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Evaluating the Impact of Feed Supplementation on Productive and Reproductive Efficiency in Smallholder Dairy Cattle in Arusha, Tanzania

Hayley Hall

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Hayley Hall
Cornell University, Animal Science
Academic Director: Felicity Kitchin
Advisor: Ndenngo Ngowi
Arusha, Tanzania
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Lastly, I want to say thank you to my fellow students. Everyone on this program contributed something unique. It was a pleasure to learn from everyone and I feel lucky to have met and shared this experience with them.

ABSTRACT:

This study was performed to determine if supplementing concentrates and/or minerals significantly affect productive and reproductive efficiency in smallholder dairy cattle in Arusha, Tanzania. The goal was to estimate the necessity and effectiveness of supplementing a forage diet on production and reproduction. Data was collected through interviews of small scale dairy cattle owners in nine regions within and around Arusha. Productive efficiency was measured by milk yield per cow per day. Reproductive efficiency was evaluated by the amount of time to heat resumption after calving and reproductive disease status. This was studied because determining the factors that improve the efficiency of dairy cows and implementing them would expand the dairy sector. This would in turn promote rural development, supplement incomes and significantly contribute to the Tanzanian GDP. The study was very limited, but the results showed that supplementing forage improved productive and reproductive efficiency. Specifically, milk yield was improved by both concentrate and mineral supplementation, time between calving and heat was decreased by feeding mineral supplement, and reproductive disease presence decreased with feeding of concentrates.

Keywords: Smallholder, production, reproduction, supplementation

INTRODUCTION:

The dairy industry in Tanzania is small. Smallholder dairy owners sell milk to their neighbors with little to no profit. There is potential to expand the industry, which will provide jobs and a source of income for local people. The expansion of the diary sector requires further studies on cattle nutrition and improving reproductive and productive efficiency.

The dairy industry in Tanzania is small due to a multitude of factors, including: the history of the diary sector and its regulations, the breed of cattle indigenous to the country, the lack of dairy inputs, and a lack of diary consumption culture.

Regulation in the dairy sector has undergone significant changes. Before 1961 the dairy industry was dominated by large-scale farmers. Come 1961, with the formation of three Zonal Dairy Boards, farmers held shares in processing plants that were run by the boards (Mwakatundu, 1995). In 1965, the Boards were replaced with the National Dairy Board, which was controlled by the government and had broader objectives. It was authorized to enact law regarding the dairy sector (Mwakatundu, 1995). The regulations included directing farmers to sell their milk to the closest processing plant, which gave the plants a monopoly-like power to buy and sell the milk at any price ("The Tanzania Dairy Board"). The National Dairy Board operated until 1974 when the government established the Livestock Development Authority (LIDA), which formed subsidiary companies including Tanzania Dairies Limited (TDL) and Tanzania Dairy Farming Company (DAFCO). These subsidiary companies acted to start and operate nationalized dairy farms and processing plants ("The Tanzania Dairy Board"). During this time productivity was consistently low, but started to rise in the 1980s because of government efforts in coordination with donors to promote smallholder dairy farm development (Katjiuongua, 2014). This was followed by the privatization of the dairy sector and the breaking up of TDL and DAFCO. To supervise the newly decentralized industry, the Tanzanian Dairy Board was appointed in 2004 ("The Tanzania Dairy Board"). With the growth of the smallholder dairy sector came a rise in production. International programs were introducing improved cattle to different regions in Tanzania in an effort to promote development and supplement incomes. These improved breeds can be found most concentrated in Arusha and the Kilimanjaro regions (Mwakatundu, 1995).

Even with the increase in improved cattle, dairy supply wasn't meeting demand and still isn't. This gap is being met by importing dairy products from abroad. The dairy sector has high potential to contribute to the GDP, to create jobs, supplement incomes, and meet the demand. Currently, livestock production contributes approximately 5% of the GDP in Tanzania, 30% of which comes from the dairy sector. While more than 2.4 million households are raising cattle, less than 1% consume processed milk (Katjiuongua, 2014). The culture in Tanzania is not that of dairy consumption. Smallholder dairy cow owners use and sell milk to their neighbors with marginal profits. Poorer households source milk from their own production while wealthier households will purchase more dairy product. Demand for livestock products is increasing and will continue in this upward projection (Katjiuongua, 2014). Despite the large number of cattle in Tanzania (30 million), supply of milk is not meeting demand because milk production and marketing is inefficient (Mwakatundu, 1995). A major factor in the low production is species and breed. In Tanzania, the indigenous species is Bos Indicus, which has low genetic potential for production. Because of this low milk supply, the 50 processing plants in Tanzania are only working at 30% capacity (Katjiuongua, 2014) and imported milk makes up almost half of the consumption in Tanzania. Expansion of the dairy sector is necessary to meet the growing demand for milk as well as to contribute to the country's economy.

Already, the introduction of improved cattle breeds has boosted productivity. Improved cattle make up less than 3% of herds yet account for 30% of Tanzania's dairy production (Katjiuongua, 2014). In a previous ISP study, Claire Dileo found that most of the improved breeds belonged to small-scale dairy farms, and that they had significantly higher milk yields than the indigenous breeds of pastoralists. She found that the average milk yield for an improved breed is 6.45L/cow/day (Dileo, 2017). This is supported by a paper, which states that milk production is limited by access to feed and disease control, going on to explain that production can be improved through crossbreeding (Katjiuongua, 2014). In smallholder systems, the majority of cows are indigenous crosses with exotic. The exotic species is Bos Taurus and the most common breeds are: Holstein-Friesian, Ayrshire and Jersey. Purebred exotic, usually Holstein-Friesian, are very few and found on large private farms. (Katjiuongua, 2014). Bos Taurus (exotic) are higher producing, adapted to temperate environments, and are found in America and Europe. Genetic selection for milk production within Bos taurus has led to the dominance of the Holstein-Friesian breed (Cunningham, 1987). The Holstein-Friesian originated in the area on the Danish-German border to the Northern Netherlands. In Europe it is referred to as the Friesian and in North America as Holstein. Differences between these breeds developed, with the Holstein producing more milk and having a higher body weight. But, sharing of genetics has largely closed the gap between the populations. Bos indicus (Zebu) is the species indigenous to Tanzania. They are low producing and have short lactation periods. The Bos indicus has a clearly defined hump on the posterior neck and loose hide. They are heat tolerant, have smaller body sizes and therefore lower nutrient requirements. The two species differ morphologically and physiologically but can be interbred successfully (Cunningham, 1987). The cross between exotic and Zebu would produce a more productive animal than the indigenous breed. The optimal cross would be 50% or more exotic given the right environment (not too harsh). Since exotic cattle are adapted to temperate environments they would need to be managed correctly to yield optimal milk given the Tanzanian climate (Ogle, 1990). The performance of these crossbreeds depends on adaption to the local environment and management practices (Katjiuongua, 2014). These are the crossbreeds that are being introduced to smallholder farmers. Their productive efficiency depends on more than just breed, but nutrition and management as well.

The goal of this study is to determine the effects of supplemental feeding on productive and reproductive efficiency in smallholder dairy cattle. The objectives of this study include: estimating if the cows are meeting their nutrient requirements, if supplementation significantly improves milk yield, and if supplementation impacts reproductive efficiency measured by time between calving and resumption of heat. The hypothesis is that supplementation is an important factor influencing production and reproduction given the correct management strategies. This paper consists of several sections. The first will review past literature concerning the purpose of this study and explain the relevance of this paper. I will then go into the methods used to perform the study, including site description, demographics, and methods of collecting and analyzing data. The next section will show the results of my data collection, while the fourth section will discuss and explain the results found. The concluding section will wrap up the paper and highlight major findings and future direction.

LITERATURE REVIEW:

Previous literature not only mentions breed, but consistently states that nutrition and management play significant roles in milk production. A previous ISP comparing smallholder dairy cattle vs pastoralist cattle management in Tanga, Tanzania emphasized that diary consumption is expected to increase but almost half of the milk is imported (Dileo, 2017). This shows the need to increase milk production in Tanzania. Dileo goes on to say that most of the cattle in Tanzania is indigenous, yet the improved breeds make up 30% of the milk production (Dileo, 2017). Introducing these improved breeds is clearly effective at increasing milk production, but the results can be variable. A study was done to assess the effectiveness of introducing improved cattle in Mvumi, Tanzania. They found that the minimum milk yield of an improved breed was 2L/day, while the maximum was 18L/day (Kisusu, 2000). Another study showed consistent results in Turiani, finding that improved breeds were only producing 4L/day (Lekule, 2001). These low milk yields were attributed to poor nutrition and management. The Holstein cows in America are producing more than 35L/day. This is in part because of the breeding practices in America. But, it is also because cows are fed good rations determined by cattle nutritionists and management practices are usually given a lot of focus. Lekule also found that farmers were usually unable to maintain the high milk yield of genetically high producing cows, again due to nutritional and management practices (Lekule, 2001). I wanted to look at how nutrition effects production and reproduction because of this. If nutrition has such a huge role in milk yield, how can it be optimized here? In Mvumi, only 31.6% of households were using supplemental feeding, instead relying completely on forage (Kisusu, 2000). This allowed me to narrow my interest to supplemental feeding within nutrition. Supplementation seems very important in promoting health because grasses in the tropics are generally low in nutritional value. An article published in *Tanzania Veterinary Association*, Volume 21 (2001) studied the effect of supplementing smallholder dairy cows with a urea-molasses multinutrient blocks. The blocks had higher crude protein, calcium and phosphorus levels than the normal forage and maize bran supplements given to smallholder cattle. This supplementation led to a significant increase in milk yield (1.2L/day), likely because the ratio of metabolizable energy and crude protein were balanced. This balance allowed maintenance of ammonia in the rumen, thus creating a good environment for rumen microbes to promote digestibility and feed intake. The time between calving to estrus was also significantly decreased with the nutrient block. The researchers explain that there is an association between inadequate feeding and anestrus, so the multinutrient block was likely improving a deficiency. (Mwanga, 2001). The rumen environment is very sensitive to changes in the diet or the environment, so nutrition is important for milk yield in dairy cattle. In addition, productive and reproductive efficiency are linked, so I wanted to look at both factors. Mwanga found that low nutrition during dry season, due to lack of access to green and nutritious forage, in tandem with milk production caused a decrease in reproductive performance (Mwanga, 2001). And so, I thought it would be important to evaluate both factors; reproductive efficiency by the time between calving and heat resumption, and production by milk yield per day. In addition, I thought that reproductive disease status played a role in both productive and reproductive efficiency. A study in the Iringa region was assessing the prevalence of mastitis in smallholder dairy cows. It found that 28% of cows showed clinical signs of mastitis, but 80% showed subclinical mastitis. Mastitis is a reproductive disease characterized by inflammation of mammary tissue. It is a major cause of economic loss in the dairy industry because it decreases quality and production of milk (Karimuibo, 2000). Reproductive disease like mastitis, retained placenta, milk fever and difficulty birthing all play a role in production and reproduction. I was curious if the disease status of cows changed with supplemental feeding because all of them could be caused by undernutrition, thus negatively influencing milk yield and reproductive turnover.

This study is relevant because given the number of cattle in Tanzania, introducing more cattle could be detrimental to the environment. The dairy sector would benefit if the proportion of improved cattle to indigenous cattle was greater, but I think right now it is more important to improve efficiency of current cattle. If exotic breeds are producing as low as 2L/day, then productive and reproductive efficiency could improve greatly. Many people are dependent on milk as their only source of income, but if the milk yield is that low then there would be no profit. If production could be boosted to 10L/day or 20L/day, then people's lives could improve. It would supplement income, increase food security, promote development, create jobs, and move to stabilize the Tanzanian economy. The benefits would be seen from the individual level to the country level.

METHODS:

Data for this study was collected through structured interviews. The interviews consisted of 32 structured questions and each interview lasted approximately 20 minutes. The participants were asked to sign an informed consent form before each interview and were given an "asante" of 2000 TSh at the end. The interviews were conducted at the participants' farms/homes. The participants were found through different veterinarians working in Arusha. My advisor, Dr.

Ngowi, would connect me with these veterinarians, who would take me to the farmers that they work with. The veterinarians would also act as the translators. I worked with 5 different veterinarians (4 male, 1 female) in nine different regions of Arusha. Questions were divided into sections: introduction, production, reproduction and education. The questions asked are included in the appendix of this paper. Following the interviews, the participants would be given the chance to ask me questions and I would observe their cattle.

With the data collected I pulled the questions that gave me the most complete picture of milk production and reproductive efficiency. This gave me three dependent variables: milk yield (L/cow/day), time between calving and resumption of heat (mo), and presence or absence of reproductive disease. I chose to ask and analyze the time between calving and heat because I read the variable in previous literature (Mwanga, 2001)**,** and it represents the time for the reproductive system to turn over. So, the sooner heat resumes after calving, the sooner the cow can be bred and calve again, which I believe is reproductive efficiency. I also pulled the data for the variables I thought would affect that: breed, feeding concentrates, and feeding minerals. With this data, I performed multiple statistical tests using R studio. The first was MANOVA, which tests for the difference in two or more vectors of means. I used this test because it determines the effects of multiple independent variables on multiple dependent variables as well as the interactions between independent variables. Considering I had multiple independent variables, I had to use MANOVA instead of ANOVA. I also performed multiple linear regression, which fits a linear equation to show the relationship between multiple independent variables and a dependent variable. So, I performed three multiple linear regressions for the three dependent variables that I had. This also gave me three R^2 predictor values.

ETHICS:

I introduced myself in Swahili to participants and explained who I was and what this study was. The translator would repeat what I said in better Swahili and summarize my consent form. The participants would then sign in my notebook, agreeing to participate in the study and acknowledging that they understood the consent. The form was handwritten in my notebook, and participants would sign on the page next to the form. I had some issues with the veterinarians not wanting to read my consent form, nor ask for consent. I had to ask multiple times in order to get my translators to ask participants for informed consent. This posed a problem because they would ask in Swahili and I wasn't sure what they were saying. I can't be sure if or how consent was asked for, but I did my best to get it. All participants were over the age of 18 years and could give their own consent. I didn't interview any children. No sensitive questions were asked and all participants retain their anonymity.

There were also power dynamics between me, the vet, and the participant. The veterinarians were mostly male, and the majority of participants were female, which could have caused tension.

After interviews I would give participants 2000 TSh asante for their time. It was supposed to act as a thank you for taking time away from work to answer my questions. I ran into a dilemma one time when a farmer asked me for 10,000 TSh as compensation for his time. I told him that I was sorry if I took up too much of his time, but I only had a 2000 TSh note. The veterinarian that was with me at the time was laughing about it. But, it had me thinking that the asante wasn't equivalent to the work that participants lost during interview time.

At the end of the interviews I would ask participants if they had any questions for me. Most of the questions were about how I would help them or how this study would help them. I had to explain again that I was only a student and that this study is relatively insignificant. But, it could help further research on smallholder dairy cattle which could potentially help them. Some questions would be directly about cow health, and I would respond again that I was just a student and ask the veterinarian with me to answer their questions.

LIMITATIONS/BIAS:

There were many limitations to my study that makes the results unreliable and insignificant. Firstly, my sample size was very small. I interviewed 52 total farmers, but most of that data couldn't be analyzed. Breed is a very important factor in productive and reproductive health, so I had to account for that factor. Many people I was interviewing did not know the breed of cow they had, and when a veterinarian was acting as my translator they would confirm the breeds. But, I had a translator at one point who wasn't a vet and so for more than 10 interviews the breeds were unknown. I couldn't identify them with any certainty because I am only a student and my scope of knowledge is limited. I am by no means an expert in this field and all of my knowledge comes from classes at my university. In addition, I didn't differentiate between mineral and concentrate supplements for my first couple of interviews. This was because the first vet I worked with told me that “pumba”, meaning a mix of different concentrates and mineral supplement, just meant maize bran. It wasn’t until I was working with the second vet that he explained the correct meaning of pumba and I was able to ask more specific questions to get data for mineral supplementation. These, and other factors, limited the number of interviews with enough data to analyze all the variables, so my true sample size was between 30 and 40. Another limitation on my study was time. The study period for this paper was one month, which limits the sample size, the depth of study, and analysis. As a student, I lack resources that could have improved my study. I wish I could have done feed analysis, digestibility trials, an analysis of the milk constituents, measures of reproductive health etc. My study was done only using interviews, which leaves room for error in translation, misunderstandings, and falsified data (by veterinarians or farmers). There were also power dynamics at play, considering my translator was usually male and the veterinarian of the participants. This could have altered the responses of the interviewees in an effort to please or avoid tension with the vets. Sometimes the veterinarians would also answer questions in place of the participants, laugh at my questions, or correct the participants. The language barrier played a large role in the limitations of my study. I couldn’t understand how the vets were translating my questions, nor could I understand the responses of the participants. This created problems in my data because sometimes the vet would give me numbers that I didn’t hear, and when I clarified with my limited Swahili, the interviewee would say a different number. I don’t know if the vet was misunderstanding the participant or purposefully changing the answers. I also made a lot of assumptions about my data when I performed the statistical tests. I assumed normality, linearity, absence of multicollinearity, absence of multivariate outliers, etc. (“Checking...MANOVA, 2015). There are so many factors that contribute to milk production in cattle but it was impossible for me, in this situation, to control for all of them. So, there could be confounding factors in the data that I can’t account for, and make the margin of error for this study very high.

SITE DESCRIPTION:

For this study, participants were found in different areas of Arusha where the veterinarians, with whom I was working, knew farmers. There were nine different areas that I went to, namely: Sombetini, Sakina, Njiro, Shangari, Makao Mapeya, Ngavenaro, Moivo, Kisongo, and Mbrefu. Arusha has one of the highest populations of improved dairy cattle (after

Kilimanjaro). In Arusha, there are more than 1,800,000 total cattle, and more than 78,000 improved cattle (Figure 3a and 3b). Arusha is a cool highland region with subtropical climates, which makes it suitable to keep improved breeds (Kurwijila, 2012). Exotic cattle are not tolerant to heat, so crossbreeds would be better off in cooler regions with proper management.

Figure 1: Tanzanian and Kenyan boarder, showing Arusha relative to the border and Arusha and Mount Kilimanjaro National Parks.

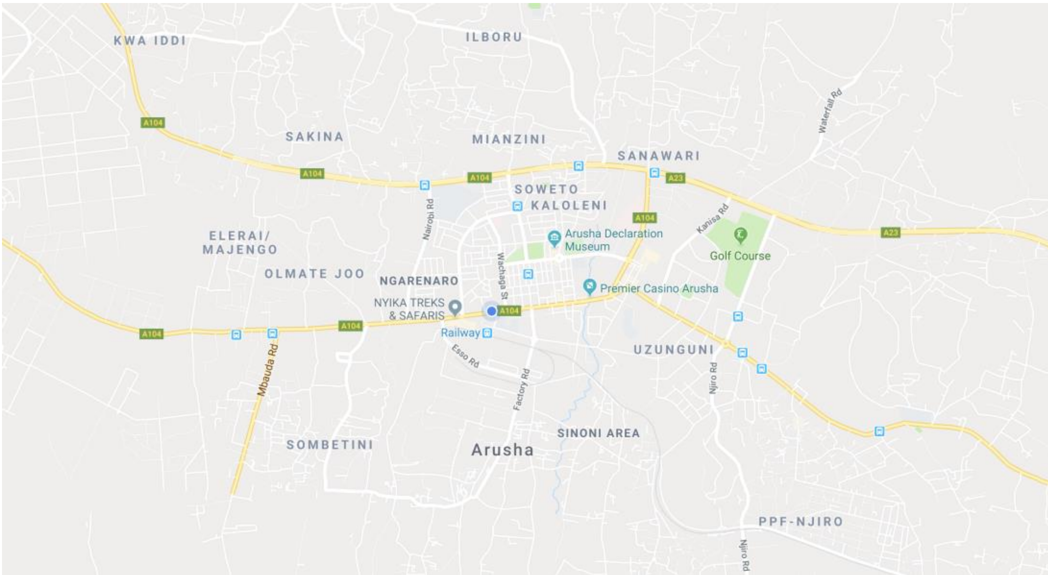
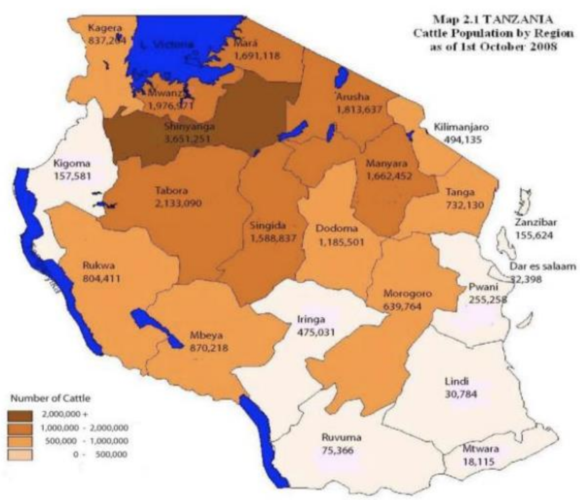


Figure 2: Close picture of Arusha, showing some areas of study within the city.



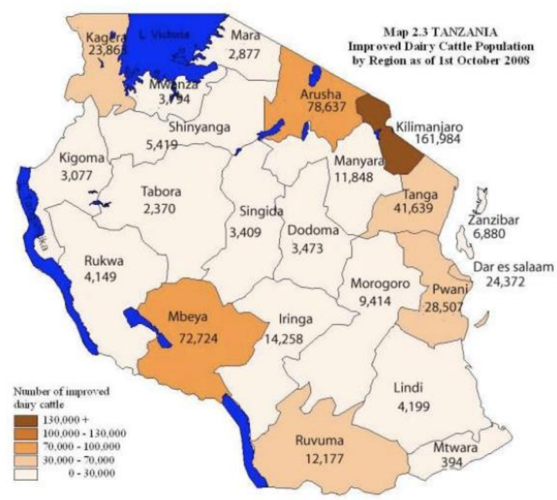


Figure 3a (left): Map of Tanzania showing the concentration of total cattle in each region (Kurwijila, 2012)
Figure 3b (right): Map of Tanzania showing the concentration of improved cattle in each region (Kurwijila, 2012).

DEMOGRAPHICS:

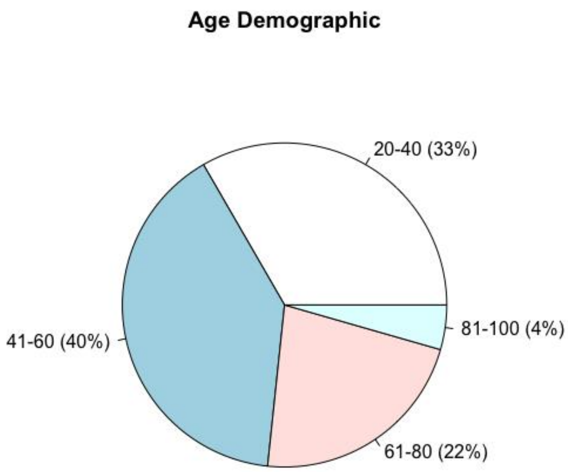


Figure 4: The majority of participants ranged from ages 41-60.

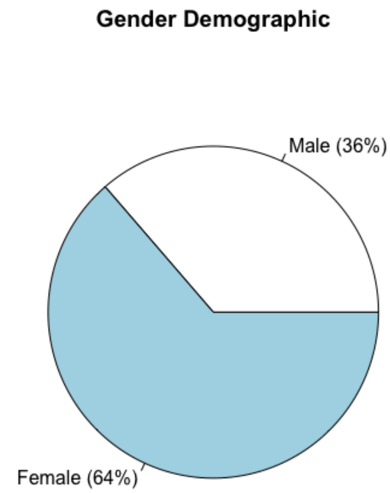


Figure 5: There were more female (64%) smallholder cattle owners than male (36%) in this study

RESULTS:

Productive efficiency was measured by liters of milk per cow per day. Most milking cows were giving 5-10L/day, with a mean yield of 10.6L/day. The results of MANOVA statistical testing showed that milk yield was significantly affected by the feeding of a mineral supplement and breed of cow. The median production of cows fed a mineral supplement was 10L/day (with large variation), and the median for cows without a mineral supplement was around 8L/day. In terms of breed, Friesian cows were found most commonly and were the highest producing, averaging 13L/day. MANOVA results also showed that feeding of concentrates did not significantly affect milk yield. This was contradicted by the multiple linear regression statistical test which found that all three variables, feeding concentrates, minerals, and breed, could significantly predict 47% of the variance in production.

The results of MANOVA also show that time between calving and resumption of heat was significantly reduced by the presence of a mineral supplement. The median number of months to estrus for cows fed the mineral supplement was 3mo, while those lacking the supplement had a significantly greater time at a median of 6mo. This is consistent with the results of the multiple linear regression test which found that 9.9% of the variance in measures of time between parturition and heat can be predicted by the presence of a mineral supplement.

MANOVA also showed that the presence of reproductive disease is significantly affected by concentrate supplementation. Reproductive disease declines as feeding concentrates increases. This is also consistent with the findings of the multiple linear regression test. The results found that 18% of the variance in reproductive disease status can be predicted by concentrate feeding.

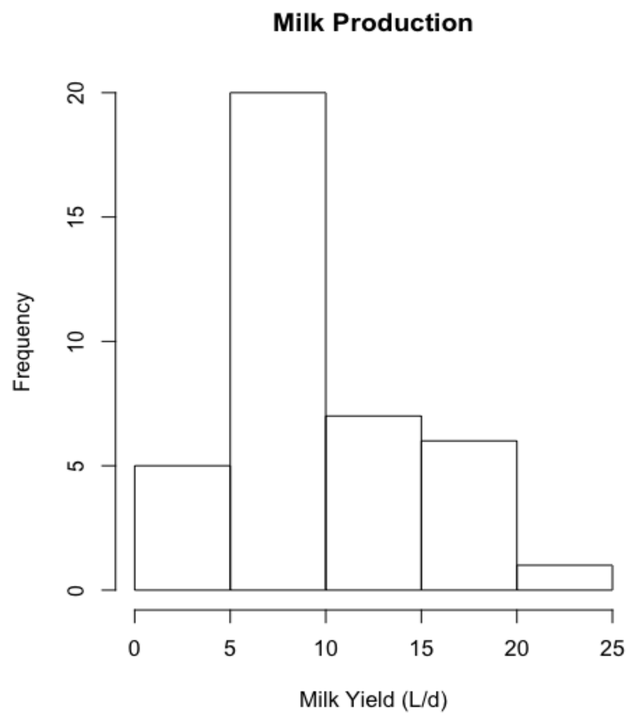


Figure 6: Histogram showing data collected on production, most milking cows were giving 5-10L/day

I. MANOVA

Table 1: The results of MANOVA statistical test

Dependent Variable	Independent Variable	Degrees Freedom	Sum of squares	Mean Square	F Value	P Value
Milk Yield						
	Concentrates	1	27.22	27.22	1.59	0.223
	Minerals	1	142.03	142.03	8.30	0.01 *
	Breed	9	445.89	49.54	2.89	0.03 *
Calving to Heat						
	Concentrates	1	0.41	0.41	0.088	0.77
	Minerals	1	20.96	20.96	4.46	0.049 *
	Breed	9	26.24	2.92	0.62	0.76
Repro Disease						
	Concentrates	1	1.68	1.68	8.30	0.01 *
	Minerals	1	0.40	0.40	1.95	0.18
	Breed	9	1.83	0.20	1.00	0.47

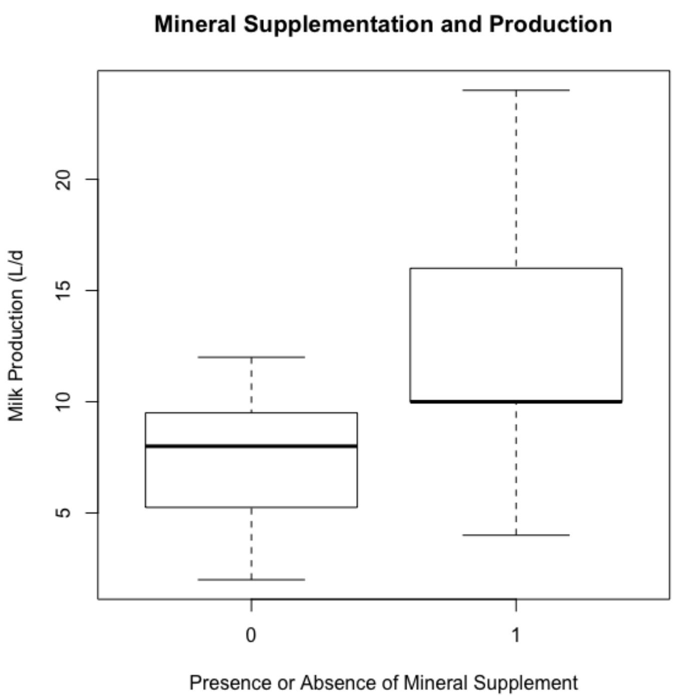


Figure 7: Milk yield was found to be significantly affected by the presence or absence of a mineral supplement (p = 0.01), n = 38

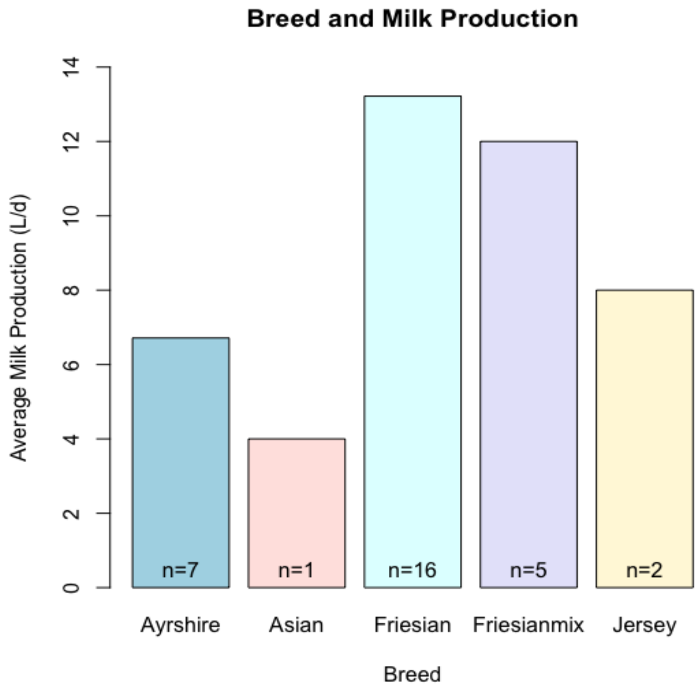


Figure 8: Friesian breeds produce significantly more milk than other improved breeds, with an average of 13L/day (p = 0.03)

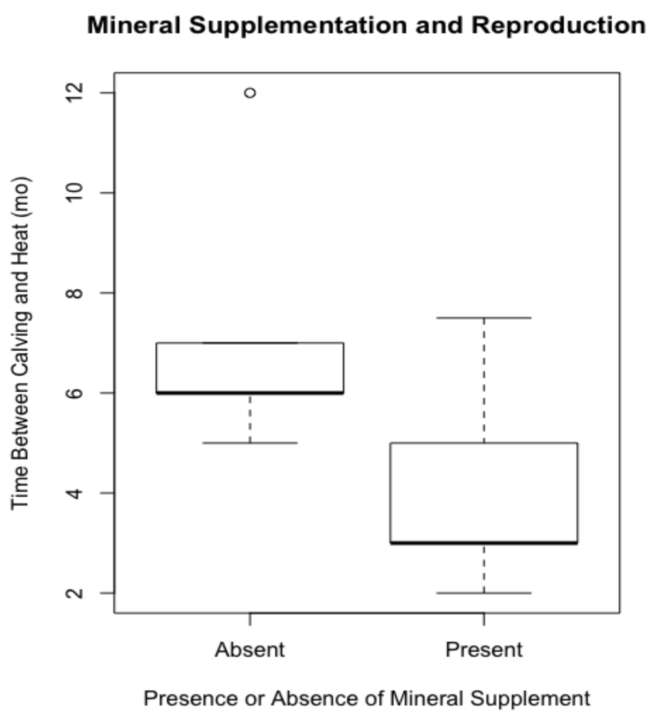


Figure 9: The number of months between calving and heat is significantly affected by the presence of a mineral supplement (p = 0.049)

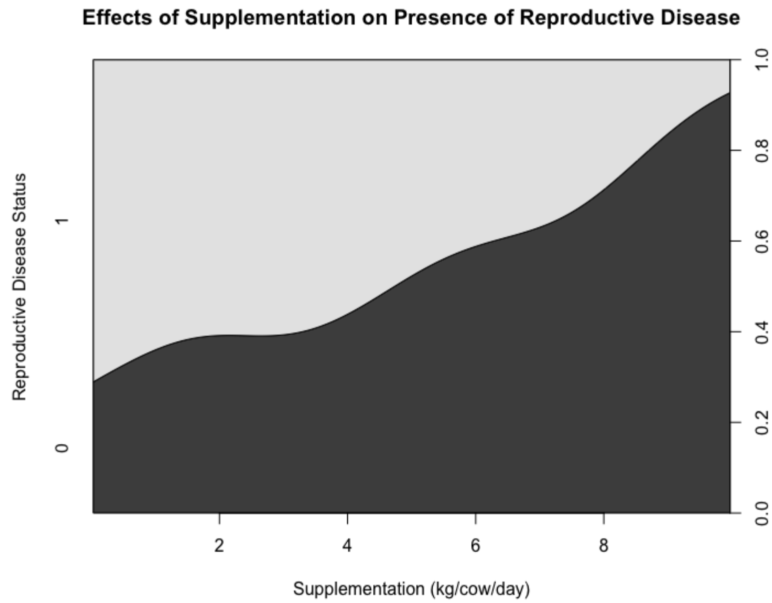


Figure 10: The presence of reproductive disease significantly declines with increasing feeding of concentrate supplement, with a p-value of 0.01

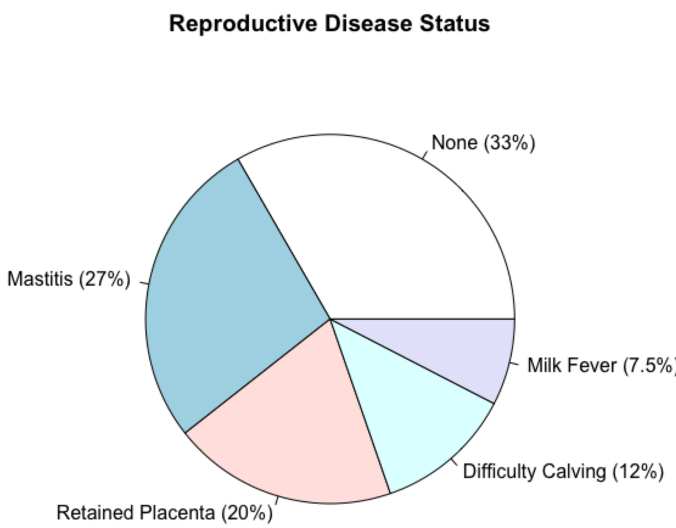


Figure 11: Prevalent reproductive diseases included: mastitis, retained placenta, difficulty birthing, and milk fever. Majority of smallholder cows showed signs of reproductive disease

II. MULTIPLE LINEAR REGRESSION

Table 2: Results of Multiple Linear Regression, showing significant predictors, the linear equation relating the variable, and the R^2 predictor values.

Dependent Variable	Independent variable	Intercept / Estimate	P-value	R^2	Linear equation
Milk Yield		-0.84		0.47	Milk Yield = --0.84 + 0.46*Concentrate + 6.84*Minerals + 7.89*Friesian + 8.19*Jersey
	Concentrate	0.46	0.041 *		
	Minerals	6.84	0.0002 *		
	Breed (Friesian /Jersey)	7.98 / 8.19	0.0004 * / 0.02 *		
Time to Heat		6.00		0.099	Time to Heat = 6.00 – 1.78*Minerals
	Concentrate	-0.036	0.77		
	Minerals	-1.78	0.035 *		
	Breed	-1.55	0.16		
Repro Disease		0.80		0.18	Repro Disease = 0.80 – 0.07*Concentrate
	Concentrate	-0.07	0.005		
	Minerals	-0.20	0.32		
	Breed	0.10	0.68		

DISCUSSION:

All my data was qualitative, gathered through interview questions, that I analyzed quantitatively. This creates error because more in depth analyses of productive and reproductive health couldn't be measured. Even so, many of the results found are supported by previous research. Figure 6 shows that breed plays a large role in milk production. Friesian-Holstein breeds have the highest genetic potential for milk production, which is why they are being bred with indigenous breeds and introduced to smallholder farms. I wanted to control for breed when looking at supplementation so that it didn't act as a confounding factor. Breed affecting milk production is consistent with my hypothesis and the literature (Lekule, 2001).

I also thought that milk yield would be increased with feeding concentrates. The energy requirements of lactating cows spike, especially in early lactation, because they are losing important substrates in the milk. Milk constituents like milk fat, milk protein, and lactose come from triacylglycerides, amino acids and glucose. These substrates are needed for both maintenance and lactation, so nutritional requirements increase. During lactation, energy is the most important requirement. Adequate glucose levels are critical because it is necessary for normal bodily functions and is the substrate for milk lactose. Milk production is directly related to the rate of lactose synthesis in the mammary tissue. Glucose, in ruminants, is from gluconeogenesis in the liver. Nonruminants, on the other hand, can derive glucose directly from the diet. Ruminants are characterized by a four-compartment stomach, including the rumen, which ferments feed. It is known that cows fed a high concentrate:forage diet will produce more propionate in the rumen. Propionate is a volatile fatty acid produced by rumen microbes during fermentation, and is produced in a higher concentration when the diet has more concentrate. The propionic acid is absorbed across the rumen wall and reaches the liver to act as a substrate for gluconeogenesis. This process produces 80-90% of the glucose in ruminants. Because most of the glucose comes from gluconeogenesis, glucose levels should remain relatively constant in ruminants given a proper diet. If cows are undernutritioned they will obtain substrates for gluconeogenesis from adipose mobilization and protein degradation. From what I observed over the course of my data collection, most of the cows were suffering from undernutrition, which evaluated by protruding ribs. I therefore believed that feeding concentrate would increase propionate production, increase gluconeogenesis and glucose production, increase energy availability, increase lactose synthesis and therefore increase milk yield. However, the MANOVA statistical test found concentrate feeding to be insignificant in affecting milk yield. The results for multiple linear regression showed that concentrate feeding contributed to predicting milk yield, but the value wasn’t very significant. This could be chalked up to error and limitations in the study. The question I asked about concentrate feeding was: how much concentrate to you feed and how many times a day? I had to take this value and divide it by the number of cows that were being fed the concentrates, but I don’t know how accurate the values are.

Milk production was most significantly affected by feeding mineral supplement. This is consistent with previous literature **(**Mwanga, 2001). Minerals should only be supplemented if they are correcting a deficiency. This is because many minerals, if overfed, lead to toxicity. Many of the farmers that I interviewed did not have a formal education in cattle nutrition or management. I asked some farmers how they knew in what ratio to mix the concentrates. The responses were almost always that they didn’t know, they just mixed the concentrates together and fed it. The amount fed depended on how much of the supplement they could afford. From this, I assume that their knowledge on mineral deficiency is also limited. I also have little knowledge on mineral supplementation, but I know that forage in the tropics is low in nutrition.

Generally, cows eating healthy green pasture have low incidence of mineral deficiency (Kumar, 2011). But, due to climate change and other factors, it hadn't been raining in Arusha during the study time. This likely led to feeding of more dry forage or very low nutrient grasses. This could have led to mineral deficiency that the mineral supplement corrected, which would improve milk yield. I had no way to determine a mineral deficiency, so this analysis is only a possibility to explain my results.

Reproductive efficiency was determined by evaluating both the time between calving and resumption of heat and reproductive disease status. The shorter the time between parturition and receptivity to breeding means that the reproductive system is turning over faster and can produce more young. To me, that is reproductive efficiency. But, I also wanted to include reproductive disease because they have a significant impact on the function of the reproductive system, as well as production. The time between calving and heat was found to be significantly decreased when fed a mineral supplement. This is because the supplement may have been correcting a deficiency. Trace minerals play an important role in reproductive health because they affect hormone production and interaction, metabolism, etc.

The incidence of reproductive disease significantly decreased with increasing concentrate feeding. Poor feeding is a major cause of reproductive disease because the body lacks the ability to support reproduction. I looked at mastitis, milk fever, retained placenta, and difficulty birthing. Mastitis is the inflammation of mammary tissue and is prevalent among smallholder dairy cattle (Karimuribo, 2000). This can be attributed to poor management and milking techniques, but an excess of dry forage can cause a deficiency in vitamin A or D which can increase the incidence of mastitis (Karimuribo, 2000). So, feeding is an important factor in preventing mastitis as well. Milk fever is the depletion of calcium levels soon after calving. Cows become lethargic and will die if untreated. To prevent this, it is important to feed more dry forage, to not overfeed calcium prior to calving, and to transition slowly to higher concentrate diets. Feeding concentrate should help supplement calcium (although very little) during early lactation, when it is necessary, without overfeeding calcium prior to birth. It is important not to overfeed calcium because it decreases sensitivity to calcium absorption from the diet and resorption of bone, which leads to the depletion of blood calcium. One study found that supplementing magnesium, which is found in most of the concentrates fed to the studied cows, decreased incidence of milk fever (Roche, 2003). Retained placenta is the infection and inflammation of the placenta, causing it to remain in the uterus, which can be detrimental to reproductive health. It can be caused by poor nutrition and management. Difficulty calving can also be caused by undernutrition. Proper feeding of forage and concentrate increase cattle nutrition and decrease incidence of reproductive disease.

CONCLUSION:

This was a small study, so the results are likely insignificant, but it proves interesting for further research on the topic. I found that both concentrate and mineral supplementation improve productive and reproductive efficiency. However, problems lie in education, management, and economics.

The majority of farmers that I interviewed lacked an education in cattle feeding and management practices. Most of their knowledge came from experience and some attended seminars held by agricultural institutes. This poses problems when balancing rations, knowing when to supplement, how to prevent and treat reproductive disease, and management strategies. Dairy cattle are sensitive to changes in diet. For optimal rumen function, it is important to balance rate of carbohydrate fermentation and rate of protein degradation. This balance improves production and reproduction. So, not only is it important to feed concentrate supplement, but proper feeding of forage is necessary. Green forage also provides many essential minerals and trace elements that are vital for different body functions. Knowing the nutrient requirements of your cattle, and meeting those requirements stem from an education in cattle nutrition. In America, dairy farms bring in nutritionists to evaluate the cattle and create a specialized ration that meets their requirements. This may be a factor in the production difference between American dairy cows and the dairy cows that I was studying. I think that to further improve reproductive and productive efficiency, educating smallholder farmers needs to become a priority. Perhaps further studies can look into if education level impacts milk yield in smallholder farms.

Management practices also play an important role in preventing disease and optimizing production. Much of the literature I read emphasizes the importance of management strategies. Milking techniques are important in maintaining udder health and high production, but almost no farmers, in a study from 1998, use post-milking drips or therapy (Karimuribo, 2000). I think knowledge of management strategies stem from an education in dairy cattle.

I think the largest obstacle to proper dairy management practices is income. The programs that introduced improved breeds to the smallholder dairy sector did so to supplement low income areas (Karimuribo, 2000). It takes money to provide proper dairy inputs, which would in turn improve production. Many farmers cannot afford to maintain high production of high producing cows (Lekule 2001). Some improved breeds will only produce 2 liters of milk per day because farmers cannot afford to properly meet their nutrient requirements. A lot of the interviewees said that they were not able to make a profit, or that the profit from selling milk was very small. There need to be programs to make supplements and education on how to make supplements more readily available.

It is important to explore ways to optimize productive and reproductive efficiency of dairy cattle because many people are dependent on milk to supplement their income. Improving the dairy sector would better the lives of farmers by increasing income, providing jobs, and promoting development. As milk production increased, processing plants would be working at higher capacities and supply would be able to meet demand of dairy products. This would benefit the Tanzanian economy and contribute to the GDP.

With better resources and more time, more in depth studies can be performed. Every variable that I wanted to look at could be analyzed further to find more significant results. Analysis of feeds, milk constituents, reproductive health, general health, disease status, and others would be interesting. Further studies could also compare productive and reproductive efficiency between different areas in Tanzania (like Arusha vs. Kilimanjaro). I also think it would be interesting to compare differences in feeding and management with large scale fairy farms and how significant its effects are on production and reproduction.

APPENDIX

Interview Questions:
1. Date
2. Region
3. Gender
4. Age
5. What is your relationship to the household?
6. What is the main source of income in the household?
7. Why do you raise dairy cattle?
8. How long have you been raising dairy cattle?
9. How did you obtain the cattle?
10. Who is responsible for taking care of the cattle?
11. What breed of cattle do you have?
12. How many cows do you have?
13. What are the ages and sexes of the cattle?
14. How many are currently lactating? In gestation?
    a. What breed are lactating cows?
15. How long is lactation period?
16. How many times a day do you milk?
17. How many liters of milk per day do you get (averagely)?
18. What do you do with the milk?
19. For how much do you sell one liter?
20. Are you currently making a profit from selling milk?
21. What do you feed your cows?
22. How many times a day do you offer food?
23. How much feed do you offer?
24. Do you give concentrates? Mineral supplement?
    a. How many times a day? How many kilos per day? To which cows?
25. Are your cows bred naturally or with AI?
    a. How many attempts does is take for pregnancy?
26. How long is gestation?
27. How long between calving and resumption of heat?
28. Do your cows cycle into heat normally?
29. Have your cows had difficulty birthing?
30. Have you noticed any reproductive diseases like mastitis, retained placenta, or milk fever?
31. Where did you learn to take care of cattle?
32. Would you want to further your education on cattle management?

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