ASSESSING ASSOCIATIONS OF BIOSECURITY AND ANIMAL WELFARE STATUS WITH PRODUCTION PERFORMANCE IN SMALLHOLDER DAIRY FARMS OF KENYA

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DEDICATION

I dedicate this work to The Lord God Almighty

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ACKNOWLEDGEMENT

I thank The Almighty God for seeing me through the course of my study, for He knew the good plans He had for me. I am greatly indebted to Egerton University for facilitating my studies this far. I sincerely appreciate all those who contributed to the success of this work, may our good Lord remember you all in good measure: first to my lead supervisor Prof. Bockline Omedo Bebe, my sincere gratitude for his valuable guidance, contribution and resource mobilization towards the completion of this study. Secondly, Dr. Mary Ambula, my second supervisor who always got time off her busy schedule to advice and comment on my work. You jointly kept me on my toes that this work may bear fruit, apparently to recover the lost years, I appreciate your help and God bless you. My appreciation also goes to the team at Mtakatifu Clara in Lare, led by Godfrey, and the team at Kabiyet farmers' co-operative led by Laban, and assisted by Esther the livestock extension officer for the great assistance and coordination during field work. I also acknowledge my family's support: firstly my loving husband Kelvin Shamalla who was always by my side through thick and thin to see that this work is complete. You told me there are priorities in life, this was one and I thank you. Secondly my children Shirley, Jeremy and Elian who tried to understand my absence attributed to academics, continually cheering me on so that they may partake of the graduation cake. My sincere thanks to my parents Eng. Joshua and Esther Rotich, Dr. Oscar Ouya and Hilda. To all my siblings, Daniel, Enock, Dorcas, Jeniffer, Judy, James and Mercy. You put too much pressure on me, how it was done in love I don't know, but here I am. For as much as your encouragement and help was that I cannot measure, so I pray that The Almighty God remembers you. I appreciate each one of you, not to forget Abigael. Sincere gratitude to my friends who always encouraged and prayed for me. Maureen and Naomi, thank you.

This project was funded by *Innovations for Sustainable and Profitable Intensification of Smallholder Dairy in Kenya* (ISPID), a project funded by The Netherlands Organization for Scientific Research (WOTRO), Project Number W.08.270.2015.308.

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ABSTRACT

Bio-security and animal welfare are important in preventing disease transmission between and within farms and this improves animal performance and product quality, minimizes production losses and increases returns to dairy farmers. However, smallholder farmers have difficulties of consistently practicing biosecurity and animal welfare in their farms. Most farmers prefer marketing milk in the informal market outlets where compliance with quality and safety standards is not a stringent requirement. The objective of this study was to contribute to enhanced implementation of on-farm biosecurity and animal welfare for increased herd productivity and profitability in smallholder dairy by assessing the associations of milk market outlet on biosecurity and animal welfare status; and the association that these have with milk quality, production losses and gross margins. Data was obtained in a cross-sectional survey from a random sample of 140 farms in two sites that contrasted in milk marketing: formal and informal outlets. Data was subjected to Chi square to test for frequency differences, logistic regression to obtain odds ratio estimates and univariate analysis to compare mean estimates all at 95% significance level. Implementation of on-farm biosecurity and animal welfare measures differed between the farms participating in formal and informal milk marketing. It was more likely for farms in formal than in informal milk marketing to observe farm hygiene, vaccinate and deworm new stock, not to trade animal products when the herd had an infectious disease and to keep cows cleaner. Implementation of on-farm biosecurity and animal welfare measures was associated with better milk quality as farms in formal milk marketing were more likely to produce milk of acceptable organoleptic, alcohol and density tests. Implementation of on-farm biosecurity and animal welfare measures were associated with lower production losses when observing antibiotics withdrawal period, not trading products when the herd had an infectious disease, and when handling milk from sick animals separately. However, production losses were higher when deworming purchased stock was a management practice. The gross margins did not differ with the biosecurity measures implemented but differed with the animal welfare measures. Higher gross margins were earned with cows that were in good body condition compared to cows that were lean. It is concluded that milk market has influence on farmers' implementation of on-farm biosecurity and animal welfare practices and these are management strategies to improve milk quality and profitability in smallholder dairy farms.

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LIST OF ABBREVIATIONS AND ACRONYMS

CI	Confidence interval
EADD	East Africa Dairy Development
ECF	East Coast Fever
FAO	Food and Agriculture organization
GAP	Good Agricultural Practices
GLM	General Linear Model
GoK	Government of Kenya
IDF	International Dairy Federation
IFAD	International Fund for Agricultural Development
IFC	International Finance Corporation
ILRI	International Livestock Research Institute
ISPID	Innovations for Sustainable and Profitable Intensification of Smallholder Dairy in Kenya
KCC	Kenya Cooperative Creameries
KDDP	Kenya Dairy Development Program
MoLD	Ministry of Livestock Development
OR	Odds ratio
SE	Standard error
USAID	United States Agency for International Development

CHAPTER ONE

1. Introduction

1.1 Background information

Assuring safe and quality milk is a requirement for marketed dairy products (FAO, 2011; GoK, 2015; Rademaker *et al.*, 2016). Market oriented dairy production can assure safety and quality of the products with implementation of on-farm biosecurity and animal welfare measures. Biosecurity is a management strategy of preventing pathogens from entering into a herd (external biosecurity) or reducing the spread of pathogens within the herd (internal biosecurity). The biosecurity measures are preventive rather than curative and are relevant for both endemic and epidemic disease outbreaks. When adequately implemented, biosecurity measures can improve animal welfare and economic performance of the farm. Preventing the spread or transmission of infectious diseases reduces usage of antimicrobial drugs, improves animal welfare and immune responses to vaccines, which resultantly should improve production, productivity and profit (FAO, 2011).

An animal is in good welfare state if it is healthy, comfortable, well nourished, safe, and is able to express innate behavior, not suffering from unpleasant states such as pain, fear or distress (IFC, 2014). An animal on a farm where welfare measures are good can better cope physiologically, behaviorally, cognitively and emotionally with their production environment (Veerasamy *et al.*, 2011). Farms that address or enhance animal welfare are likely to realize good herd performance (IFC, 2014).

In intensifying their dairy production, farmers have three possible pathways of participating in the domestic milk market. They can participate in the local raw milk chains, processed milk supply chain or in niche chains for high quality dairy products (Vander Lee *et al.*, 2017). The last two pathways demand that farmers produce milk of high safety and quality standards, which are attainable with implementation of on-farm biosecurity and animal welfare measures.

In Kenya, smallholders producing milk for the market are encouraged to join cooperative societies in order to access input and output markets. In a cooperative society, farmers can strengthen their capacity in producing and handling safe, quality milk and build entrepreneurial skills (IFAD, 2013; Rademaker *et al.*, 2016). Membership in a cooperative society is therefore expected to encourage implementation of on-farm biosecurity and animal welfare measures so as to reduce production losses and earn more profits from quality milk.

However, participation of smallholder farmers in the formal milk markets is challenged, predominantly by inability to consistently comply with quality and safety standards (Rademaker *et al.*, 2016). The formal milk market in Kenya is distinctively fragmented into four levels, which include large processors, mid-sized processors, producer organizations/hubs and milk bars (IFAD, 2012).

The formal milk markets pay attention to milk quality attributes and implement regular testing to ascertain quality before accepting milk delivery. Farmers participating in these markets therefore are expected to implement biosecurity and animal welfare measures to comply with the market requirements for milk safety and quality standards. In contrast, informal milk market outlets are unlicensed middlemen operating between the milk producers and the consumers (FAO, 2011) and they include individual consumers, hawkers, brokers and restaurants. Milk in the informal channel thus pose public health risks (Orregård, 2013) as it is not subjected to any quality tests.

Despite the potential benefits of implementing bio-security and animal welfare measures, smallholder farmers have difficulties implementing those measures on their farm environments (Sayers *et al.*, 2013). Difficulties experienced in effectively implementing animal welfare and bio-security measures lead to high disease morbidity and prevalence to which farmers respond with higher use of antibiotics, often indiscriminately (Seymour *et al.*, 1988; Ndungu *et al.*, 2016). Use of antibiotics is associated with antibiotic residuals in food products, which lowers product safety and quality as well as causing rejection of milk by processors as farmers often do not observe the recommended safe withdrawal periods (FAO and IDF, 2004; Orregård, 2013). In addition, veterinary curative treatment increase production costs while disease can impair performance, lower productivity, cause mortality loss, culling and abortion (Sayers *et al.*, 2013) as well as being barrier to trade (Weersink *et al.*, 2002; Adams *et al.*, 2012).

1.2 Statement of the problem

Failure to implement bio-security and animal welfare measures on dairy farms exposes the herd to disease transmission between and within the farms. This can impact on herd productivity resulting to poor animal performance, poor product quality and production losses from diseases, treatments and poor milk quality. Where smallholder farms market their milk can influence the biosecurity and animal welfare they implement because the requirements for compliance with milk quality and safety standards do differ between the informal and

formal market outlets. Most of the smallholders prefer to market their milk though informal market outlets where customers do not stringently demand compliance with quality and safety standards. This implies that marketing milk through informal and formal market outlets can influence milk quality and production losses from diseases and treatments as well as returns to farmers. Knowledge gap however exits about the influence that milk market outlet can have on biosecurity and animal welfare status and the association that status of biosecurity and animal welfare has with milk quality, production losses and rewards to farmers. This study fulfils these knowledge gaps about the milk quality, production losses and gross margins that farmers earn when their implementation of biosecurity and animal welfare measures differs.

1.3 Objectives of the study

1.3.1 Overall objective

The overall objective was to contribute to enhanced implementation of on-farm biosecurity and animal welfare for increased herd productivity and profitability in smallholder dairy.

1.3.2 Specific objectives

i. To determine the associations between milk market outlet and biosecurity and animal welfare status.

ii. To determine the associations of biosecurity and animal welfare status with milk quality.

iii. To determine the associations of biosecurity and animal welfare status with production losses.

iv. To determine the associations of biosecurity and animal welfare status with the gross margins earned.

1.4 Research questions

i. Do the milk market outlets have significant associations with implementation status of biosecurity and animal welfare measures in smallholder dairy farms?

ii. Does the status of biosecurity and animal welfare measures have significant associations with milk quality in smallholder dairy farms?

iii. Does the status of biosecurity and animal welfare measures have significant associations with production losses in smallholder dairy farms?

iv. Does the status of biosecurity and animal welfare measures have significant associations with the gross margins earned in smallholder dairy farms?

1.5 Justification of the study

Empirical evidence demonstrating that implementation of biosecurity and animal welfare measures can offer benefits that translate into improved nutrition, livelihood and incomes in dairy herds is of importance to farmers, traders, extension and consumers. Implementation of biosecurity and animal welfare measures improves compliance with food safety and quality requirements that enable farmers attain high product quality, increased productivity and minimized associated production losses. Knowledge of the benefits of implementing biosecurity and animal welfare measures is therefore relevant for up scaling practices that work on smallholder dairy farms.

1.6 Definition of terms

a. Formal market outlet: Refers to a market in which players who receive milk from farmers for sale, are duly registered with relevant authorities to handle milk and therefore comply with regulations and standards set out for milk handling, storage, transport, sales and, or processing. In the study, there is no distinction between market outlet and outlet.

b. Informal market outlet: Refers to market in which players who receive milk from farmers for sale, are not duly registered with relevant authorities in Kenya to handle milk and therefore have no basic standards to which they must adhere to but create their own *modus operandi*, a way in which they carry out their activities from the farm to the market.

c. Milk quality: Refers to milk standards accepted by regulatory authorities representing the Government of Kenya as fit for consumption based on recommended basic milk quality tests.

CHAPTER TWO

2. Literature review

2.1 Dairy Intensification and commercialization process in Kenya

Smallholder dairy sub-sector in Kenya is one of the fastest growing within the Agriculture sector, with a population of over 3.5 million head of improved dairy cattle and dominated by smallholders who produce up to 80% of the total milk produced (GoK, 2012). It is the dominant dairy production system in much of sub-Saharan Africa and South Asia (Bebe *et al.*, 2003) and produces over 4.2 million liters of milk every year.

Smallholder dairy farmers in Kenya have been working towards boosting their milk yield and income in the recent past through dairy commercialization. Significant changes in the traditional dairying have occurred over the years resulting in major shift towards market oriented smallholder production (Muia *et al.*, 2011). This has been achieved by formation of producer groups/organizations, and linkage of such organizations and individual farmers to the input and output market (milk processors and milk bars) and trainings through private and public partnerships with farmers. Such organizations increase efficiency and profitability of farmers by strengthening their capacity in milk collection, transport, processing and marketing (FAO, 2011).

One such program is the Kenya Dairy Development Program (KDDP) which has introduced interventions to improve animal production during dry seasons and develop smallholder business capacity (ILRI, 2007). The partners have also been involved in training farmers good dairy husbandry, business practices, and operations, and marketing of dairy products (IFAD, 2012), which has had a positive impact on dairy productivity and commercialization. Such programs are looking into ways of shifting the current programs that focus on production more to marketing and commercialization with support to the strengthening of local milk marketing bodies to dairy business units with increased marketing power (IFAD, 2013).

As the dairy industry was liberalized, the formal milk sector came into play in milk processing. However, 20-30% of milk is sold in the formal market and 70-80% in the informal market (Orregård, 2013). In Kenya, the formal milk markets to which smallholder dairy farmers are affiliated to is distinctively fragmented into four levels. These markets are duly registered by national or County governments and relevant public health and dairy offices. They are the large processors, mid-sized processors, producer organizations/hubs,

and milk bars that also tend influence the level of commercialization on the farm and hence the farming practices to keep up with their levels of milk output and quality requirements. For instance, the large processors like Brookside dairy and new KCC control the largest market and have a wide network of raw milk collection centers as well as service facilities where farmers collect their materials from. They have formal contractual agreements with farmers and they dictate and vary milk prices with season. The second level of marketing is the mid-sized processors who have a relatively smaller network of raw milk supply but have relatively same characteristics as large processors where they also train farmers on recommended practices. They provide credit facilities and input to farmers in partnership with service providers and input suppliers (FAO and IDF, 2004).

These market outlet levels dictate the quality and quantity of milk to be supplied by the farmers. Preliminary testing for basic quality conformation at the collection points before bulking is regularly done. These practices also apply for the third level which is producer organizations/organizations but the major difference is that the third level does not own processing plants but come into contract with the processors to supply them milk. These organizations also train farmers on good farm practices. At the lowest level are the milk bars which do not engage farmers in training but influence the farm practices in that they reject milk which does not conform to the standards they are given by authorities like the Kenya Dairy Board and The Local County Public Health Department whom they are registered with. They may also reject milk on basis that it has odor or inconsistencies and therefore not fit for sale (FAO, 2011).

There are also informal markets to which farmers directly channel their milk to who include hawkers, restaurants and institutions, neighbors and brokers who normally are not registered with any relevant body. They also reject milk based on physical appearance and presence of odor but they do not subject the milk to any basic quality test. Public health risks are always a concern in this outlet due to the weak monitoring of unprocessed milk in the market (Orregård, 2013).

2.2 Biosecurity measures

2.2.1 Importance of biosecurity

On farm practices should ensure that milk is produced by healthy animals under acceptable conditions for the animals and in balance with the local environment (FAO and IDF, 2004). Farm biosecurity are a set of measures designed to protect a property from the entry and

spread of pests and diseases (FAO, 2011). A study in the South East Asian countries to understand constraints linking smallholders to market indicates that the most cited constraining factor of production is producer knowledge about market opportunities and the production techniques that would enable them produce products acceptable to market (Adams *et al.*, 2012). Biosecurity is overlooked in many livestock operations (Smith, 2001).

A study on livestock trading patterns found out that traders actively seek out animals that are sick and purchase them at greatly reduced prices and more than half of the respondents acknowledged they sold stock with Foot and Mouth disease with the major reason being that the animals might not recover fully (Adams *et al.*, 2012). Such animals normally find themselves in commercial dairy enterprises and become a disease risk in these enterprises and potential cause of losses. In addition, pre-purchase inspections are done without necessary veterinary skills and thus increases probability of infected animals with unapparent infections to pass undetected along the market chain. This is because sensitivity for clinical inspections of diseases such as Foot and Mouth disease during early stages is low (Alemayehu and Leta, 2014). Risks associated with animal movements can be reduced by producers only purchasing animals from farms with a known disease history (Brennan and Christley, 2012).

From raw material production to point of consumption, all dairy products should therefore be subject to a combination of control measures also referred to as good agricultural practices that should meet appropriate level of public health protection (FAO and IDF, 2004). A report by Food and Agriculture Organization suggests some basic principles of biosecurity recommended for use by farmers to improve on milk output and quality and involves good practices on animal health, milking practices and hygiene, good nutrition, animal welfare and environment (FAO, 2011). Improving the management of biosecurity, occupational health and safety, animal welfare and environmental risks and meeting international biosecurity standards is increasingly important for improving animal productivity, expanding and diversifying market opportunities and protecting public health (Wells, 1998 and FAO, 2011).

Occurrence and spread of diseases can result from intrinsic management and extrinsic factors along the livestock production value chain and the environment (Oladele *et al.*, 2013). Farmers should therefore be in a position to identify risk factors of disease introduction, have precautions for purchasing stock and inputs, identify diseases leading to production losses or premature culling and have ways of implementing biosecurity measures that meets specific

goals for the dairy as most dairy producers aim at profitably and sustainably producing high quality, safe milk.

2.2.2 Measurable indicators of biosecurity

The health profile of a dairy herd will determine its success in terms of milk production, reproductive status and growth rates-the key aspects of a successful dairy operation (Sayers *et al.*, 2013). Some of the indicators commonly used in biosecurity studies include milking hygiene measures, milk and feed storage precautions and methods, precautionary measures and traceability of inputs and purchased stock, precautionary drug use, withdrawal periods observed following treatment of animals, and disposal of milk from infected cows.

2.2.3 Practice of biosecurity in smallholder dairy farms

Studies in Australia show that farmers are very aware of risks that can reduce profitability of their enterprise, and are especially vigilant in recognizing any event that could reduce the quality of their milk. Farmers have many elements of biosecurity in place as part of their normal operations. In Europe, reports show on-farm biosecurity measures involving strict batch management system in pigs with all in all out system or decontamination between consecutive batches being practiced (Laurette *et al.*, 2011). Logistic regression results from a study of opinion towards biosecurity measures in Irish dairy farms showed regional differences in biosecurity practices and opinions (Sayers *et al.*, 2013).

However, many studies in developing countries suggests that traders had little knowledge or understanding of biosecurity practices relevant to trading (Oladele *et al.*, 2013), and farmers in Madagascar swine farms had poor biosecurity (Costard *et al.*, 2009). Oladele *et al.* (2013) also reported in the study of biosecurity knowledge among farmers along border villages of South Africa that the more the contact with extension agents, the better the farmers' knowledge of biosecurity.

2.2.4 Association between biosecurity and production losses

Biosecurity practices are a good management strategy in a dairy herd that producers can review as insurance against disease introduction and spread. Implementing biosecurity practices on a dairy enterprise can increase profitability by reducing clinical disease and improving production efficiency hence reducing losses in the farm. It is however tends to be overlooked in many dairies though its implementation may be the difference between success and failure of a dairy enterprise (Smith, 2001). Mastitis in dairy cows increases microbial load in milk leading to spoilage. A study on biosecurity in dairies showed that risk factors for

Staphylococcus aureus which causes mastitis, and *Salmonella spp.* included bringing new cattle in the herd, failure to vaccinate before introducing cattle into the herd, mixing calving cows with sick cows, failure to separate sick from healthy cows and udder hygiene (Wells, 1998).

2.2.5 Association between biosecurity and profitability

The benefits of undertaking biosecurity for disease prevention and/or control include improved production efficiency resulting in greater profits (Brennan and Christley, 2012). David (2001); Adams *et al.* (2010) and Sagwe (2012) suggest that the only meaningful way to study an Agricultural enterprise, including dairy enterprises, is to regard it as an economic system whereby there is an interaction between supply and demand in a free market economy. Other studies however underpin the importance of implementation of biosecurity practices in a dairy farm to improve profitability by reducing clinical disease and improving production efficiency. Controlling disease will reduce risk with minimal cost (Wells, 1998).

A report by FAO and IDF (2004) concurs with the latter and suggests that focus should be on preventing a problem (including animal diseases), rather than solving it after it has occurred through employment of good agricultural practices that contribute to ensuring milk and milk products are safe and of high quality and suitable for consumers. Improved milk output may therefore be translated into profitable dairy enterprises if the farmer will maximize utility given certain constraints. Maximum profit is a product of milk output from the herd, milk price, and feeds, other inputs and veterinary expenses (Kinambuga, 2010) and is associated with biosecurity and animal welfare practices inherent in the farm.

2.3 Animal welfare measures

2.3.1 Importance of animal welfare

Animal welfare is described as the ability of an animal to cope physiologically, behaviorally, cognitively and emotionally with its physiochemical and social life environment (Veerasamy *et al.*, 2011). The safety and quality of the food chain is indirectly affected by the welfare of farm animals due to the close links among animal welfare, animal health and food borne diseases. Stress factors, poor welfare and poor nutrition can increase susceptibility to diseases among animals, thus increasing the need for veterinary treatment. This poses a risk to consumers, decreasing profitability and endangering environmental sustainability of the livestock production systems and of the associated food chains (FAO, 2013).

Positive features of livestock production systems should include the potential for better animal nutrition, feed conversion efficiency, health management and environmental control, control over reproduction, genetic selection of better performing animals, and consistency of product quality and delivery to the market place. Addressing the welfare of the animals is likely to reduce costs due to improved human-animal relationships and other welfare benefits, which can lead to increased productivity (IFC, 2014). It is therefore imperative that these measures be in place at the farm for the sake of the dairy herd and all players in the dairy value chain.

2.3.2 Measurable indicators of animal welfare

Animal welfare deals with related, but different questions of health and well-being of the animals. Assessment may be based on a wide range of measures in addition to health indices (Veerasamy *et al.*, 2011). The indicators can be classified into behavioral, physical, physiological, and production categories. Behavioral responses are the most pertinent indicators of the well-being or welfare of an animal. Indicators such as prevalence and intensity of certain health problems in the herd, cuts or injuries, reduced feed intake, impaired growth and reproduction, reduced milk production, cleanliness of the herd are also important indicators and fall in the above categories.

2.3.3 Practice of animal welfare in smallholder dairy farms

A study in the South East Asian countries (Adams *et al.*, 2012), showed that livestock disease constraints livelihood development through loss of animals and their productivity, restriction of trade and more recently diseases that can be transmitted from livestock to humans. An animal is in good state of welfare if it is healthy, comfortable, well nourished, safe, and is able to express innate behavior, and if it is not suffering from unpleasant states such as pain, fear and distress. Acceptability of production systems is now judged not only by inputs such as their design but also by animal welfare-related responses to them (IFC, 2014). Measures are required in dairy farms to optimize the current health status of dairy herds in order to optimize productivity into the future.

2.3.4 Association between animal welfare and production losses

Dairy farmers must be able to combine profitability with the responsibility of protecting human health, animal health, animal welfare and the environment (FAO and IDF, 2004). This implies that they should minimize production losses and optimize production in the herd by applying good Agricultural practices. Dairy operations that address or enhance animal

welfare are likely to win or retain a competitive advantage in the market place by reducing costs due to improved welfare benefits. This may lead to increased productivity, realizing market opportunities for food produced in animal welfare credentialed systems (IFC, 2014).

A properly balanced diet and water supplied in adequate amounts avoids physical and psychological suffering from hunger and thirst. Underfed animals may probably become more susceptible to diseases and parasite challenge while weight loss has an impact on animal productivity, compromising animal welfare and income of farmers (FAO, 2013). A study by De Vries (2013) on assuring cattle welfare showed an association between water intake and milk production and composition. The findings also showed that good stall design may reduce lameness in zero-grazing systems. Zero-grazing tends to show positive association with lame cows while lame cows had lowered milk yield in second or later parity. Vulva discharge is an indicator for reproductive diseases. The discharges were found to be positively associated with lower pregnancy rate.

2.3.5 Association between animal welfare and profitability

The safety and quality of the food chain is indirectly affected by the welfare of farm animals. This is due to the close links among animal welfare, animal health and food-borne diseases. Stress factors, poor welfare and poor nutrition can cause increase in susceptibility to diseases among animals, thus increasing the need for veterinary treatment, posing risks to food consumers, endangering the livestock associated food chains, and decrease profitability (FAO, 2013). Micro-organisms causing Mastitis can lead to increased total bacterial in bulked milk and lead to milk rejection which reduces profitability (Orregård, 2013). A study on assuring cattle welfare found that bulk tank milk somatic cell count was positively associated with dirty lower hind legs and udder, and association was also found between cow cleanliness and major Mastitis pathogens like *Staphylococcus aureus* and *Streptococcus uberis* in bulk milk tank (De Vries, 2013).

2.4 Production losses

2.4.1 Importance of production losses

Production losses in the context of dairy production is the gradual reduction of animal products or their level in a cow or herd and it involves loss of animal by culling, which could otherwise have been sold for meat, reduced milk production or loss of milk due to mortality, reproductive problems, and diseases (Weersink *et al.*, 2002), and poor animal welfare. FAO (2011) estimates losses at the farm level to be more than 6% of total production.

Losses at the farm level are as a result of spillage, lack of market and rejection at the market. Rejection at the market is a result of poor handling and the time taken to reach the market due to long distances and bad roads (FAO, 2011). Spillage is likely on the minimal side while most milk is lost through spoilage (FAO, 2003). Significant production losses are also associated with exposure to unregulated cattle diseases at farm level. For instance, Mastitis, along with fertility disorders and lameness were found to be common diseases of dairy production and a source of economic losses in Bulgaria (Kvapilik *et al.*, 2014), while daily reduction in all parity cows with mastitis was 1.0-3.0 kg of milk (Hortet and Seegers, 1998).

Another study showed that profits in unvaccinated herds were reduced by €94 per cow per year as a result of exposure to Salmonella (Sayers *et al.*, 2013), while mean milk yield loss to Bovine Tropical Theilerosis in Algeria was 2.76L/day/cow (Ayadi *et al.*, 2016), and milk loss in litres/day through Foot and Mouth disease in India ranged from 3.15-3.72 in four different states of India. In the same study, losses from Mastitis ranged from 4.10-5.67L/day in the four states of India (Paul *et al.*, 2013).

2.4.2 Measurable indicators of production losses

Various studies have employed different indicators for production losses. The baseline of many of these studies has been the relation of those indicators to productivity and profitability of a dairy enterprise and has mainly adopted indicators relating to milk and carcass value in the smallholder dairy. One such study estimated production losses associated with non-regulatory diseases using herd performance data on milk production, fertility and mortality (FAO, 2011). Another indicator used in production losses include premature culling. Milk spoilage, which is a factor of milk quality could also be used.

2.4.3 Management of production losses

The overarching principles applying to production, processing and handling of all milk and milk products should be that they are subjected to a combination of control measures from raw material production to point of consumption. All dairy farmers should be part of an integrated food safety and assurance management system (FAO and IDF, 2004). These measures cumulatively assist in reducing production losses in the smallholder dairy for sustainability of the dairy enterprise into the future. Farmers should be taught to take preventive health measures to ensure well-being such as methods for disease prevention, disease treatment and milk hygiene (EADD, 2014) which will significantly help in reducing losses at farm level.

2.4.4 Association between production losses and profitability

Production losses in the farm are economic losses that hamper profitability and sustainability of smallholder dairy and ultimately retard efforts of commercialization of smallholder dairy. This study focused on the dairy farmer and practices therein and how they relate to production losses and ultimately profitability rather than the whole dairy chain due to financial and time constraints and because the role of the farmer is to ensure that good agricultural, hygienic and animal husbandry practices are employed at farm level.

The Food and Agriculture Organization of the United Nations gives a guiding objective for good dairy farming practices in the areas of animal health, milking hygiene, animal feeding and water, and animal welfare and environment. It is from these objectives that this study sought to find the relationship between various practices formulated from these FAO objectives and how they related to production losses and commercialization of dairy enterprises in Kenya. Many biosecurity studies have adopted regression analysis for data analysis as it is able to explain relationships existing between the independent variables and the dependent variable.

2.5 Assessment of farm biosecurity and animal welfare measures

There are several approaches to sampling herds to obtain appropriate sample size for assessing implementation of farm practices. They vary with population size, level of precision desired among others. Some studies suggest the use of a sample size of a similar study to the one planned. A study of implementation of biosecurity measures in dairy farms in Northern England randomly sampled 56 farms within a radius of 100Km (Brennan and Christley, 2012). In contrast, a similar study in Sweden conveniently sampled 398 dairy farms on basis of accessibility and collaboration with organizations distributing the questionnaire and response rate was 79.6% (Nöremark and Sternberg, 2014). Singh and Masuku (2014) indicate that the same sample size as those of other studies can be used and cost can also be a contributor to the eventual sample size.

Tweel (2006) suggests a formula for obtaining the relevant sample size with two independent groups to be compared with respect to a dichotomous variable. The formula also applies statistical power that is need from the study and difference in assumed success rate of the parameters of interest in the study. Higher power is desirable and is obtained with large sample size. This should however be balanced with the number of individuals that can be feasibly investigated. Setting of the minimum difference is based on judgment or experience

from other related studies with the problem being investigated and may be estimated by assuming a range of values if preliminary data are not available (Singh and Masuku, 2014). The implementation of on-farm biosecurity and animal welfare measures are often measured in categorical scale, either in dichotomous or more levels.

Regression models are relevant for obtaining a mathematical model to describe the relationship between observations of outcome variable with a set of explanatory or predictor variables (Hosmer *et al.*, 1991). The outcome variable is quantified by applying multivariate analysis with logistic regression, multiple regressions or generalized linear modeling. For instance, Oladede *et al.* (2013) when assessing knowledge of biosecurity among livestock farmers along border villages of South Africa used logistic regression analysis to show relationship among farmers personal and farm characteristics and farmers' knowledge of biosecurity practices. A study in North west England to assess biosecurity on dairy farms carried out univariable logistic analysis to investigate differences between the isolation stock following introduction into the farm from different sources and whether access of stock to water courses was affected by whether or not the watercourse traversed the farmland upstream (Brennan and Christley, 2012).

Multiple regression analysis was used in a study assessing influence of dairy commercialization program on milk marketing in Borabu, Nyamira County to identify determinants in milk marketing and the strength of each determinant (Sagwe, 2012). Logistic regression has been used in a study implementing biosecurity measures on dairy farms in Ireland by Sayers *et al.* (2013) where the effect of four independent variables on biosecurity practice were assessed. Logistic regression is normally used when the response variable is binary in nature (yes/no, present/absent) and will be used in the biosecurity and welfare study. Generalized linear model is well suited when the response variable is continuous in nature or measured on a scale (Generalized linear model with logit link) and the data observes a non-normal distribution.

Logistic regression model has two components with the first being the random component where the distribution of Y is assumed to be binomial (n, π) where π is the probability of success. The second component is the systematic component where Xs are the explanatory or predictor variables and can be continuous, discrete or both and are linear in parameters ($\beta_0+\beta_1X_1+...+\beta_kX_k$). It estimates the probability of occurrence of an event in terms of odds ratio (Reed and Wu, 2013). The odds ratio of an event is the ratio of the probability that an

event will occur to the probability that it will not occur. If the probability of, for instance biosecurity being practiced is p, the probability of biosecurity not being practiced is (1-p). The odds value is given by odds of [production loss] = p/ (1-p). For the multinomial logistic regression, the event of interest is observing a particular score or less. All the odds are of the form; P_J = prob (score $\leq$ j)/ (1- prob (score $\leq$ j)) since the probability of a score greater than j is 1- probability of a score less than or equal to j.

The odds ratio is a measure of association between an exposure and an outcome. This odds ratio will be used to determine whether the exposures represented in the independent variables are a risk factor for a particular outcome of dependent variables. An odds ratio OR=1 indicates exposure does not affect odds of outcome. OR>1 indicates exposure is associated with higher odds of outcome; OR<1 indicates exposure associated with lower odds of outcome. For instance if the variable production loss is coded as 0 = (presence of biosecurity measures) and 1= (absence of biosecurity measures) and odds ratio for this is 3.2, then the odds for a positive outcome in presence of biosecurity measures are 3.2 times higher than in no production losses outcome. For the ordinal model, a positive coefficient means higher scores are more likely for the first category, negative coefficient means that lower scores are more likely.

2.6 Approaches in quantifying production losses and gross margin in dairy herds

In a study to estimate production losses in Canadian dairy herds with *M. avium paratuberculosis* infection, a partial budget simulation model with four components of direct production losses (decreased milk production, premature voluntary culling, mortality and reproductive losses) was developed, while in other studies reviewed by the same author, estimation methods such as regression were utilized or directly multiplied the estimated prevalence with costs of effects associated with the disease studied such as decreased milk yield (Tiwari *et al.*, 2008). Hortet and Seegers (1998), in a review of calculating milk production losses associated with elevated somatic cell counts in dairy cows suggests that the most relevant basic input to estimate production losses at the herd level are values for losses in milk yield.

Thirunavukkarasu *et al.* (2010) concurs by calculating direct losses due to the disease by summing up the loss in milk yield during the affected period and multiplying it by the farm gate value of milk in their study quantifying economic losses due to milk fever in dairy farms. Economic losses due to culling and mortality were taken as the value of cow at

slaughter. Total economic losses were then summed up as treatment cost, add milk reduction in form of currency, and add cull value in currency. Milk loss (%) due to Bovine Tropical Theileriosis in Algeria has also been obtained by calculating mean milk loss weekly for two months as the affected herd was under treatment by subtracting milk yield during the first visit from milk yield from the second visit then divided by milk yield from the first visit multiplied by 100 (Ayadi *et al.*, 2016), yet in assessing direct production losses and treatment costs due to four cattle diseases (Weersink *et al.*, 2002), the estimated herd losses associated with John's disease on US dairy operations was calculated as value of production on a per cow basis for each of the farms. This net return was then regressed against a number of explanatory variables.

In this study, the average losses due to diseases including infertility problems and culling were directly calculated from records availed by farmers. For instance, milk losses due to disease were obtained from calculating the difference between the average daily milk produced when the animal was diseased from average milk production when the animal was healthy then multiplied by the milk gate price. Losses from milk spoilage were obtained from farmer records while losses due to culling and mortality was taken as the value of the healthy animal before it was diseased and died or culled less the value at culling. Once the losses from diseases, and culling were determined, the means estimate for the formal and informal markets were then obtained and variables regressed in a generalized linear model. A dairy enterprise is considered profitable if the farmer will maximize utility given certain constraints. Maximum profit is a product of milk output from the herd, milk price, and feeds, other inputs and veterinary expenses (Kinambuga, 2010). Calculation of gross margin is the essential first step in farm budgeting and planning. It enables one to directly compare the relative profitability of similar enterprises and consequently provides a starting point to deciding or altering the farms overall enterprise mix. The gross margin was obtained from the difference between gross income and variable costs relating to milk production in the farm (FAO, 1992; Mawa *et al.*, 2014). The means estimates for gross margins were similarly obtained for the formal and informal outlets then compared for performance once variables were regressed in a generalized linear model.

2.7 Testing of milk samples

Milk quality is one of the important indicators of production losses as poor quality milk is likely to be rejected at the market outlets. Testing of milk and quality control is an essential component of any milk processing industry and the dairy value chain. The high nutritive

value of milk makes it an ideal medium for the spread and multiplication of bacteria (Orregård, 2013). It is highly perishable and therefore requires careful handling or will otherwise lead to losses for producers and processors. In Kenya, the milk quality is regulated by the Kenya Dairy board through the Dairy Industry Act (2012). The body has power to prescribe and enforce grades for dairy produce and minimum standards. They also prescribe the manner of handling, transporting and storing of dairy produce for consumption. Several tests are done at different levels from the farm, to collection points, and to the processing plants. There are basic tests that processors regularly perform for quality conformation. The relevant procedures are reported by Lovibond (1997).

2.7.1 Organoleptic test

The organoleptic test is done to detect abnormal smell and taste and consistency. The test allows for rapid segregation of poor quality milk at the receiving platform. If the milk has off-flavors and taste or abnormal consistency it fails the test.

2.7.2 Alcohol test

The alcohol test is based on instability of proteins when the levels of acid is increased and acted upon by the alcohol and is essentially used to test the processing quality of raw milk. Increased levels lactose results in a positive test. Milk with mineral imbalances (McCarthy and Singh, 2009) such as colostrum and milk with mastitis can be detected positive by this test. If the tested milk is of good quality, there is no coagulation, clotting or precipitation. The first clotting due to acid development would be seen at 0.21-0.23% lactic acid.

2.7.3 Specific gravity test

Milk has a specific gravity and when adulterated the density changes. The density is tested through the lactometer test. If the temperature of the milk is different from the calibration temperature of the lactometer, the temperature correction is calculated. For each degree C above the calibration temperature, 0.2°L is added. For each °C below the calibration, 0.2°L is subtracted from the lactometer reading. Kenyan standards expect milk to have a specific gravity of 1.026-1.032g/ml which implies a lactometer reading range of 26.0-32.0 L. External interference of milk with water or skimming (McCarthy and Singh, 2009), chemicals, sugar, formalin (Azad and Ahmed, 2016) or diseases like mastitis results in readings outside the normal range .

2.7.4 Resazurin test

The 10 minutes resazurin test is the most widely used test for hygiene and the potential keeping quality of raw milk. It tests the microbial activity in a milk sample. Resazurin is a dye indicator and once milk is mixed with resazurin solution and placed in an incubator for 10 minutes, it is placed in a lovibond comparator. The comparator has readings from 0-6 in order from white, pink, light pink, purple pink, purple, light blue and blue respectively. A reading of 4-6 is acceptable. A reading of 2 or 3 means the milk should be separated while a reading of 0 or 1 indicates that the milk should be rejected.

CHAPTER THREE

3. Materials and methods

3.1 Data source

Data on on-farm biosecurity and animal welfare measures were obtained among smallholder dairy farms in two regions which have contrasting compliance requirements for milk safety and quality standards. One was where farmers predominantly sell milk to dairy cooperatives and processors (Kabiyet in Nandi County) and another where farmers predominantly sell milk to mobile traders and to consumers directly (Lare in Nakuru County). Both Counties are in the Kenya highlands within the Rift Valley region where dairy keeping in zero grazing housing units is a common practice (Bebe *et al.*, 2003).

Both zero grazing and open grazing of dairy cattle are practiced in Nandi County (Wafula *et al.*, 2015). The milk marketing structure is more organized with many active dairy cooperatives and processors (New KCC and Brookside Dairies) procuring milk from farmers which they test for quality before acceptance for chilling and processing. In contrast, the milk marketing structure in Lare is not well developed. Farmers sell unchilled raw milk directly to mobile traders and neighbors who in general do not have the capacity to regularly test milk for quality. The clients traditionally boil milk before consuming.

3.2 Sampling procedure

The sample size was computed from the formula of Tweel (2006) for two independent groups (formal and informal market outlets) with a dichotomous variable (whether biosecurity was practiced, or animal welfare status was good or not). The formula is expressed as:

$$n \geq \frac{[\{Pc\,(1-Pc)\} + \{Pe\,(1-Pe)\}]^* [\,(Z_\alpha + Z_\beta)^2]}{\delta^2}$$

Where:

Pc = the proportion of the farms that have implemented biosecurity or welfare measures in the first outlet;

Pe= the proportion of farms that have implemented biosecurity or animal welfare measures in the second outlet;

δ = Pe – Pc= the relevant difference to detect.

The Z values refer to a sample from a large population (Singh and Masuku, 2014) while the strength is the statistical power to predict outcome (Tweel, 2006), with its Z_β values at 80% and δ being 20%.

The assumptions made included; that farms implementing biosecurity and animal welfare measures among the informal market outlets were 70% and among the formal market outlets were 90% at 95% level of significance ($Z_\alpha = 1.96$) with a strength of 80% ($Z_\beta = 0.84$) per description of Singh and Masuku (2014). The minimum calculated sample size required for each group was 59. An additional 11 more samples were included to cater for non-responses, thus the sample totaled to 70 for each market outlet.

This sample of 140 farmers was stratified by milk market outlet to reflect compliance with requirements for milk quality standards. One stratum comprised farms with membership to farmer co-operative society to which they deliver milk or sell milk to a processor. Both cooperative and processor routinely subject milk to quality testing to assure compliance with high quality standards. The other stratum comprised farms selling milk directly to mobile traders and neighbors who do not subject milk to quality testing for compliance with quality standards.

A cross sectional survey was applied in which the individual farms were selected using simple random sampling procedure from a list of farmers. The list of farmers trading milk in the formal market was obtained from the Co-operative offices in Kabiyet, Nandi while the list of farmers trading milk in the informal market was obtained from a Development Centre (St. Clara Mtakatifu) in Lare sub county of Nakuru. The centre is implementing a dairy empowerment program targeting 150 smallholder farmers in the study area.

3.4 Data collection

3.4.1 On-farm biosecurity and animal welfare

Each identified farm was visited with the guidance of an official of the Cooperative Society or the Development Centre. Data on each of the farms visited was obtained using a questionnaire that was designed to capture data on production system, milk market outlet, on-farm biosecurity and animal welfare measures implemented, milk quality related to spoilage and health risks and production losses from diseases, mortalities and treatments. Other data captured included inputs and outputs with their quantities and prices to enable computation of revenues and costs for deriving gross margins. Data on milk quality was obtained from the Co-operative and milk sample taken on the farms. For the milk samples, approximately 300ml of milk was collected in the morning from the farmers in sterilized plastic bottles. The samples were then placed in a cool box and transported to the lab within an hour of collection and analyzed within two hours upon arrival.

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For data that was categorical, measurements were in binary response (Brennan and Christley, 2012) to enable estimation of the odds ratio from logistic regression model. The binary variables were milk market outlets (formal or informal), milk quality from alcohol test (positive or negative), milk density test to Kenyan milk quality standards (acceptable or unacceptable), whether purchased stock was vaccinated (yes or no), whether milk from sick or treated animals was separated or disposed, watering frequency (*ad-lib* or once) and state of bedding (dry or wet) in the dairy unit.

Body condition scores described by Hulsen (2016) were used to identify whether a cow was lean or not. Five scores are recognized with a score below two meaning that the cow had poor body condition. At this score the cow had the ribs being clearly visible, with deep holes between the tail and the pin bones and the skeleton could clearly be made out. For the study, the cow was classified as either having a good condition or poor (lean). Responses on animal welfare were measured in percent cases observed in the herd, for instance, whether the cow was lean or not and whether cows were soiled on the lower hind legs. The percentage observed in the herd was then collapsed into binary variables on the criteria of the thresholds defined by De Vries (2013) for assessing welfare indicators and are described in Table 3.1.

Table 3.1 Welfare assessment indicators

Welfare indicator	Good (minor problem)	Poor (major problem)
Percent of very lean cows in the herd	≤6.7	>6.7
Percent of cows with dirty lower hind legs	≤50	>50
Percent of cows with dirty lower hind quarters	≤19	>19
Percent of cows in herd with uneven gait	≤11.8	>11.8
Percent of cows in herd with arched back	≤11.8	>11.8
Percent of lame cows	≤33.0	>33.0
Percent of cows with hairless patches	≤44.1	>44.1
Percent cows with lesions and swellings	≤58.8	>58.8
Percent cows with nasal discharge	≤10	>10
Percent cows with ocular discharge	≤6	>6
Percent cows with diarrhea	≤6.5	>6.5
Percent cows with vulva discharge	≤4.5	>4.5
Animal deaths/year	≤4.5	>4.5

3.4.2 Milk quality tests

The basic milk quality tests followed the procedures of Lovibond (1997). The tests were done by experts in milk testing at the Kenya Co-operative creameries lab and Kabiyet farmers' co-operative. The organoleptic testing was by opening the milk container and immediately smelling the milk then observing its appearance for inconsistencies. The routine alcohol testing was done by mixing equal amounts of milk (2mls) with 2mls of 68% alcohol solution in a small test tube while observing for any coagulation, clotting or precipitation. On the other hand, the lactometer test was done by mixing the milk sample and gently pouring it into a measuring cylinder (300-500mls). The lactometer was then sunk slowly into the milk. The lactometer degree (^{o}L) was then read and recorded just above the surface of milk.

The 10 minutes Resazurin test was performed with solution of Resazurin prepared by adding one tablet to 50 mls of distilled sterile water. The milk was then mixed and with a sanitized dipper, 10 mls milk was put into a sterile test tube. One ml of Resazurin solution was added using a sterile stopper, then the dye was mixed gently into the milk and the tube marked before the incubation in a water bath. The test tube was placed in a Lovibond comparator with Resazurin disk and compared colourimetrically with a test tube containing 10 ml milk of the same sample, but without the dye (Blank).

3.4.3 Production losses and gross margins

Production losses from diseases, milk spoilage, and involuntary culling and mortality in monetary value represented economic value loss. Losses of milk from spoilage was obtained from records availed by farmers based on recall. Production losses for milk when cow was diseased were computed from the difference between average milk yields of a cow in normal health versus that in sick condition status. Losses resulting from involuntary culling and deaths were taken as the values of the cow before it was diseased or died less the value at culling (Thirunavukkarasu *et al.*, 2010). The gross margin was obtained as total revenue less total costs and then computed for average margins per liter of milk produced. The revenue included milk sales, value of milk consumed at home, and value of milk fed to calves. The variable costs included veterinary, feeds, water and labor appertaining to dairy (Mawa *et al.*, 2014).

3.5 Data analysis

Descriptive statistics were generated to show the sample characteristics in distribution, dispersion and means. The associations between milk market outlets with biosecurity and

animal welfare status, and milk quality was examined using Chi square test statistics and odds ratio from logistic regression because the response variables were binary (Dohoo *et al.*, 2009). In the first logistic regression, outcome variables were the measures of on-farm biosecurity or animal welfare and the explanatory variable was milk market outlet (formal and informal). The fitted logit model estimated the probability of a farm practicing a measure of biosecurity or animal welfare (Y):

$$\mathbf{Logit Y_i(\pi) = \beta_0 + \beta_1 X_1 + \varepsilon}$$

Where Y = is binary outcome variable (biosecurity or animal welfare measure), β_0 = the intercept, β_1 = regression coefficient, X= the explanatory variables (market outlets- formal and informal), ε= random residual error

In the second model, milk quality was an outcome variable and biosecurity or animal welfare measures and milk market outlet were explanatory variables fitted in logit model (Proc Logistic of SAS version 9.0, 2002):

$$\mathbf{Logit Y_i(\pi) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_i + \beta_i X_i + \varepsilon,}$$

Where Y = the response variable (milk quality), β_0= the intercept, βs = regression coefficients, X= the explanatory variables (market outlets, biosecurity and animal welfare status), $\boldsymbol{\varepsilon}$= random residual error.

The means estimates for production losses and gross margins were generated from generalized linear model and pairwise comparisons made with contrast estimates between the levels of biosecurity or welfare practices in the sample farms. The generalized linear model option in SPSS software version 21 was fitted to account for deviation from normal distribution in the response variable.

CHAPTER FOUR

4. Results

4.1 Biosecurity and animal welfare status

4.1.1 Association of biosecurity status with milk market outlets

Table 4.1 displays the distribution of biosecurity measures observed on the sample farms. Of the measures examined three internal and two external biosecurity measures were frequently implemented in majority of the sample farms.

Table 4.1 Status of on-farm biosecurity measures observed in the sample farms (%), n=140

Biosecurity measure	Biosecurity practiced (%)	
	Frequently/Yes	Sometimes/No
Internal biosecurity		
Cows calving in clean dry environment	75.7	24.3
Cows when calving are isolated from sick animals	53.6	46.4
Mastitis testing in every milking	28.6	71.4
Milk from sick, mastitis or treated cows handled separately	77.9	22.1
Milk from sick, mastitis or treated cows fed to calves	9.3	90.7
Hand washing in every milking	96.4	3.6
Disinfecting udder and teats in every post milking	18.6	81.4
Milk man trained in hygienic milk handling	50.0	50.0
Fore-stripping milk in every milking	50.7	49.3
Dipping teats after milking	17.9	82.1
Handling milk in plastic containers	35.7	64.3
Milking cows on concrete floor	17.1	82.9
External biosecurity		
Examining health records when purchasing stock	22.1	77.9
Vaccinating purchased stock when introducing into the farm	54.3	45.7
Deworming purchased stock when introducing into the farm	85.0	15.0
Withdrawing sale of products when infectious disease present (*complying with antibiotic withdrawal period*)	73.6	26.4
Footbath provided on the farm	0.0	100.0

The frequently implemented internal biosecurity measures were cows calving in dry clean environment (76%), separate handling of milk from sick, mastitis or treated cows (78%) and washing hands during every milking (96%). The frequently implemented external biosecurity measures were deworming purchased stock when introducing into the farm (85%) and withdrawal of products from sale when the herd had infectious disease (74%). In all the sample farms visited, none had a footbath.

Table 4.2 shows the frequencies and odds ratio estimates for the association of on-farm biosecurity measures with milk market outlets in the sample farms. The odds ratio reflects odds of implementing a biosecurity measure frequently in the formal outlet relative to the informal outlet. One out of six internal biosecurity measures and four out of five external biosecurity measures showed significant association with the milk market outlet. For the internal biosecurity measure, cows calving in clean dry environment was frequently implemented by a larger proportion of farms selling milk in the formal market outlets (90%) than those selling milk in the informal market outlets (61.4%). The odds ratio estimate show that farms selling milk in the formal market outlets were 5.65 times more likely to frequently have their cows calve in clean dry environment than the farms that sold milk in the informal market outlets.

The external biosecurity measures that were significantly ($P<0.05$) associated with the market outlet were examining health records, vaccinating and deworming purchased stock before introducing into the farm and withdrawing products from sale when infectious disease was present. The farms that frequently examined health records when purchasing stock were fewer among those selling milk in the formal market outlets (14.3%) than among those selling milk in the informal market outlets (30.0%). Thus farms selling milk in the formal market outlets were 0.39 times less likely to frequently examine health records when purchasing stock than the farms that sold milk in the informal market outlets. However, a large proportion of farms selling milk in the formal market outlets than those selling milk in the informal markets vaccinated purchased stock (77.1% vs. 31.4%,), dewormed purchased stock (94.3% vs. 75.7%) and withdrew products from sale when infectious disease was present (91.4% vs. 55.7%).

Table 4.2 Association of on-farm biosecurity measures with milk market outlets

Biosecurity measure	Market outlet	n	Biosecurity measure practiced		
			Odds ratio[1]	Frequently	Sometimes
				Percent	Percent
Internal biosecurity					
Cows calve in clean dry	Informal	70	1	61.4	38.6
environment	Formal	70	5.65***	90.0	10.0
Isolate calving cows from sick	Informal	70	1	57.1	42.9
animals	Formal	70	0.75	50.0	50.0
Mastitis testing in every milking	Informal	70	1	31.4	68.6
	Formal	70	0.76	25.7	74.3
Milk from sick, mastitis or treated	Informal	70	1	74.3	25.7
cows handled separately	Formal	70	1.52	81.4	18.6
Milk from sick, mastitis or treated	Informal	70	1	11..4	88.6
cows fed to calves	Formal	70	0.60	7.1	92.9
Hand washing in every milking	Informal	70	1	95.7	4.3
	Formal	70	1.52	97.1	2.9
External biosecurity					
Disinfecting udder and teats in every	Informal	70	1	22.9	77.1
post milking	Formal	70	0.56	14.3	85.7
Examine health records when	Informal	70	1	30.0	70.0
purchasing stock	Formal	70	0.39**	14.3	85.7
Vaccinate purchased stock when	Informal	70	1	31.4	68.6
introducing into the farm	Formal	70	7.36***	77.1	22.9
Deworm purchased stock when	Informal	70	1	75.7	24.3
introducing into the farm	Formal	70	5.29***	94.3	5.7
Withdraw sale of products when	Informal	70	1	55.7	44.3
infectious disease present	Formal	70	8.48***	91.4	8.6

OR[1] Reflect odds of practicing biosecurity measure frequently in the formal outlet relative to the informal outlet

Significance ***0.01, **0.05

Odds ratio estimates reveal that it was more likely for farms selling milk in the formal market outlets than farms selling milk in the informal markets to vaccinate purchased stock (Odds

ratio 7.36), deworm purchased stock (Odds ratio 5.29) and not to trade products when infectious disease was present (Odds ratio 8.48).

4.1.2 Association of animal welfare status with milk market outlets

Table 4.3 presents the distribution of animal welfare indicators assessed on the criteria of welfare indicator thresholds defined by De Vries (2013). Results show that farms kept animals in good welfare status for all the animal welfare indicators assessed, with at least six in ten of the farms (>60%) scoring good welfare status.

Table 4.3 Status of cow welfare indicators observed in the sample farms n=140

Herd welfare status indicator	Indicator thresholds		Observed welfare status (%)	
	Good	Poor	Good	Poor
Very lean cows (%)	≤6.7	>6.7	60.0	40.0
Cows with dirty lower hind legs (%)	≤50.0	>50.0	84.3	15.7
Cows with dirty lower hind quarters (%)	≤19.0	>19.0	74.3	25.7
Cows with uneven gait (%)	≤11.8	>11.8	90.7	9.3
Cows with arched back (%)	≤11.8	>11.8	92.9	7.1
Cows lame (%)	≤33.0	>33.0	97.1	2.9
Cows with hairless patches (%)	≤44.1	>44.1	92.9	7.1
Cows with lesions and swellings (%)	≤58.8	>58.8	100.0	0.0
Cows with nasal discharge (%)	≤10.0	>10.0	91.4	8.6
Cows with ocular discharge (%)	≤6.0	>6.0	80.0	20.0
Cows with diarrhea (%)	≤6.5	>6.5	92.1	7.9
Cows with vulva discharge (%)	≤4.5	>4.5	96.4	3.6
Cows deaths in a year (%)	≤4.5	>4.5	67.9	32.1
Cows accessing water (%)	*Ad-lib*	Restricted	72.1	27.9
Calf bedding condition (%)	Dry	Wet/soiled	77.1	22.9

The score observed in health indicators (vulva discharge, ocular discharge, calf diarrhea, lesions and swelling) was over 90 % good welfare status while hygiene and feeding indicators (bedding condition, dirt in hind quarters, water access and body condition) scored below 75% good welfare status. Table 4.4 presents the logistic regression results for the

association of animal welfare status with milk market outlets. A larger proportion of farms marketing milk through formal than informal milk market outlets scored good animal welfare status in cow lean body condition (72.9% vs. 47.1%). The observation was repeated in hygiene indicators: dirty lower hind legs (98.6% vs. 68.6%), dirty lower hind quarters (98.6% vs. 48.6%) and in calf bedding condition (90.0% vs. 64.3%).

Table 4.4 Association of animal welfare status with milk market outlets

Animal welfare measure indicator	Milk market	n	Herd welfare status		
			OR[1]	Good welfare	Poor welfare
				%	%
Percent very lean cows	Informal	70	1	47.1	52.9
	Formal	70	3.01***	72.9	27.1
Percent cows with dirty lower hind legs	Informal	70	1	68.6	31.4
	Formal	70	2.51***	98.6	1.4
Percent cows with dirty lower hind quarters	Informal	70	1	48.6	51.4
	Formal	70	7.31***	98.6	1.4
Percent cows with uneven gait	Informal	70	1	88.6	11.4
	Formal	70	1.68	92.9	7.1
Percent cows with arched back	Informal	70	1	90.0	10.0
	Formal	70	2.48	95.7	4.3
Percent lame cows	Informal	70	1	97.1	2.8
	Formal	70	1.00	97.1	2.8
Percent cows with hairless patches	Informal	70	1	87.1	12.9
	Formal	70	10.18**	98.6	1.4
Percent cows with lesions and swellings	Informal	70	Not estimatable	100.0	0.0
	Formal	70		100.0	0.0
Percent cows with nasal discharge	Informal	70	1	92.9	7.1
	Formal	70	0.69	90.0	10.0
Percent cows with ocular discharge	Informal	70	1	78.5	21.5
	Formal	70	0.84	81.4	18.6
Percent cows with diarrhea	Informal	70	1	91.4	8.6
	Formal	70	0.82	92.8	7.2
Percent cows with vulva discharge	Informal	70	Not estimatable	100.0	0.0
	Formal	70		100.0	0.0
Percent cow deaths in year	Informal	70	1	70.0	30.0
	Formal	70	0.82	65.7	34.3
Percent cows accessing water	Informal	70	1	67.1	32.9
	Formal	70	1.65	77.1	22.9
Calf bedding condition	Informal	70	1	64.3	35.7
	Formal	70	5.00***	90.0	10.0

OR[1] Reflect odds of practicing good welfare in the formal outlet relative to the informal outlet
Significance ***0.01, **0.05

The results show that compared to farms marketing milk through informal milk outlets, those marketing through formal market outlets were 3.01 times more likely to have cows that are not lean, 2.51 and 7.31 times more likely to have cows with clean lower hind legs and hind quarters. In addition, marketing milk through formal market outlet was 2.51 and 7.31 times more likely than those marketing through the informal market outlet to have cows with clean lower hind legs and lower hind quarters. Similarly, the formal outlet was 10.18 times more likely to have cows with no hairless patches relative to the informal outlet. They were also 5.0 times more likely to provide dry calf bedding relative to the informal outlet.

4.2 Association of milk quality with biosecurity and animal welfare status

Results in Figure 4.1 indicates that the formal outlet outperformed the informal outlet when it came to three milk quality tests; alcohol, density and organoleptic. They had over 90% of the sampled farms having good milk quality from the alcohol and density tests. On the other hand, over 50% of the sampled farms in the informal outlet had poor quality milk from the same tests.

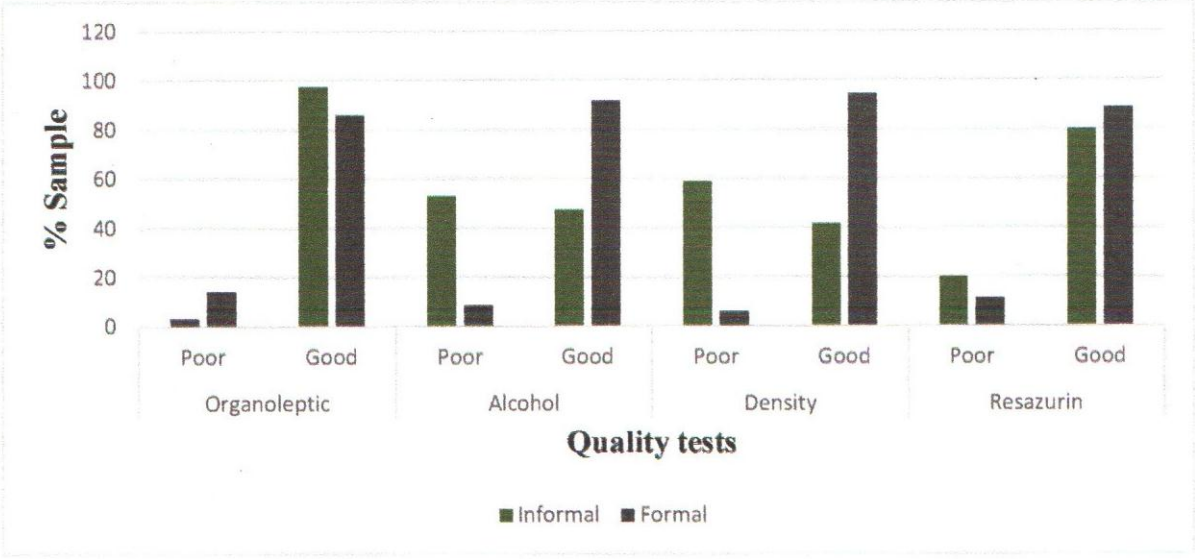


Figure 4.1 Comparison of milk quality in the formal and informal outlets (n=70)

Milk quality tests presented in Figure 4.2 for the samples tested reveal that 91.4% were acceptable for odor and appearance in the organoleptic test, 83.6% were acceptable for Resazurin test, 69.3% were acceptable for coagulation or precipitation in the alcohol test and 67.9% were acceptable for density test. The observed non-compliance with quality standards

was highest in alcohol and density tests (30.7 and 32.1%) and lowest in organoleptic and in Resazurin tests (8.6 and 16.4%) respectively.

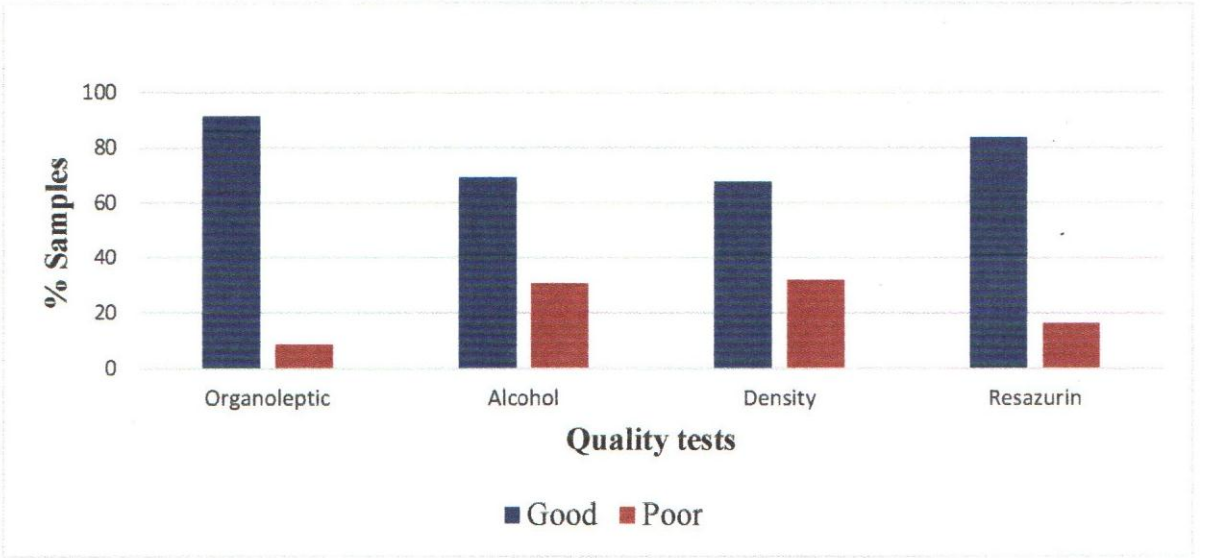


Figure 4.2 Milk quality tests on the sample farms (n=140)

Results presented in the frequency table 4.5 indicates that the quality of milk from the resazurin test was good irrespective of whether biosecurity was practiced or not. For instance, when cows calved in an unclean environment, no milk sample had poor quality milk. All of the practices recorded over 90% acceptance of milk in the organoleptic test regardless of whether biosecurity measure was practiced or not except when hands were not washed prior to milking which had 80% of samples still recording good quality milk when hands were not washed. Additionally, welfare measures presented showed a similar pattern for the organoleptic test with some measures having all samples tested with good quality milk regardless of whether welfare was poor as in the case of dirty lower hind legs and hind quarters.

Table 4.5 Status of milk quality in the sampled farms

Practice	Response	Milk (%)			
		Organoleptic	Alcohol	Density	Resazurin
		*Good	*Good	*Good	*Good
Market outlet	Frequently	85.7	91.4	94.3	87.1
	Sometimes	97.1	47.1	41.4	80.0
Biosecurity measures					
Cows calve in clean dry environment	Frequently	88.7	74.5	70.8	84.9
	Sometimes	100.0	52.9	58.8	79.4
Calving cows separated from clean cows	Frequently	92.0	72.0	66.7	84.0
	Sometimes	90.8	66.2	69.2	83.1
Mastitis tested in every milking	Yes	90.1	77.5	76.1	83.1
	No	92.8	60.9	59.4	84.1
Hand washing in every milking	Frequently	91.9	69.6	67.4	83.7
	Sometimes	80.0	60.0	80.0	80.0
Udder and teats disinfected every post milking	Yes	92.3	69.2	65.4	80.8
	No	91.2	69.3	68.4	84.2
Examine health records when purchasing stock	Yes	93.5	67.7	58.1	90.3
	No	90.8	69.7	70.6	81.7
Vaccinate purchased stock when introducing to farm	Yes	90.8	81.6	76.3	86.8
	No	92.2	54.7	57.8	79.7
Comply with antibiotic withdrawal period	Yes	90.3	76.7	75.7	87.4
	No	94.6	48.6	45.9	73.0
Milk from sick, mastitis or treated cows handled separately	Yes	90.8	70.6	68.8	82.6
	No	93.5	64.5	64.5	87.1
Welfare measures					

Table 4.5. Continued...

Percent very lean cows	Good	89.3	78.6	71.4	85.7
	Poor	94.6	55.4	62.5	80.4
Percent cows with dirty lower hind legs	Good	89.8	77.1	72.9	85.6
	Poor	100.0	27.3	40.9	72.7
Percent cows with dirty lower hind quarters	Good	88.5	79.8	77.9	86.5
	Poor	100.0	38.9	38.9	75.0
Percent cows with vulva discharge	Good	91.1	69.6	68.9	83.7
	Poor	100.0	60.0	40.0	80.0

*Percent poor =1- percent good

Tables 4.6 and 4.7 shows results from logistic regression of milk quality when biosecurity and welfare measures were either present or absent in the sample farms. The results indicate that relative to the informal outlet, the formal outlet was 0.18 less likely ($P<0.1$), and 11.96 and 23.32 times more likely ($P<0.01$) to have good quality milk from organoleptic, alcohol and density tests respectively. Alcohol test shows that when cows were calved in a clean, dry environment, they were 2.60 times more likely to have good quality milk ($P<0.05$) relative to when they calved in an unclean environment. From the same test, disinfecting udder and teats every post milking, was 17.89 times more likely to have good quality milk relative to when teats were not disinfected ($P<0.01$).

Table 4.6 Association of on-farm biosecurity with milk quality (OR and 95%CI, n=140)

Factors	Organoleptic	Alcohol	Density	Resazurin
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Market outlet (Formal vs. informal)	0.18** (0.04-0.84)	11.96*** (4.58-31.22)	23.32*** (7.64-71.17)	1.93 (0.76-4.96)
Biosecurity status				
Cows calve in a clean dry environment (Frequently vs. sometimes)	0.001 (0.001-999.99)	2.60** (1.16-5.89)	1.69 (0.76-3.77)	1.46 (0.54-3.91)
Calving cows isolated from sick cows (Frequently vs. sometimes)	1.17 (0.36-3.82)	1.32 (0.64-2.70)	0.89 (0.44-1.81)	1.07 (0.44-2.64)
Mastitis tested in every milking (Yes vs. no)	0.78 (0.22-2.76)	1.24 (0.55-2.79)	0.98 (0.45-2.14)	0.90 (0.34-2.38)
Milk from sick, mastitis or treated cows handled separately (Frequently vs. sometimes)	0.68 (0.14-3.29)	1.32 (0.57-3.08)	1.21 (0.52-2.81)	0.70 (0.22-2.24)
Hand washing in every milking (Yes vs. no)	2.82 (0.29-27.45)	1.53 (0.25-9.50)	0.52 (0.06-4.76)	1.28 (0.14-12.04)
Udder and teats disinfected every post milking (Frequently vs. sometimes)	1.15 (0.24-5.61	17.89*** (8.09-39.57)	0.87 (0.36-2.14)	0.79 (0.26-2.36)
Examine health records when purchasing stock (Yes vs. no)	1.47 (0.30-7.07)	0.91 (0.39-2.15)	0.58 (0.25-1.31)	2.10 (0.58-7.59)

Table 4.6. Continued...

Vaccinate purchased stock when introducing into farm (Yes vs. no)	1.84* (0.25-2.77)	3.67*** (1.72-7.85)	2.35** (1.14-4.86)	1.68 (0.68-4.15)
Comply with antibiotic withdrawal period (Yes vs. no)	0.53 (0.11-2.55)	1.65 (0.66-4.14)	3.67*** (1.67-8.07)	2.56** (1.01-6.50)

Significance *0.1, **0.05, ***0.01

The estimates from density test also indicate that vaccinating purchased stock before introducing to the farm and complying with antibiotics withdrawal period was 2.35 and 3.67 times more likely to have good quality milk relative to when vaccination was not done prior to introduction into the farm and when antibiotics withdrawal period was not adhered to.

Table 4.7 Association of welfare practices with milk quality (OR and 95%CI, n=140)

Factors	Organoleptic	Alcohol	Density	Resazurin
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Welfare Status				
Percent very lean cows (Good vs. poor)	0.47 (0.12-1.83)	2.96*** (1.41-6.20)	1.50 (0.73-3.08)	1.47 (0.60-3.60)
Percent cows with dirty lower hind legs (Good vs. poor)	0.001 (0.001-999.99)	8.99*** (3.20-25.22)	3.88*** (1.51-9.96)	2.23 (0.76-6.49)
Percent cows with dirty lower hind quarters (Good vs. poor)	0.001 (0.001-999.99)	6.21*** (2.73-14.15)	5.53*** (2.45-12.50)	2.14 (0.84-5.49)
Percent cows with vulva discharge (Good vs. poor)	0.001 (0.001-999.99)	1.53 (0.25-9.50)	3.32 (0.54-20.62)	1.28 (0.14-12.04)

Significance *0.1, **0.05, ***0.01

Nevertheless, the alcohol test indicated that cows that were not lean and those with clean lower hind quarters were 2.96 and 8.99 times more likely to have quality milk ($P<0.01$) relative to lean cows and cows with dirty lower hind quarters respectively.

4.3 Assessment of production losses in the sample farms

Results from Figure 4.3 shows that the losses at farm level for the sample farms do not show a normal distribution both in the formal and informal outlet. 11.4% to 14.3% of sample farms had extreme observations.

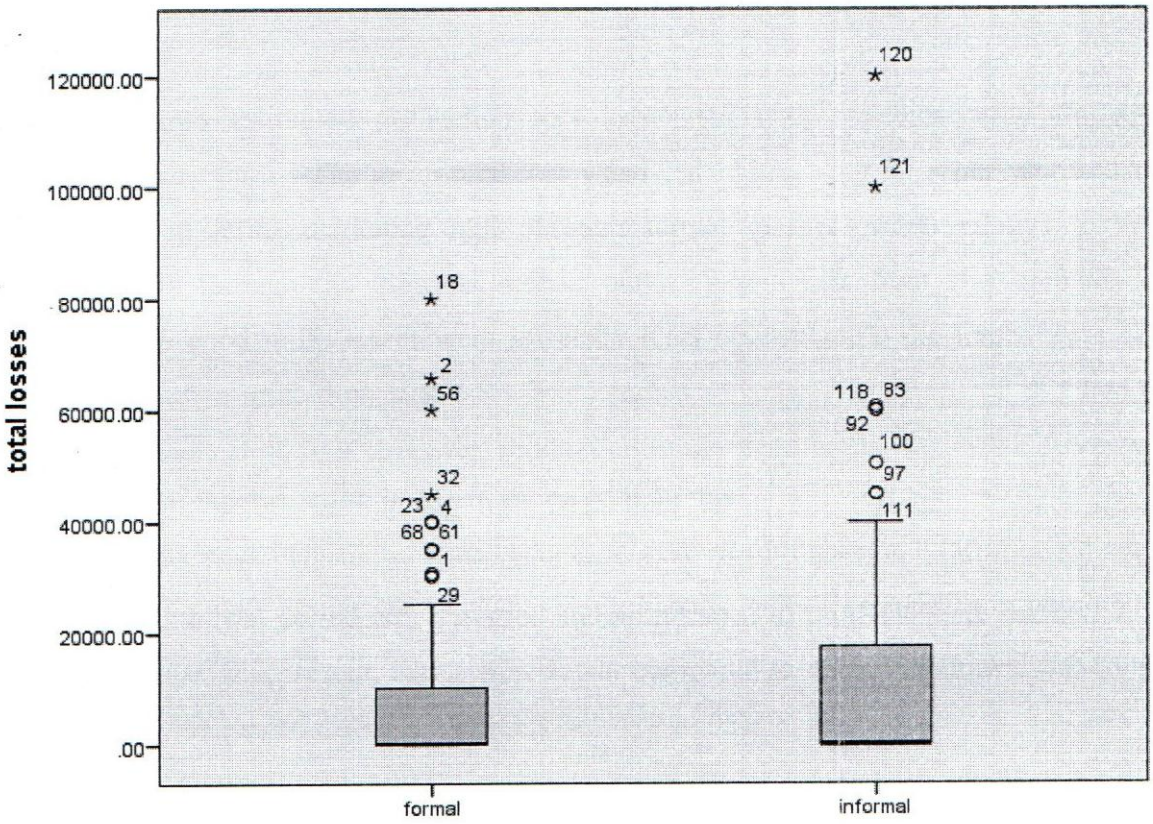


Figure 4.3 Distribution of production losses in the formal and informal outlets (n=70)

Results from Table 4.8 below indicate that losses from mortality are the major contributor to the total losses in the farms accounting for 98.82% of the total loss.

Table 4.8 Distribution of losses in the sample farms (n=140)

Source of loss	Percent contribution to total loss (%)
Milk losses from diseases	0.73
Milk spoilage	0.45
Mortality	98.82

Table 4.9 shows estimated production loss associated with the biosecurity status on smallholder dairy farms. The mean total loss was KES 11126.7 per farm per year and was 13.9% lower in farms marketing milk through formal market outlets relative to those marketing milk through the informal market outlet. When milk from sick animals was separated from good milk, losses were lower by KES 4023.8 while the losses were KES 4023.8 lower when milk from sick cows was handled separately as compared to when not handled separately ($P<0.05$). However, production losses were higher for farms deworming purchased stock before introducing into farm than farms not deworming stock before introducing into farm. The mean difference was KES 9879.9 ($P<0.1$). Additionally, when antibiotics withdrawal period was observed and withdrawal of products from markets when infectious disease was present, losses were lower compared to when withdrawal period was not observed with a mean difference of KES 815.4 ($P<0.05$).

Table 4.9 Mean production losses for biosecurity measures in the sample farms (n=140)

Variable	Response	Estimate	SE	P> | T |
Market outlet for milk	Formal vs. informal	-3100.5	3529.9	0.092*
Internal biosecurity				
Cows calving in clean dry environment	Frequently vs. sometimes	-1194.61	3423.6	0.758
Calving cows isolated from sick animals	Frequently vs. sometimes	575.7	3448.6	0.156
Mastitis testing at every milking	Yes vs. No	-614.3	3690.8	0.368
Milk from sick, mastitis or treated cows handled separately	Frequently vs. sometimes	-4023.8	3968.9	0.026**
Hand washing at every milking	Yes vs. no	-5131.2	11523.6	0.525
Disinfecting udder and teats in every post milking	Frequently vs. sometimes	2513.8	4689.9	0.985
External biosecurity				
Vaccinate purchased stock when introducing into the farm	Yes vs. no	5341.5	3379.8	0.357
Deworm purchased stock when introducing into the farm	Yes vs. no	5341.5	2592.9	0.076*
Withdraw f product sales when infectious disease present	Yes vs. no	-815.4	3551.9	0.027**

Significance *0.1, **0.05

Table 4.10 below shows contrast estimates of production losses when welfare practices were good versus when were poor. The results indicate that cows with clean lower hind quarters incurred less loss (KES 4930.8) relative to those with dirty lower hind quarters. In addition, the more the mortality at farm level, the higher the losses. Results showed that fewer incidences of mortality loss reported can be associated with lower loss of KES 23401.6 ($P<0.05$) relative to when mortality cases were more.

Table 4.10 Mean production losses for the welfare practices in the sample farms (n=140)

Herd welfare status indicator	Response level	Estimate	SE	P> | T |
Percent very lean cows	Good vs. poor	3071.4	3352.7	0.477
Percent cows with dirty lower hind legs	Good vs. poor	-3227.3	5528.9	0.753
Percent cows with dirty lower hind quarters	Good vs. poor	-4930.8	4265.8	0.059*
Percent cows with uneven gait	Good vs. poor	-4946.0	9404.3	0.303
Percent cows with vulva discharge	Good vs. poor	-1607.2	10511.7	0.507
Percent cows deaths in a year	Good vs. poor	-23401.6	4172.4	0.028**
Calf bedding condition	Good vs. poor	1656.3	3652.2	0.500

Significance *0.1, **0.05

4.4 Assessment of gross margins in the sample farms

Figure 4.4 shows the distribution of gross margins across the formal and informal outlets. It is evident from the plots that the margins across the farms do not observe a normal distribution.

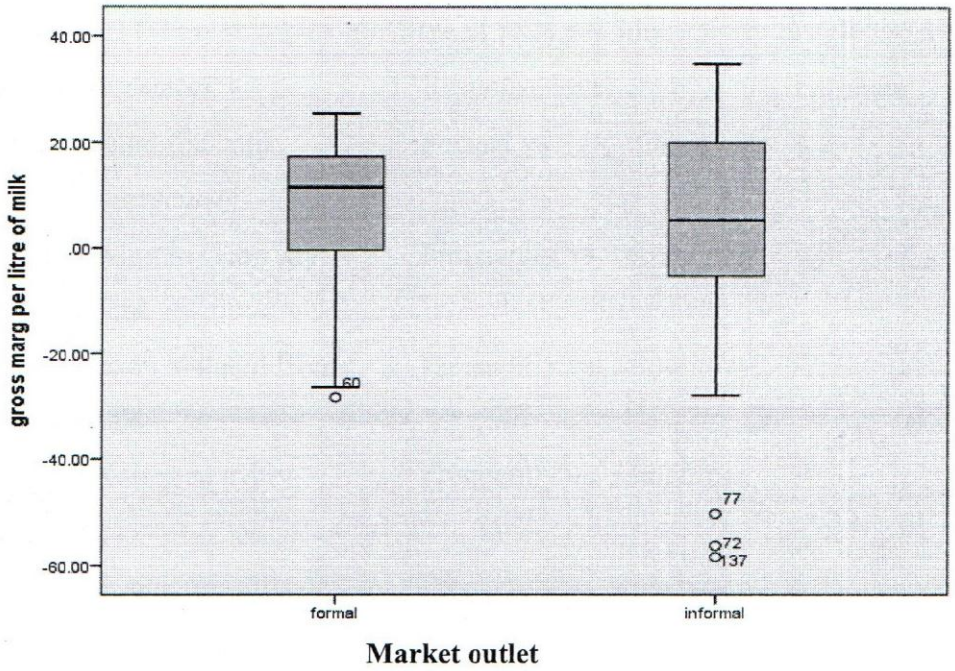


Figure 4.4: Distribution of gross margins in the formal and informal outlets (n=70)

Table 4.11 shows that the formal outlet had lower milk prices (KES 29.7) but with higher milk production (12.0Lts) when compared to the informal outlet which had higher milk prices (KES 32.6) but lower milk production (10.7Lts). Milk production in the formal outlet was 5% higher than the informal outlet. Similarly, the formal market reported higher margins by KES 4.2 per litre of milk compared to the informal outlet.

Table 4.11 Mean milk production and price by market outlet for the sample farms

Market outlets	Average milk production (L/farm/day)	Milk price (KES/L)
Informal (n=70)	10.7	32.6
Formal (n=70)	12.0	29.7
Average	11.4	31.2

The gross margins per litre of milk for biosecurity practices (Table 4.12) and for animal welfare status (Table 4.13) show that none of the biosecurity measures examined had significant association with the margins earned.

Table 4.12 Gross margins per litre of milk for biosecurity practices (n=70)

Biosecurity status	Response level	Estimate	SE	P >| T
Market outlet for milk	Formal vs. informal	4.2	2.8	0.0696*
Internal biosecurity				
Cows calving in clean dry environment	Frequently vs. sometimes	0.2	3.6	0.449
Calving cows isolated from sick animals	Frequently vs. sometimes	-2.7	2.8	0.776
Mastitis testing in every milking	Frequently vs. sometimes	-4.0	3.7	0.197
Milk from sick, mastitis or treated cows handled separately	Frequently vs. sometimes	5.5	3.0	0.923
Hand washing in every milking	Frequently vs. sometimes	1.6	7.6	0.549
Disinfecting udder and teats in every post milking	Frequently vs. sometimes	-3.6	4.4	0.516
External biosecurity				
Vaccinate purchased stock when introducing into the farm	Frequently vs. sometimes	3.5	2.9	0.455
Deworm purchased stock when introducing into the farm	Frequently vs. sometimes	-3.4	3.6	0.637
Withdraw sale of products in the when infectious disease present	Frequently vs. sometimes	-3.5	3.5	0.553

Significance *0.1

However, the margins were KES 3.9 higher (P<0.05) for cows that are not lean compared lean cows.

Table 4.13 Gross margins per litre of milk for welfare practices (n=70)

Herd Welfare status indicator	Response level	Estimate	SE	P >| T |
Percent very lean cows	Good vs. poor	3.9	3.0	0.003**
Percent cows with dirty lower hind legs	Good vs. poor	-3.2	4.9	0.119
Percent cows with dirty lower hind quarters	Good vs. poor	-4.2	3.6	0.638
Percent cows with uneven gait	Good vs. poor	6.5	5.0	0.201
Percent cows with vulva discharge	Good vs. poor	5.1	8.3	0.314
Percent cows deaths in a year	Good vs. poor	-5.5	2.9	0.664

Significance **0.05

CHAPTER FIVE

5. Discussion

5.1 Association of biosecurity and animal welfare status with milk market outlets

The implementation of on-farm biosecurity and animal welfare practices were better in sample farms participating in the formal than in the informal milk marketing. This was expected because formal milk markets which include processors, cooperatives and licensed milk bars demand quality milk (IFAD, 2012; Rademaker *et al.*, 2016). The formal milk markets pay attention to milk quality attributes and implement regular testing to ascertain quality before accepting milk delivery. It is important for farmers participating in these markets to implement biosecurity and animal welfare measures to comply with the market requirements for milk safety and quality standards. Dairy cooperatives and processors thus train farmers on hygiene and good management practices in order to improve quality of milk that they receive (Costard *et al.*, 2009; Oladele *et al.*, 2013).

However, farmers participating in the formal milk marketing did not examine health records when purchasing stock. Several reasons can possibly explain this observation. These farmers rarely keep records of individual animal performance. Orregård (2013) in his milk quality analysis in Kiambu observed that farmers have poor or no treatment records for their cows; therefore there were no records to avail to potential buyer. Smallholders purchase stock from fellow farmers known to them on common trust among themselves. The veterinary authorities are unable to enforce regulation governing livestock sales and therefore cannot ensure that animals have records to prove their health status.

The finding that farmers participating in the formal milk marketing were more likely to vaccinate and deworm purchased stock before introducing into the farm reflects good dairy management practices acquired in training to ensure high quality and safety standards are maintained for traded dairy products. This should minimize economic losses incurred. Farmers that participate in the formal milk marketing linked to cooperatives and dairy processors enjoy veterinary services from the organizations and therefore more likely to access better veterinary services.

Formal milk marketing was associated with better compliance with safe withdrawal periods for products when animals were diseased or under treatment. This demonstrates that participation in formal markets encourages high uptake of biosecurity measures to manage risks and minimize potential losses associated with unhygienic handling of cows and milk

(Ndungu *et al*, 2016). For them to meet quality standards demanded by dairy processors and cooperatives (Veernoij, 2016), farmers participating in the formal milk marketing have to ensure that milk or other products do not have antibiotic residues or is affected by disease which lowers the product quality. If affected, the product risks rejection, thereby causing losses to them. This corresponds to observations by Orregård (2013) that there is a conscious awareness along the milk value chain to reduce spoilage and ensuring the quality of the milk.

Lean cows were less likely found in farms participating in the formal than in informal milk marketing. This can be linked to easy access to feeds from the cooperative societies on check-off arrangements and training on feed conservation to maintain cows in good nutritional condition this has been observed in Nandi and Bomet where co-operatives contract extension services for their members to offer trainings on a regular basis on feed conservation (Veernoij, 2016).

Cows with cleaner lower hind legs and hind quarters were more prevalent in the farmers participating in formal than informal milk marketing. Dirty hind legs and hind quarters is a result of dirty and poor housing conditions affecting cows that stand long or rest in a dung filled floor, which soil the legs and hind quarters. Wet bedding is prevalent in zero-grazing units, which farmers participating in informal milk marketing are more likely to be members of. This explanation is supported by the observations of Tuei (2010) that showed that zero-grazing units are not kept clean, because of lacking labor for maintenance and sometimes use of earth floor with poor drainage systems. Majority of the farmers in the formal outlet practiced open grazing and it was unlikely for the cows to soil their lower hind legs and hind quarters.

5.2 Association of status of biosecurity and animal welfare with milk quality

There were some biosecurity and welfare practices associated with acceptable milk quality standards. This is attainable with practicing recommended good management practices which when delivering milk to formal market outlets involves subjecting milk to quality tests at delivery intake point by the co-operatives or processors (Ndungu *et al.*, 2016). Milk quality testing is to reduce risks associated with unsafe and poor quality milk. Farmers practice biosecurity and animal welfare to reduce the risk of rejection and resulting losses. In support of this, Oladele *et al.* (2013) have observed that frequent extension contacts enhance farmers' knowledge and adoption of biosecurity practices.

Milk quality was better with practice of good hygiene. This is observed with cows calving in a clean and dry environment, and udder and teats disinfection every post milking. The observation of Wells (1998) supports this: that mixing calving cows with sick cows is a risk factor for *Staphylococcus aureus* which causes mastitis. This occurs if infections gains entry in to the cow's udder or teats, and then load milk with disease causing organisms which lowers milk quality.

Disinfection of udder and teats is a preventive mechanism to disease entry into the udder and teats. In the study of Kunda *et al.* (2015), presence of micro-organisms in milk and milk products was an indication of unsanitary handling of either milk or milk utensils. In the study of Smith (2001), failure to teat dip after milking and failure to observe udder hygiene was a risk factor for contagious mastitis caused by *Staphylococcus aureus*. Presence of mastitis in milk results in coagulation of milk in the alcohol test and deviation of specific gravity from normal, rendering the quality poor and of unacceptable standards.

Vaccination of purchased stock was associated with acceptable alcohol and specific gravity tests. This is because vaccination prevents disease entry or spread, thus helps in maintaining the quality of milk by yielding disease free milk that easily passes basic quality tests. Brennan and Christley (2012) in their biosecurity study observed that risks associated with cattle movements can be reduced when producers only purchased animals from farms with a known disease history and through isolation, disease testing and prophylactic treatment of purchased stock. In concurrence, Wells (1998) found that risk factors for *Staphylococcus aureus* which causes mastitis included bringing new cattle in the herd and failure to vaccinate before introducing cattle into the farm.

Acceptable milk quality in specific gravity and resazurin tests was obtained with the withdrawing sale of products when an infectious disease was present, which is an adherence with antibiotic withdrawal periods. When farmers fail to comply with instructed withdrawal periods when using antibiotic treatment, the residual effects are likely to occur in the milk and this inhibits starter culture activity in processing fermented milk (Orregård, 2013) and poses a public health risk (FAO, 2011). Antibiotic residues in milk can alter the specific gravity beyond the normal acceptable levels. The resazurin test assesses the keeping quality of milk and a difference in normal acceptable bacterial constitution alters the quality. It then goes without saying that antibiotic and drug residues as well as milk infected with disease is bound to fail the specific gravity and resazurin tests. This best explains why those who

observe safe withdrawal periods for their products at diseased or medication times produce milk of acceptable quality tests.

Of the animal welfare measures, cows that were not lean produced milk of acceptable alcohol test, which can be attributed to better feeding enabling animal to build natural immunity defenses against pathogens which can lower milk quality. Cattle leanness impairs animal gait, depresses feed intake and can be clinical condition for which farmers treat with antibiotics. As such, leanness can affect milk quality as observed in FAO (2013) and Aleri *et al.* (2012) through weight loss, antibiotic residual effect and unhygienic exposures and increased susceptibility to diseases and parasite challenges (De Vries 2013). Acceptable alcohol and specific gravity tests of milk quality were obtained with cows cleaner in the hind legs and hind quarters. Poor hygiene easily cause milk contamination that may hamper milk quality in conformity with previous study (Aleri *et al.*, 2012) that showed that failure to maintain hygienic conditions may increase mastitis prevalence which lowers milk quality.

5.3 Association of biosecurity and animal welfare status on production losses and gross margins

Production losses were lower with formal milk marketing and the larger proportions of the losses were due to mortality. This demonstrates superior herd health with the formal milk marketing. This is unlike the informal milk marketing where training is limited. Low biosecurity and welfare uptake reflects lack of knowledge of the same and lack of coordinated message delivery from supporting networks (Sayers *et al.*, 2013). Oladele *et al.* (2013) reported in his biosecurity study that the more the farmer contact with extension agents, the better the knowledge of biosecurity practices. Addisu *et al.* (2012) in his study of production aspects of intensification and milk quality in Ethiopia reported that as the level of market quality improved, trends towards better feed production and utilization, use of improved dairy cattle and milk production improved.

Production losses were lower with separate handling of milk from sick animals because this practice assures quality is uncontaminated and is not rejected by processors or cooperatives (Orregård, 2013). In contrast, practicing deworming of purchased stock when introducing into the farm had higher production losses. This is possibly resulting from costs of deworming because deworming is a common treatment in the dairy farms as found in the study of Orregård (2013). There are many instances when huge investments in animals did not pay off due to ineffective control measures (Oladele *et al.* 2013). A study in Ethiopian

feedlots (Alemayehu and Leta, 2014) showed that pre-purchase inspections along the market chain are conducted without the necessary veterinary skills. Sometimes they end up with a diseased animal which ends up dying and causing losses in the farm. A similar observation were made by Adams *et al.* (2012) that traders sometimes sell diseased stock to producers and sensitivity is low for clinical inspections of diseases such as Foot and mouth disease (Alemayehu and Leta, 2014). This impact on herd revenues when infected animal passes undetected in the market.

Production losses were lower when farmers adhered to antibiotic withdrawal periods and thereby withdrawing sale of products when an infectious disease was present. Detection of antibiotic residues in milk is a cause for milk rejection by processors and cooperatives because antibiotic residues can inhibit starter culture activity in fermented milk (Orregård, 2013).

Production losses were found lower with cows cleaner in hind legs and hind quarters. This is because good hygiene ensures cleaner cows in their hind legs and hind quarters and thus clean milk which eliminates milk rejection. This concurs with the observations made by Sayers *et al.* (2013) that significant production losses are associated with exposure to unregulated cattle diseases at individual farm level. Veerasamy *et al.* (2011) showed that diseases, in many cases is associated with negative experiences such as pain, discomfort and distress and is therefore important to welfare. If in general farmers could make specific effort to consult veterinarians while purchasing stock, they would be more likely to reduce production losses from disease treatment expenditures and deaths. Farmers need to improve more on their welfare and biosecurity practices to improve herd productivity and profitability.

The gross margins were measured on per litre of milk to enable fair comparison. The higher margins realized with the formal than with informal milk marketing, could have been resulted from higher milk production, affordable feeds and higher milk prices (EADD, 2014; Mawa *et al.*, 2014). Farms with cows that were not lean earned higher margins, probably from good nutrition indicated by good body condition which supports higher milk production.

CHAPTER SIX

6. Conclusions and recommendations

6.1 Conclusions

This study fulfils knowledge gaps about the association that milk market outlet, biosecurity and animal welfare measures have with the milk quality, production losses and gross margins on smallholder dairy farms with market oriented production. Results show that that milk market influences farmers' implementation of on-farm biosecurity and animal welfare practices and these are management strategies to improve milk quality and profitability in smallholder dairy farms. The results obtained provide answers to the research questions that:

i. Implementation of on-farm biosecurity and animal welfare measures differed between the farms with formal and informal milk marketing.

ii. Implementation of on-farm biosecurity and animal welfare measures influenced milk quality.

iii. Implementation of on-farm biosecurity and animal welfare measures was associated with production losses.

iv. Gross margins earned were not associated with any of the bio-security measures examined but had significant association with some animal welfare measures.

6.2 Recommendations

i. Findings revealed that the informal outlet was less likely to observe biosecurity and welfare practices in general. If these practices were worked on and improved in the informal outlet, herd productivity and profitability would greatly improve across board in the smallholder dairy. Policies should be geared towards improving extension activities and bridging the farmer-extension link, and tailoring training activities towards improvement of these biosecurity and welfare practices while strengthening farmer organizations to further improve implementation of biosecurity and welfare practices. This would lead to improved productivity and profitability.

ii. Implementation of on-farm bio-security and animal welfare measures influenced milk quality with formal than for informal milk marketing more likely to produce acceptable milk. If farmers in the informal outlet had the trainings received in the formal outlet, thanks to their membership in farmer organizations, milk quality would greatly improve. This could better and easily be achieved if the farmers in the informal outlet were organized in farmer organizations. The government and private actors like Non-governmental organizations should pull up efforts to organize these

farmers into such groups for trainings. There should also be reforms in policy to encourage actors in the informal outlets to improve on their practices for better milk quality or otherwise there be a form of incentive by stakeholders to encourage production of quality and hygienic milk. Improved milk quality and production resulting from such interventions would significantly improve productivity and profitability of the dairy herd for smallholders.

iii. Findings showed that implementation of certain on-farm biosecurity and animal welfare measures were associated with lower production losses. To ensure that production losses were minimized, these practices should be implemented in more farms. Extension activities should be scaled up to reach more farmers who are not aware of the advantages of having the measures in place, and increase awareness as to how these practices can work to farmers' advantage. The government should allocate more resources in ensuring more farmers are reached by extension agents for this to be fully achieved. In addition, more partnerships should be built between and among government and non-government actors for speedy and efficient extension delivery which would greatly minimize losses for improved productivity and profitability in the smallholder dairy.

iv. Findings also revealed that gross margins earned were not associated with any of the bio-security measures examined but had significant association with some animal welfare measures. This implies that good agricultural practices lead to healthy animals which in turn improves productivity and minimizes losses leading to higher margins earned. Training and extension activities should therefore be geared towards improvement of such practices that ensure wellbeing of the herd if farmers are to make any meaningful earning from their dairy activities. The government should scale up extension activities in an effort to help farmers improve on-farm biosecurity and welfare practices which would improve productivity and income and thereby increasing profitability of the dairy herd.

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APPENDICES
APPENDIX 1

QUESTIONNAIRE

This survey is conducted by a post graduate student at the Department of Animal Sciences, Egerton University in partial fulfilment of a degree in MSc. Livestock Production Systems. Information provided herein will be treated with utmost confidentiality.

Date [ ] **Questionnaire Number [ ]**

Enumerator name [ ]

A. GENERAL INFORMATION

Farm owner (Full names) **Tel No.**	**Farm size**	**1.Rented** **2.Owned**	**Location**	**Division**

A/1. List the farm agricultural enterprises and the acres of land allocated

Enterprise	[__ __]	[__ __ _]	[_ __]	[__ __ _]	[_ _]	[__ __ _]
Land Acres	[__ __]	[__ __]	[_ _]	[__ __ _]	[_ _]	[__ __]

A/2. Provide the following details about the owner of the farm

Gender 1 = Male 2 = Female	Age (years)	Primary occupation	Education level	Five important household incomes sources in order of (1^{st} to 5^{th}) importance
[_____]	[__ __]	[____]	[__]	**1^{st}**[_] **2^{nd}** [_] **3^{rd}** [_] **4^{th}** [_] **5^{th}**[_]

A/2 General information

Primary Occupation

1= Business

2 = Farming

3 = Permanent employment

4= Casual employment

5= others specify

Education Level

1 = No formal education

2 = Adult literacy education

3 = Primary education

4= Secondary education ('o" & "A' level)

5 = Post-secondary education

6 = university degree education

Income Sources

1=crop farming

2= dairy farming

3=business

4=permanent employment

5= casual employment

6=remittances 7. pension

A/3. Provide the following details about **the farm**

Distance to the nearest market for agricultural inputs & outputs	Dairy keeping experience (years)	Household member responsible for day- to-day dairy husbandry tasks	Best description of your dairy production system?	Best description of your dairy production objective?
[__ ___]	[__ ___]	[_ __]	[__ __ _]	[__ __ _]
Production objectives 1. Primarily for home consumption 2. Mostly for home consumption with		***Household member:*** *1 = Father;* *2 Mother;* *3= Employee;* *4= Children*	**Production system** 1= Only grazing (free-range or tethered) 2 = Mainly grazing with some stall feeding	

intension of selling available surplus 3. Partly for home consumption and partly for market 4. Primarily for market	*5=Mother and father*	3= Only stall feeding (zero grazing) 4= Mainly stall feeding with some grazing

A/4. Record the number of dairy animals on the farm by their classes

Females	***Number***	***Males***	***Number***
Births within last 12 months		Births within last 12 months	
Calves on the farm now		Calves on the farm now	
Weaned heifers		Weaned bulls	
Heifers mature for breeding and first calvers		Steers	
Cows (≥2 parity)		Bulls of breeding age	

A/5. List animal **routine management practices** for your animal identification systems, animal records and the assessments

List animal Identification systems used by the farmer	List animal records kept by the farmer	List dairy business assessments frequently done by the farmer
1 [____] 2 [____]	1 [____] 2 [____] 3 [____]	1 [____] 2 [____] 3 [____]
1= None used 3= Name 2=Ear tag 4= Branding 5=Others	1= None 2= Breeding 3=Health 4=Inventory -births & deaths 5= Production 6= Sales, purchases	1=No any assessment 2= production performance 3= financial performance 4= planning decisions

B. BIOSECURITY STATUS

B/1: How would you describe these routine dairy **biosecurity management practices** on your farm?

1.	Cows calve in clean dry area	
2.	Foot bath provided at the farm	
3.	Calving cows are isolated from any sick animal or calving area	
4.	Separate and dispose milk from sick or treated animals	

1= Frequently, 2= Only Sometimes or not at all

B/2. What is your level of satisfaction with **Management Practices** in your dairy herd?

Herd health	Milking hygiene	Feed quality and quantity	Water quality & quantity	Animal environment	Compliance with instructions for using antibiotics& vaccines	Managerial standards
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

1= satisfied | 2=Not satisfied |

B/3. How would you describe these **precautionary management practices** in your dairy herd?

1	Cattle movement on the farm is		*1=Open, 2= Restricted*
2	Precautions when purchasing stock	1[ ] 2[ ]	1= Necessary precautions taken (Enquire about disease history; Examine animal

3	Precautions when purchasing feeds	1[ ] 2[ ]	/feeds physically; Seek advice of a veterinarian/extension/fellow farmers); 2=No any specific precaution taken;
4	Purchased stock is vaccinated		1=Yes; 2= Only sometimes; 3=No
5	De-worm the animals soon after purchase		
6	Health records available from the animal sellers?		
7	If 4 is yes, list three diseases you have vaccinated against in the in last three years?	1 [ ] 2[ ] 3[ ] 1=Foot Mouth Disease 2=Lumpy Skin Disease 3=Bovine Pleuropneumonia 4=Rift Valley Fever, 5=Anthrax /Black quarters 6=Brucellosis 7=Salmonellosis 8. ECF 9=Other (specify)	
8	Precautions frequently in feed storage	1=Protected storage 2=Non protected storage	

C. WELFARE STATUS

C/1: How would you describe **the animal environment** in your farm?

1. Housing design is adequately allows normal animal movement and interactions *(1=yes, 2= No)*	
2. Dry bedding is provided for the animals *(1=yes, 2= No)*	
3. Hygiene is maintained in the dairy unit *(1=yes, 2= No)*	
4. Do you physically assess the herd to ensure well-being and comfort? *(1=yes, 2= No)*	

C/2: How would you describe these routine dairy **welfare practices** on your farm?

1.	Calves stay with their dams for more than six hours soon after birth	
2.	Udder and teats are disinfected post milking	
3.	Calves are fed colostrums from other (pooled) dams	
4.	Calves are fed pooled milk	
5.	Calves are fed warm milk only	
6.	Calves are fed milk from sick including mastitis	
7.	Calf pen is free of manure and standing water	
8.	Hooves are trimmed	

1= Frequently, 2= Only sometimes or not at all

Feeding status

9.	Percent (%) very lean cows in the herd	
10.	Watering frequency daily 1. Once 2. Twice 3. Ad-lib	

11.	Hygiene of drinkers **1. Good 2. Poor**	

Housing status

12.	Percent (%) cows in the herd with dirty lower hind legs	
13.	Percent (%) cows in the herd with dirty hind quarters	
14.	Type of bedding **1. Concrete 2. Slated timber 3. Earthen**	
15.	State of bedding **1. Dry 2. Wet**	

Health status

16.	Percent (%) cows in the herd with uneven gait	
17.	Percent (%) cows in the herd with arched back	
18.	Percent (%) lame cows in the herd	
19.	Percent (%) cows in the herd with hairless patches	
20.	Percent (%) cows in the herd with lesions and swellings	
21.	Percent (%) cows with nasal discharge	
22.	Percent (%) cows in the herd with ocular discharge	
23.	Percent (%) cows in the herd with diarrhea	
24.	Percent (%) cows in the herd with vulva discharge	
25.	Percent (%) animal deaths on the farm in the last 12 months	

C/3: Provide details on your **milk handling practices**

1. The milker has had training in milk handling?	**1= Yes 2= No**	
2. The milker washes hands before milking?		
3. Fore stripping is a regular practice at milking		
4. Teat dipping post milking is a regular practice		
5. Mastitis testing is a regular practice		
6. Floor of milking shed is	**1=Earth soil 2=.Concentrate/stone/Wooden slate**	
7. Types of milking containers used	**1=Plastic 2=Aluminum 3= Mazzi can 4= Others, specify**	
8. Types of milk storage containers		
9. How do you use the milk in case mastitis is positive?		
10. Water used for udder washing is	**1=Cold water 2= Warm water**	
11. Sources of water for the animals	**1=Borehole 2=Roof catchment 3=River 4= Natural spring 5=Tap water 6=Dam 7=Runoff harvested water**	

D. PRODUCTION LOSSES

D/1. What are the 3 **most important dairy herd diseases on your farm** (in order of importance)?

	Disease 1	Disease 2	Disease 3
Which Disease?	[__]	[__]	[__]
Three Importance of the disease	[__][__][__]	[__][__][__]	[__][__][__]
Costs of treating disease (drugs &Vet fee) per animal			
Cost of controlling the disease (vaccine, acaricide) per every event			
Estimate reduction in milk (litres/day) during the disease compared to when cow is in normal health			
If treating or on drug, what is milk withdrawal period in days?			

DISEASES

1 = East Coast fever
2 = Anaplasmosis
3 = Other tick-borne diseases
4= Respiratory / Pneumonia
5 = Diarrhea's
6 = Intestinal worms
7 = Trypanosomosis
11 = Milk fever
12 = Reproduction (abortion, fertility)
13 = Foot problems
14 = Poisoning (acaricide, snake bite, plants, Bloat
15 = Anthrax
16 = Eye disease
17= Others specify_____

IMPORTANCE OF DISEASE

1. More frequent cases
2. Causes deaths
3. Decreases milk yield
4. Expensive to treat
5. Expensive to prevent
6. Other (specify)_____

8= Lumpy Skin Disease 18=None 7. None

9= Calf mortality

10= Mastitis

D/2: Record estimated liters of morning and evening milk produced and losses for the herd by seasons

Milking time	Wet season yields	Dry season yields	Milk sales		Spillage		Spoilt & rejected		Fed calves & family		Calculate total herd
			Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	
Morning											
Evening											
Calculate total herd											

D/3: Record estimated morning and evening milk sales, prices reasons for spoilage and value added products

Milking time	Two regular sale outlets	Price per liter	Frequent reasons for spoilage	Frequent reasons for rejection	Milk value addition
Morning	1[_____] 2[_____]	1[_____] 2[_____]	1[_____] 2[_____]	1[_____] 2[_____]	1[_____] 2[_____]
Evening	1[_____] 2[_____]	1[_____] 2[_____]	1[_____] 2[_____]	1[_____] 2[_____]	1[_____] 2[_____]

Regular milk sale outlets

1= Cooperative society 2=New K.C.C

3=Brookside 7=Other private processors

4=Mobile trader 5=Individual consumer

6=Institutions/ Hotels

Reasons for spoilage

1=Contamination on the farm

2=contamination outside the farm

3=Rejection by buyers

4=Lack of cooling facilities

5=Lack of market outlet

6=Due to medication

Milk value addition

1= None,

2=Mala,

3= Yoghurt,

4= Ghee,

5=Milk shake,

6=Others specify

Reason for milk rejection: 1=Mastitis 2=Dirt in milk 3=Bad smell 4= Adulteration (e.g. water, chemical)

D/4: What do you do with the spoilt/ rejected milk?

E: INPUTS

E/1. Estimate the **AVERAGE COSTS in a month of what you incur** in the dairy herd enterprise

Purchased pasture, fodder & crop residues	Purchased concentrate & minerals	Purchased water	Acaricide & disinfectants	Vaccinations & Treatments	AI services	Bull services

Cost of own farm fodder	Dairy loan interests	Hired labor for dairy	Family labor for dairy	Market transaction costs (e.g transport)	Animal mortality loss

Cost of cows	Cost of heifer	Dairy shed	Milk cans	Milk buckets	Panga	Wheelbarrow	Chaff cutter

Record animal SALES by their classes in the last 12 MONTHS

Cows	Cost	Bulls	Cost	Heifers	Cost	Steers	Cost	Calves	Cost

F: MILK QUALITY

F/1: MILK SAMPLES FOR TESTING

Milk tests	Sample 1	Sample 2	Sample 3
Organoleptic			
Alcohol			
Density			
Resazurin			
1= acceptable ; 2=Not acceptable			

APPENDIX 2

Results output

The SAS System 12:12 Friday, November 5, 2018 1

The FREQ Procedure

Table of market by biopractice

market biopractice

Frequency, Col Pct	frequent	sometime	Total
formal	63 59.43	7 20.59	70
informal	43 40.57	27 79.41	70
Total	106	34	140

The FREQ Procedure

Statistics for Table of market by biopractice

Statistic	DF	Value	Prob
Chi-Square	1	15.5383	<.0001
Likelihood Ratio Chi-Square	1	16.3557	<.0001
Continuity Adj. Chi-Square	1	14.0233	0.0002
Mantel-Haenszel Chi-Square	1	15.4273	<.0001
Phi Coefficient		0.3331	
Contingency Coefficient		0.3161	
Cramer's V		0.3331	

The FREQ Procedure

Statistics for Table of market by biopractice

Fisher's Exact Test	
Cell (1,1) Frequency (F)	63
Left-sided Pr <= F	1.0000
Right-sided Pr >= F	6.546E-05
Table Probability (P)	5.487E-05
Two-sided Pr <= P	1.309E-04

Sample Size = 140

The LOGISTIC Procedure

Model Information

Data Set	WORK.BIOMEASURED
Response Variable	biopractice
Number of Response Levels	2
Number of Observations	4
Frequency Variable	counts
Sum of Frequencies	140
Model	binary logit
Optimization Technique	Fisher's scoring

Response Profile

Ordered Value	biopractice	Total Frequency
1	frequent	106
2	sometime	34

Probability modeled is biopractice='frequent'.

The LOGISTIC Procedure

Class Level Information

Class	Value	Design Variables
market	formal	1
	informal	-1

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

The LOGISTIC Procedure

Model Fit Statistics

Criterion	Intercept Only	Intercept and Covariates
AIC	157.218	142.863
SC	160.160	148.746
-2 Log L	155.218	138.863

Testing Global Null Hypothesis: BETA=0

Test	Chi-Square	DF	Pr > ChiSq
Likelihood Ratio	16.3557	1	<.0001
Score	15.5383	1	<.0001
Wald	13.6917	1	0.0002

formal or informal morning outlet1 * organoleptic test Crosstabulation

			organoleptic test		Total
			acceptable	unacceptable	
formal or informal morning outlet1	formal	Count	60	10	70
		% within formal or informal morning outlet1	85.7%	14.3%	100.0%
		% within organoleptic test	46.9%	83.3%	50.0%
		% of Total	42.9%	7.1%	50.0%
	informal	Count	68	2	70
		% within formal or informal morning outlet1	97.1%	2.9%	100.0%
		% within organoleptic test	53.1%	16.7%	50.0%
		% of Total	48.6%	1.4%	50.0%
Total		Count	128	12	140
		% within formal or informal morning outlet1	91.4%	8.6%	100.0%
		% within organoleptic test	100.0%	100.0%	100.0%
		% of Total	91.4%	8.6%	100.0%

formal or informal morning outlet1 * alcohol test Crosstabulation

			alcohol test		Total
			acceptable	unacceptable	
formal or informal morning outlet1	formal	Count	64	6	70
		% within formal or informal morning outlet1	91.4%	8.6%	100.0%
		% within alcohol test	66.0%	14.0%	50.0%
		% of Total	45.7%	4.3%	50.0%
	informal	Count	33	37	70
		% within formal or informal morning outlet1	47.1%	52.9%	100.0%
		% within alcohol test	34.0%	86.0%	50.0%
		% of Total	23.6%	26.4%	50.0%
Total		Count	97	43	140
		% within formal or informal morning outlet1	69.3%	30.7%	100.0%
		% within alcohol test	100.0%	100.0%	100.0%
		% of Total	69.3%	30.7%	100.0%

formal or informal morning outlet1 * density test Crosstabulation

			density test		Total
			acceptable	unacceptable	
formal or informal morning outlet1	formal	Count	66	4	70
		% within formal or informal morning outlet1	94.3%	5.7%	100.0%
		% within density test	69.5%	8.9%	50.0%
		% of Total	47.1%	2.9%	50.0%
	informal	Count	29	41	70
		% within formal or informal morning outlet1	41.4%	58.6%	100.0%
		% within density test	30.5%	91.1%	50.0%
		% of Total	20.7%	29.3%	50.0%
Total		Count	95	45	140
		% within formal or informal morning outlet1	67.9%	32.1%	100.0%
		% within density test	100.0%	100.0%	100.0%
		% of Total	67.9%	32.1%	100.0%

formal or informal morning outlet1 * resazurin test Crosstabulation

			resazurin test		Total
			acceptable	unacceptable	
formal or informal morning outlet1	formal	Count	61	9	70
		% within formal or informal morning outlet1	87.1%	12.9%	100.0%
		% within resazurin test	52.1%	39.1%	50.0%
		% of Total	43.6%	6.4%	50.0%
	informal	Count	56	14	70
		% within formal or informal morning outlet1	80.0%	20.0%	100.0%
		% within resazurin test	47.9%	60.9%	50.0%
		% of Total	40.0%	10.0%	50.0%
Total		Count	117	23	140
		% within formal or informal morning outlet1	83.6%	16.4%	100.0%
		% within resazurin test	100.0%	100.0%	100.0%

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