median 593 respectively 89 cells/µl).

Calf management

There was a large variation in the management of calves but most farmers stated that they fed them four liter milk per day or more (58 %). Number of days before separating the calf from the cow after parturition differed widely (table 12) and also onset of weaning of calves. A majority (69 %) was weaned after three months, 19 % after less than two months and 12 % after four months. No farmers weaned the calves based on their body weight.

Table 12. *Number of days before separating the calf from the cow after parturition, as stated by farmers (n=29) answering a questionnaire about their calf management*

Days before separation of calves after parturition	Percentage of farms (%)
After 1- 2 days	34 %
After 3-4 days	34 %
After 5-7 days	19 %
Immediately	10 %
After 1 month	3 %

Disease control and reproduction

No farmer had any current health problems among the cows, and all herds except one was vaccinated regularly (specific vaccination protocols was not known by a majority of the farmers). They all used dipping or spraying to control ticks but in Palabana 40 % experienced problems with emerging resistance. Veterinarian access, health issues, medical waste handling and areas farmers wish to know more about are presented in table 15. Most farmers did have training in cattle management (22 of 29).

The breeding strategy used at the studied farms differed (table 14). The most common was to use the farm´s own bull and no farmer separated their bulls from the rest of the herd after breeding.

Table 14. *Breeding strategy at farms (n=29). As one farm could use more than one strategy, the sum of all strategies exceeds 100 %*

Breeding strategy	Percentage of farmers (%)
Bull, own	50 %
Neighbor bull	18 %
AI and neighbor bull	21 %
AI and own bull	14 %
AI only	4 %

Table 15. *Veterinarian accessibility, cattle health issues, handling of medical waste and areas in cattle management farmers wish to know more about is presented for 29 farmers that answered a questionnaire about their dairy farming*

	Number of farmers (%)
Veterinary access	
Free govermental veterinary service	90
Govermental veterinarians are easy accessible	58
Only private veteriarians accessible	10
Medical waste handling after treatment of ill cattle	
Thrown into latrine	69
Dug down in the ground on the farm or burned	17
Does not store medications at home or uses all	14
Areas that farmers wish to learn more about	
Feeding	21
Cattle management	17
AI	14
Calves management	10
Farmers that had some form of training in cattle management	76
Cattle health issues other than mastitis	38

DISCUSSION

The farmers in this study produced in mean 6.9 liter milk per cow and day, which is in line with earlier studies (Olofsson, 2013; Kaluba, 2015). Milk yield ranged from less than 1 liter per cow and day up to 17 liter, and a higher yield was seen for management factors presented below.

Farmers that milked two times per day had a higher milk yield than those milking one time per day. The mean yield in each group varied considerably (8.5 respectively 1.9 liter) and the big variation could be caused by the small study group or other management factors that have higher impact on milk yield than milking frequency. The result is in line with other studies (Stelwagen & Knight, 1997; O´Brien *et al.,* 2002) and indicates that an increase in milking frequency could improve milk yield, even if practical obstacles such as access to workers, distance to the MCC and transport possibilities first needs to be considered.

A higher yield was seen if calves were completely separated from the cows, but did also increase SCC. A higher SCC in separated systems has been shown in other studies (Ugarte, 1991; Mejia et al., 1998) but not the increased milk yield that in contrast should decrease in separated systems (Little *et al.,* 1991; Mejia *et al.,* 1998). The opposing result in milk yield could be because the cows in the present study was not high yielding from the beginning and even if they increased yield in partly separated systems in the same proportion that was seen in other studies, the increased volume would still be so low that it would be consumed by the calves. Partly separated systems may be a way to improve both udder health and production levels for farmers in the present study because, as shown in other studies, a lower SCC also improve milk yield (Neitz, 1995; Nielsen, 2009) even if correlation between SCC and milk yield was not found in the present study. However, information about milk yield was according to farmers own estimation, and the information may not be completely correct and it could be one explanation for the lack of correlation between SCC and milk yield. As most farmers used workers to milk the animals, a variety in hand milking technique skills could also influence milk yield.

Breed does affect both milk yield and SCC (Katsande et al., 2013; Eriksson, 2013; Olofsson 2013; Kaluba 2015) but because exact information on breed used by the farmers was not collected, no comparison between these factors was made.

A large proportion of the farmers in this study experienced a lack of feed (45 %) especially in the dry season, which is in line with other studies from sub-Saharan Africa (e.g. Orodho, 2006; Tolera & Abebe, 2007; Rurinda et al., 2014) including Zambia (Hicks, 1995). A lack of feed lower milk yields (Moran, 2005) and this was confirmed in this study where access to forage and concentrate did affect milk production. A significant difference in yield was seen between farmers that had or did not have forage in addition to grazing and farmers that gave forage year around compared to only in the dry season. Also, farmers that gave concentrate in early lactation had a higher milk yield as well as farmers that gave concentrate compared to those not giving any concentrate at all. This is also in line with other studies as both energy and especially protein has a major influence on milk yield (Moran, 2005). The general BCS (3) of the cows in the present study could indicate that feeding is sufficient for keeping a healthy body condition but not sufficient for a high milk production. Increasing forage may be difficult because it depends on the farms own crop production (as they mainly use residues on the farms) but concentrate was not on-farm produced and if farmers could produce it from crops available on-farm, maybe access to concentrates could increase and protein levels as well as energy levels be enough to increase milk yield.

A comparison between types of forage, concentrate and milk yield was not made due to lack of sufficient information on individual milk yield and feeding (type and amount) for each lactating animal. Even though a majority did not have criteria for assessing hygienic feed quality, the major problem is probably not the quality but a general lack of feed (both in energy and protein) in general. No correlation between milk yield and farmers own experience of either lack of or access to sufficient feeding was found. This could be due to farmers lacking knowledge on how much feed, and of which quality, is needed to maintain a high milk production. Thus, the cows may receive too little feed even if the farmers do not think so. No difference in milk yield was found for farmers that adjusted amount of concentrate given to milk yield compared to those giving the same amount to all cows. The cause could be that the amount of concentrate and forage given was too low in general to all cows, so individual differences did not increase milk yield, as all cows had a general lack of energy and protein. No significant difference in milk yield was found when compared with water access and source, which could indicate that farmers in general had sufficient water access and quality.

A majority of the herds grazed year around (93 %) which is common for small-scale farmers in sub-Saharan Africa (Rufino *et al.,* 2007), and no farmer tried to synchronize calving with the rainy season, when green pasture was more abundant, even if farmers experienced a 45 % higher production during rainy season. Only a minority used solely AI for reproduction, the rest used a combination of AI, own bull and neighbor bull in a more or less planned way. If farmers could separate the bulls from the herd, and try to synchronize calvings´, for a majority of the cows, with the rainy season, the period for peak milk yield would be synchronized with high access to feed (green pasture). The need for supplementing forage and concentrates during peak lactation would decrease as green pasture, higher in both energy and protein (FAO, 1979; Simbaya, 2000), would replace a part of the energy supplied by forage and concentrate. Also calves could grow quicker as they would have access to pasture high in energy and protein (FAO, 1979; Simbaya, 2000), at time of weaning.

From all the collected 56 samples, 64 % had a SCC over 200 000 cell/ml but no farmer stated to have any mastitis at the moment. The prevalence is in the same range (16 – 86 %) as other studies from sub-Saharan Africa (Karimuribo *et al.,* 2008; Mdegela *et al.,* 2009; Katsande, 2013; Abrahmsén *et al.,* 2014) and the SCC (446 000 in median) indicate that approximately 40 % (Eberhart *et al.*, 1982: see Smith *et al.,* 2001) of the animals had some form of mastitis. Because all farmers delivered the milk immediately after milking and had the milk collection center within a short distance (mean 25 minutes), it is less probable that somatic cell count was altered due to long storage time without access to cooling.

The MCC provided medications and advise to the farmers when their cows got mastitis. As veterinarians were not used, farmers (even if the majority had training in cattle management) may not be able to identify cattle with mastitis or evaluate the effect of mastitis treatments correctly. Medical waste was never handed in for safe destruction, and this could be a risk for human and animal health. As the MCC centers did provide both advice and medications, it could be beneficial to also arrange collection of medical waste at the centers.

Farmers milking one time per day had a significant lower SCC (median 76 cells/µl) than those milking two times per day (median 600 cells/µl). This is not in line with other studies (Hillerton, 1991: see Berglund *et al.,* 2002; Thirapatsakun, 1999; Berglund *et al.,* 2002) showing that increased milking lowers SCC. The opposite result in this study could be due to

other factors that influenced SCC more than milking frequency, such as breed, age, milk yield, milking routines and calves management or due to a small study group. Because increased milking frequency increase milk yield and udder health (as described earlier), it could still be profitable for the farmers to milk two times per day.

The underlay or bedding can affect bacterial load on the udder, and soil, especially if wet, contain all factors necessary for bacterial growth (Manahan, 1992; Lam, 2008). No lower SCC was found for farmers that tried to keep the paddock dryer in this study, but this could be due to all having paddocks with soil ground, and even if some farmers tried to keep it dry, all factors needed for bacterial growth was present. A change in underlay could be a way to decrease bacterial load on the udder, and decrease the prevalence of mastitis. Using sand as underlay could be a cheap and effective way to decrease bacterial load because it is inorganic and does not itself contain nutrients for bacteria. It also heats up more quickly than soil when exposed to heat because of the lower water content (Burström, 2010) and could in the warm days of Zambia reach more unfavorable temperatures for bacteria. Sand also has a higher permeability for water (Larsson, 2008) making it drain away instead of staying on the surface.

An improvement in milking routines could lower SCC (Lam, 2008), improve milk yield (Neitz, 1995; Nielsen, 2009) and improvement in milking routines for farmers in this study could be a way to increase milk yield, as many farmers could be spreading bacteria to and between cows with their present routines. Correlation between milking place and SCC was studied, to see if milking hygiene routines may differ depending on type of milking place. No correlation was found, indicating no difference in milking hygiene between the different milking places.

Information on own and calf consumption of milk was collected so that total milk yield from the herd could be calculated (delivered milk + own consumption + consumption by calves). Almost 50 % did not boil the milk before consuming it, and this could be a health risk for farmers as milk can contain disease causing agents (Sitima, 2012).

Most farmers (62 %) reported that they did not have any health issue (beside mastitis) among their cattle, which was positive as other diseases beside mastitis could affect milk yield (Onono *et al.,* 2013). The animals were also vaccinated regularly (specific vaccination protocols was not known by a majority of the farmers), which is important in preventing disease. Tick control programs were also used, which is positive as ticks can spread diseases and cause anemia, which lowers milk yield (Onono *et al.,* 2013). A majority also had access to free governmental veterinary service, which is of importance to decrease diseases causing lower milk yield. However, as this service often did not work properly and many used private veterinarians instead, financial limitations could cause increased disease prevalence and lower milk yield at these farms.

The health of calves and their growth is important both to increase the farmers herd and to have heifers with good health and a low age for onset of milk production. A majority gave 4 liter milk to the calves/day, which is recommended if also concentrate and forage is given (Moran, 2012). Of these farms, 90 % did not separate the calves immediately after parturition, indicating that a majority got colostrum for a sufficient length of time and in a proper amount. Time of weaning was most commonly after 3 months (69%) but not based on body weight. Weaning after body weight (usually at 9-12 weeks of age, Moran, 2012) could be more favorably for the health of calves, especially if there is a lack of feed and the calves grow slower due to breed and lack of proper feeding.

Many factors do influence milk yield simultaneously and this study group varied widely in management, feeding and breeds used. Therefor simple correlations between factors influencing milk yield could be misleading as milk yield is multifactorial. However, many of the results in this study are in line with other studies and may therefor indicate that management factors found influencing milk yield could be correct.

CONCLUSIONS

The farms in this study had a mean milk yield of 6.9 liter per cow and day. A higher milk yield was found for farmers that in addition to grazing, supplemented their cows with forage and concentrates, especially if done all year around and not only in the dry season. A majority of the herd milk tests (n=56) had a high SCC (64 % over 200 000 cell/ml) which indicate that udder inflammation were common. An improvement in feeding (both energy and protein) could improve milk yield for the herds in the present study, and an improvement in udder health could also help increase the milk yield.

APPENDICES

APPENDIX 1: Questions presented to famers

Basics

How many cows do you have?

What breed?

How many are you milking?

Do you have your own bull?

Are you satisfied with you production?

Do you want to improve anything?

Milking

How many times a day do you milk your cows? At what time?

How do you milk them (cleaning udder before/after, equipment)?

How many liter do they produce a day?

Do they produce the same amount during all seasons?

Do you store the milk or deliver immediately?

How do you deliver it? How long time does it take?

Do you consume milk yourself?

If yes, how do you treat it (direct consumption/boiling/acidification/time and way of storage)?

Fodder

How much fodder do you give each cow a day and what mixture?

Do they have free access or are they fed single/multiple times a day?

Do you give extra feed to cows in early lactation?

Where do you get you fodder (own production, buying)?

How do you know that the fodder is of good quality (color, smell, moist, mold)?

How much water do you give? From where do you take water?

Are you satisfied with the quality and amount of fodder and water to your cattle?

Housing

Do you separate your animals (calves, cows, bull)?

How long does the calf have access to the cow?

How do you keep your animals at night?

Health

How is the general health of your cattle?

Is the general health different during different seasons?

Had you ever had mastitis?

How do you treat a cow with mastitis?

How often do you use veterinary service?

Do you get veterinary service when you need it?

What do you do with antibiotics/medicine that has expired?

Reproduction

Do you use AI or own bull/neighbor bull?

Do you plan the pregnancies after seasonal access to feed?

Does the bull go with the cows all the time?

Training

How did you learn about cattle management (practical training/class/written information)?

What area would you like to learn more about?

APPENDIX 2: Advice for farmers

Thank you for participating in my study about small scale farmers. Here are some advice that can improve milk yield for dairy cows in Zambia.

Milking 2 times a day instead of one time can increase milk yield but not less than 6 hours should pass between each milking.

Cows can have subclinical mastitis that can not be seen but will lower the amount of milk. Discuss with your veterinarian on how to identify and treat these animals.

If the cow deliver in the beginning of the rainy season it can produce more milk at the peak period of lactation that normally is after 2 – 6 months due to access to enough feed/green grass. To do this you need to separate the bull from the herd and only use him 9 months before onset of rainy season.

The animals will then lactate at the same time with access to green pasture both for cows and calves. When doing this you will also put a majority of the animals on dry at the same time, in the dry season. Therefore you will have less need for workers except in "high season".

When putting animals on dry there is a risk for the animal to develop mastitis, but the risk of developing/spreading mastitis is lower in the dry season. Subclinical mastitis should be treated when the animal is on dry, and it is more cost efficient to treat all subclinical mastitis at the same time because you only need to pay the veterinary visit once.

When separating the bull you also decrease the risk of him mounting to small heifers that not yet has grown enough and has a risk of getting calving difficulties.

Also, when doing like this you can buy larger quantities of feed at once because all cows will be lactating and needing extra feed at the same time. That may make it possible to make a deal for home delivery or lower prices especially if you can organize to buy it together with your neighbors.

This will also mean that all calves come at the same time. That will make it easier to provide enough milk for all the calves, even for the one that has a mother with a low producing/low quality colostrum because you can give milk from a high producing cow. Also the pasture will be green and give a good chance for the calves to grow well.

Calves that grow well can be mature at an earlier age and produce more milk during the first lactation, therefore it is important to provide them with enough feed of good quality. To do this you can boil the milk that is given to the calves, it could have bacteria that makes them grow slower or give them mastitis later in life. It's also important to wean them after size and not age, the measurement around the chest should not be less than 1 meter when weaning starts. Milk the cow after delivering and give the calves milk through bottle, minimum 4 liters within 6 hours to ensure that they get enough colostrum the first 24 hours.

Ticks take blood and forces the cow to use energy to produce blood instead of milk. To decrease ticks you can divide the pasture into divisions and use each division for 2 years before changing to the next division. This will decrease ticks on the unused pasture. Burning grass at the pasture in the dry season also helps eliminate ticks.

Give concentrate to each cow separately. This makes sure that they get the right amount of energy for their production level. Too fat cows have a higher risk to get problems during delivering.

To decrease mastitis during the rainy season; make an angle of the floor of the milking parlor so that water easily will rinse away.

Let buckets, drinking and feeding place dry after washing and let them stand in the sun as UV-radiation is a good disinfectant.

If possible, put sand in the paddock during the rainy season. It will lead away moist and be an un-organic material that carry less bacteria than soil. If you can, divide your paddock in 3-4 parts and only use one at a time. This will make the other parts dry up and you can change place before the ground gets too wet and muddy. This will decrease the risk of mastitis and hoof diseases.

When milking, wash hands before and after washing the udder to prevent mastitis. Boil the water and cloth that you use. Use warm water with a new tissue and water for each animal. Let the udder dry before you start. Wash hands between each animal with soap. After cleaning the udder and washing hands, don't touch anything other than the udder. Let somebody else handle the cow and the bucket.

When buying new animals, try to keep them separate from the heard for 3 weeks if possible. You will then have a chance to discover if they carry diseases and stop them from passing it over to your other animals.

When discovering mastitis that is not severe, milk 3 times a day to flush away the infection. If you boil the milk you can use it for the calves if you have lack of feed for them, instead of throwing it away.

Cows with mastitis is best to milk outside the milking parlor so they don't spread bacteria to the other animals. Also milk that animal last.

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