UNIVERSITY OF NAIROBI

PREVENTING ACUTE MALNUTRITION IN WOMEN AND CHILDREN THROUGH LIVESTOCK INTERVENTIONS IN NORTHERN KENYA.

BY

MUEMA JOSPHAT MULEI

REG. No. W80/53736/2018

A DISSERTATION SUBMITTED TO THE UNIVERSITY OF NAIROBI IN FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY (PhD) IN TROPICAL AND INFECTIOUS DISEASES

DECLARATION

I, Josphat Mulei Muema, hereby declare that this dissertation is my original work and that to the best of my knowledge, it has not been presented to any institution (s) either partially or in total for any academic award (s), publication (s), or other use (s). Where other people's work or my own work has been used, it has properly been acknowledged and referenced in accordance with the University of Nairobi requirements. All previously published papers from this work were reproduced with permission from the publishers. I, therefore, present it to the University of Nairobi for consideration.

Signature: ______________________ Date: 30/11/2023

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DEDICATION

To my parents, Joseph Muema Muthusi and Sabina Ndaina Muema. You always believed in my ability to succeed. You inculcated in me the values and principles of hard work, respect, for diversity, gratitude, and honesty. It is this belief in me that has made this journey possible. This one is for you!!

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ABSTRACT

Globally, undernutrition remains a significant challenge to the health of women and children and accounted for nearly half (>45%) of deaths in children <5 years in 2020. In 2022, stunting and wasting affected 22% and 6.8% of children <5 years, with the highest burden reported in Asia and Sub-Saharan Africa. In Africa, the burden of undernutrition is especially high in Africa's drylands, where persistent global acute malnutrition consistently surpasses emergency thresholds. Nutrition – sensitive livestock interventions have the potential to prevent undernutrition in women and children through increased consumption of Animal Source Foods (ASFs), improved household income and women empowerment. However, empirical data on the impact of nutrition-sensitive livestock interventions in preventing undernutrition remains limited. This thesis addresses this dearth in knowledge by assessing the effectiveness and cost-effectiveness of livestock interventions in preventing spikes in acute malnutrition in women and children under five years of age among pastoralist communities in northern Kenya during drought periods. First, a systematic review and meta-analysis on the impact of livestock interventions on maternal and child nutrition outcomes in sub-Saharan Africa was completed. Next, a cluster randomized controlled trial (cRCT) to determine the effectiveness and cost-effectiveness of providing livestock feeds to milking animals during drought periods and enhanced nutrition counselling in preventing acute malnutrition in women and children <5 years in Laisamis area of Marsabit County in northern Kenya was conducted. A total of 1734 households assigned to one of three study arms: livestock feeding arm; livestock feeding and nutrition counselling; and control arm were recruited into the study. Each household was visited every 6 weeks and data on livestock species and numbers, household milk production, food consumption patterns and amounts by children and women, anthropometric measures of children and women, health data for people and their animals collected over a 2-year study period (September 2019 – December 2021) covering four drought seasons. Biological samples were collected from both people and their livestock and tested for exposure to brucellosis and Q-fever as well as the association between child health and nutrition. Data analysis followed intention-to-treat principle employing mixed effects regression models to compare key study outcomes across the intervention arms. The systematic review and meta-analysis showed that nutrition-sensitive livestock interventions were associated with significant positive impact on consumption of ASFs for children <5 years, OR = 5.39 (95% CI: 4.43, 6.56) and on the likelihood of meeting minimum dietary diversity, OR = 1.89 (95% CI: 1.51, 2.3). Based on GRADE quality of evidence assessment approach, the overall quality of evidence of this review was rated as low, mainly due to limitations of performance, inconsistency, and selection biases. Results from the cRCT showed that while controlling for herd sizes, births, veterinary interventions, and sources of income, households receiving livestock feeds consistently had higher milk yield per day compared to control group (1.6L vs 0.7L, $p < 0.001$). Intervention households sustained more milking animals, 1.4 and 0.6 more tropical livestock units (TLUs) compared to those in the control. While controlling for other covariates, livestock feeding was associated with an increase of 200ml (95% CI, 120ml, 280ml) in milk consumption for children; enhanced counselling was associated with consumption of an additional 40ml (95% CI: 10ml, 70ml) milk daily by children. Mothers in households receiving livestock feeds consumed an additional 210ml (95% CI: 80, 330) of milk daily compared to those in the control arm. Among children < 5 years, livestock feeding was associated with statistically significant reduction in the risk of undernutrition by 11% (95% CI: 4, 17), 8% (95% CI: 2, 14), 9% (95% CI: 3, 15) and 11% (95% CI: 7, 14) for acute malnutrition (GAM), stunting (height-for-age), wasting (weight-for-height), and underweight (weight-for-age), respectively. Livestock feeding and enhanced nutrition counselling was significantly associated with improved household dietary diversity score (HDDS) by 3% (95% CI: 1, 5), minimum dietary diversity (MDD) for children OR=2.5 (95% CI: 2.3, 2.8) and minimum dietary diversity for women OR=4.22 (95% CI: 3.29, 5.42). Prevalence of brucellosis and Q fever in household herds was high at 26% (95% CI: 24, 29) and 84% (95% CI: 82, 86), respectively. Household level prevalence of brucellosis and Q fever in people was 13% (95% CI: 11, 15). Exposure to brucellosis and Q fever was not significantly associated with risk of acute malnutrition in children and women, OR=1.82 (95% CI: 0.67, 5.21, *p*=>0.69). Child health based on reported syndromes of fever/diarrhea/ARI was associated with an increased risk of acute malnutrition, OR = 1.64 (95% CI: 1.33, 2.03) and wasting OR = 1.22 (95% CI: 1.01, 1.47). Both livestock feeding only, and livestock feeding plus nutritional counselling were considered cost-effective in preventing acute malnutrition (wasting) at a cost of $5,326 and $3,086 per case of wasting averted, with a cost-effective ratio of 2.6 and 1.5, respectively. The cost per case of stunting averted by the feed only intervention was $7,293, with a cost-effectiveness ratio of 3.6 which was above the cost-effectiveness threshold. In conclusion, the findings of this study underscore the significant impact of targeted livestock feed provision during drought periods, specifically focusing on milking animals. The results demonstrate that this intervention is not only effective in sustaining the health and productivity of livestock but also serves as a cost-effective strategy to prevent acute malnutrition in children. A key recommendation from this study is the adoption of livestock feeding targeted to milking animals during critical dry periods as an effective strategy for preventing acute malnutrition and building resilience in communities in the face of climatic shocks.

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ACRONYMS AND ABBREVIATIONS

ARI	Acute Respiratory Infection
ASAL	Arid and Semi-arid Lands
ASFs	Animal Source Foods
BCC	Behavior Change Communication
BHA	Bureau for Humanitarian Assistance
BMI	Body Mass Index
BFCI	Baby Friendly Community Initiative
CEA	Cost-Effectiveness Analysis
CEMA	Centre for Epidemiological Modelling and Analysis
CGHR	Centre for Global Health Research
CI	Confidence Interval
CMAM	Community Based Management of Acute Malnutrition
CRCT	Cluster Randomized Controlled Trial
CSG	County Steering Group
DALYs	Disability- Adjusted Life Years
DE	Design Effect
ERC	Ethics Review Committee
ELISA	Enzyme Linked Immuno-Sorbent Assay
FAO	Food and Agriculture Organization of the United Nations
GAM	Global Acute Malnutrition
GDP	Gross Domestic Product
HAZ	Height – for – Age Z -scores
HB	Hemoglobin
ICER	Incremental Cost-Effectiveness Ratio

IMAM	Integrated Management of Acute Malnutrition
IQ	Intelligent Quotient
IUGR	Intrauterine Growth Retardation
IYCF	Infant and Young Child Feeding
KDHS	Kenya Demographic and Health Survey
KEMRI	Kenya Medical Research Institute
KNBS	Kenya National Bureau of Statistics
KNH	Kenyatta National Hospital
L4H	Livestock for Health
SAM	Severe Acute Malnutrition
SD	Standard Deviation
TLU	Tropical Livestock Unit
SERU	Scientific Ethics Review Unit
MAM	Moderate Acute Malnutrition
MDD	Minimum Dietary Diversity
MIYCN	Maternal, Infant and Young Child Feeding Nutrition
MUAC	Mid-Upper Arm Circumference
OR	Odds Ratio
PACIDA	Pastoralist Community Initiative and Development Assistance
PCR	Polymerase Chain Reaction
PI	Principal Investigator
PICO	Patient/Population, Intervention, Comparison, Outcome
PPE	Personal Protective Equipment
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROSPERO	The International Prospective Register of Systematic Reviews

TB	Tuberculosis
UNICEF	United Nations Children's Fund
UNITID	University of Nairobi Institute of Tropical and Infectious Diseases
UoN	University of Nairobi
USAID	United States Agency for International Development
QALYs	Quality-Adjusted Life Years
WAZ	Weight-for-Age Z-scores
WHO	World Health Organization
WHZ	Weight-for-Height Z-scores
WOAH	World Health Organization for Animal Health
ZDU	Zoonotic Disease Unit

OPERATIONAL DEFINITIONS

Malnutrition	Malnutrition refers to deficiencies or excesses in nutrient intake, imbalance of essential nutrients, or impaired nutrient utilization. The double burden of malnutrition consists of both undernutrition and overweight and obesity, as well as diet-related noncommunicable diseases. Undernutrition manifests in four broad forms: wasting, stunting, underweight, and micronutrient deficiencies (WHO, 2020)
Double burden of malnutrition	Defined as the coexistence of undernutrition along with overweight, obesity or diet related noncommunicable diseases (NCDs), within individuals, households, and populations throughout life (Popkin et al., 2020).
Triple burden of malnutrition	Refers to the coexistence of undernutrition (stunting and wasting), micronutrient deficiencies which are often termed hidden hunger, and overnutrition which includes both overweight and obesity (Nature food editorial, 2023).
Micronutrient-related malnutrition	Refers to the lack of essential vitamins and minerals required in small amounts by the body for proper growth and development. The essential micronutrients include (but not limited to) iron, zinc, calcium, iodine, vitamin A, B-vitamins, and vitamin C (Bailey et al., 2015).
Undernutrition	Refers to the insufficient intake of energy and nutrients to meet an individual's needs to maintain a normal, active, and healthy life. Undernutrition manifests in four broad forms: wasting, stunting, underweight, and micronutrient deficiencies. Undernutrition (assessed from stunting, wasting or underweight) is measured in terms of z-scores in reference to WHO reference population (Black et al., 2008)

Stunting — Refers to children whose height-for-age index is below minus two standard deviations (-2 SD) from the median of the WHO reference population. Such children are considered short for their age and are chronically malnourished. Children whose height - for- age index is minus three standard deviation (-3 SD) from the median of the WHO reference population are considered severely stunted. Height-for-age index is an indicator of linear growth retardation and cumulative growth deficits. Stunting reflects failure to receive adequate nutrition over a long time and is affected by recurrent and chronic illness. Stunting reflects long term effects of malnutrition and it's not sensitive to recent, short-term changes in dietary intake (Onis, 2007).

Wasting — Wasting is a measure of body mass in relation to body height or length and is an indication of current nutritional status. Children with weight-for-height index below minus two standard deviations (-2SD) from the median of the WHO reference population are considered thin (wasted) and are acutely malnourished. Children whose weight-for height index is below minus three standard deviations (-3 SD) from the median of the WHO reference population are considered severely wasted. Children with a z-score of above (+2 SD) of the median weight-for-height are considered overweight or obese. Wasting may be because of inadequate food intake or a recent illness causing weight loss (Onis, 2007)

Underweight — Represents the weight-for-age index which is a composite measure of height-for-age and weight-for-height and considers both chronic and acute malnutrition. A child with below (-2SD) from the median of the

WHO reference population are considered underweight while those below (-3SD) are considered severely underweight (Onis, 2007).

Livestock interventions	All livestock related interventions or programmes with an objective of increasing production, access to, and consumption of animal source foods (ASFs) and income generation to the households. Such interventions include provision of livestock feed, provision of animal health care, animal breed improvement, livestock donation programs, provision of water, provision of shelter, and training/extension services (Dominguez-Salas et al., 2019)
Livestock	All domesticated animals such as cattle, camels, goats, sheep, pigs, other small ruminants, poultry/chicken, fish, and bees (Grace et al., 2018).
Nutrition counselling	Refers to the receiving personalized, one-on-one dietary guidance and advice from a nutrition counsellor. It is a two-way interaction through which a client and a trained counsellor interpret the results of nutrition assessment, identify individual nutrition needs and goals, discuss ways to meet those goals, and agree on next steps. Nutrition counselling aims to help clients understand important information about their health and focuses on practical actions to address nutrition needs, as well as the benefits of behaviour change. Nutrition counsellors may be nurses or other facility-based providers or community health workers or volunteers (Vasiloglou et al., 2019).
Nutrition education	Refers to presentation of general information related to health and nutrition, often to groups in clinic waiting rooms or community

settings. Educators may be trained counsellors or health volunteers who deliver prepared talks on specific topics, often using visual aids. They should encourage clients to ask questions and direct them to additional information as needed (Vasiloglou et al., 2019).

Nutrition – specific interventions	Refers to interventions that address the immediate determinants of undernutrition including inadequate food and nutrient intake, suboptimal care and feeding practices and poor health (Ruel et al., 2018).
Nutrition -sensitive interventions	Interventions that address the underlying causes of undernutrition such as poverty, food insecurity, poor maternal health, education, empowerment/livelihoods programs and water, sanitation, hygiene, and health services which include a nutrition objective (Ruel et al., 2018).
Z-score	Statistical measure of a value in relation to the mean of the population which is measured in terms of standard deviations from the mean (Seetharaman et al., 2007).
Dietary diversity	Dietary diversity refers to the variety of foods and food groups consumed by an individual or a population over a specific period. A diverse diet includes a wide range of foods with different nutritional profiles, providing a broad spectrum of essential nutrients. Dietary diversity can be measured at either the household or the individual level and higher scores represent a more diverse diet (FAO and FHI, 2016)
Household Dietary Diversity Score (HDDS)	The number of food groups consumed by a household over a given reference period and is an important indicator of food security. For

households, a higher score is an indicator of increased economic access to a varied diet for household members. However, this indicator does not provide information on intra-household dietary patterns. It measures the household dietary diversity and can be used as a proxy for household food access and socioeconomic status. Its involves measurement of twelve food (12) food groups using a 24-recall dietary intake assessment (FAO and FHI, 2016).

Minimum Dietary diversity for women (MDD-W)	Its indicator that measures the dietary diversity of an individual woman; associated with nutrient adequacy in many contexts and can be used as a proxy for overall diet quality. Ten (10) food groups are used for the assessment of MDD-W using a 24-hour recall dietary assessment approach (FAO and FHI, 2016).
Minimum Dietary Diversity for children (MDD-C)	The Minimum Dietary Diversity for Children (MDD-C) is a key indicator used in nutrition assessments to evaluate the variety of foods consumed by young children. Measures infant and child dietary quality and adoption of complementary feeding practices. The MDD-C specifically assesses whether children aged 6–23 months have consumed a minimum number of food groups over a specified period, typically within the last 24 hours (WHO/UNICEF, 2021)

LIST OF PUBLICATIONS

1. **Muema J**, Oboge H, Mutono N, Makori A, Oyugi J, Bukania Z, Njuguna J, Jost C, Ogoti B, Omulo S, Thumbi SM. Sero - epidemiology of brucellosis in people and their livestock: A linked human - animal cross-sectional study in a pastoralist community in Kenya. Front Vet Sci. 2022 Nov 18;9:1031639. doi: 10.3389/fvets.2022.1031639. PMID: 36467641; PMCID: PMC9716101.

2. **Muema J**, Mutono N, Wheelhouse N, Njuguna J, Jost C, Oyugi J, Bukania Z, Oboge H, Ogoti B, Makori A, Fernandez MDP, Omulo S, Thumbi SM. Endemicity of *Coxiella burnetii* infection among people and their livestock in pastoral communities in northern Kenya. Heliyon. 2022 Oct 21;8(10):e11133. doi: 10.1016/j.heliyon.2022.e11133. PMID: 36303929; PMCID: PMC9593183.

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4. **Muema J**, Mutono N, Kisaka S, Ogoti B, Oyugi J, Bukania Z, Daniel T, Njuguna J, Kimani I, Makori A, Omulo S, Boyd E, Osman AM, Gwenaelle L, Jost C and Thumbi SM (2023) The impact of livestock interventions on nutritional outcomes of children younger than 5 years old and women in Africa: a systematic review and meta-analysis. Front. Nutr. 10:1166495. doi: 10.3389/fnut.2023.1166495.

CHAPTER ONE: GENERAL INTRODUCTION

1.0 Introduction

Undernutrition refers to nutritional impairments characterized by stunting, wasting, underweight and deficiencies in micronutrients such as vitamin A, Zinc and iron (Black et al., 2013). The nutritional status of children under five years is an important indicator of child health and health in populations. Globally, undernutrition remains a significant public health concern, with an estimated 149.2 million (22 %) children under five years of age being stunted, and 45.4 million (6.7%) wasted, with most of the affected children being from Africa and Asia (UNICEF/WHO/WORLD BANK, 2021). Malnutrition accounts for an estimated 45% of deaths in children under five years of age world-wide (Black et al., 2013).

In Kenya, stunting, wasting and underweight were estimated to be at 18%, 5%, and 10% respectively, with the levels of child malnutrition being highest in northern Kenya (KNBS and ICF, 2023)

The effects of malnutrition are varied with both short-term and long-term consequences. These effects range from increased mortality, morbidity, susceptibility to infections, long-term growth faltering and failure to reach development potential especially when children are malnourished during the first 1000 days of life (Schwarzenberg & Georgieff, 2018).

Livestock interventions can have a direct and indirect impact on human nutrition through various pathways. These impact pathways involve the interactions between livestock, agriculture, and human health. The key impact pathways through which livestock interventions can influence human nutritio include animal source foods consumption, income and livelihoods, disease prevention and control, women empowerment, social capital and community resilience, climate change adaptation, and education and knowledge transfer. However, the impact of livestock interventions on human nutrition is context-specific and influenced by factors such as cultural practices, socioeconomic conditions, and environmental considerations. Integrated and multi-sectoral approaches that involve agriculture, health, and nutrition sectors are often more effective in addressing the complex interactions between livestock and human nutrition.

Consumption of animal source foods : Increasing access to and consumption of animal source foods (ASFs) such as meat, milk, eggs, and fish can contribute to improved nutrition. These foods are rich in high-quality proteins, essential amino acids, vitamins (e.g., B12), and minerals (e.g., iron and zinc).

Nutrient-rich diets: Livestock interventions that promote diversified farming systems, including animal husbandry, contribute to more nutrient-rich and diverse diets. This directly addresses micronutrient deficiencies.

Income and Livelihoods: Livestock farming can provide income-generating opportunities for households, leading to improved purchasing power for a variety of foods, including nutrient-dense items.

Disease Prevention and control: Livestock interventions focused on improving animal health can reduce the transmission of zoonotic diseases, contributing to better human health outcomes.

Women Empowerment: Livestock interventions that involve women in decision-making, livestock management, and income-generating activities can enhance women's empowerment. Empowered women often make choices that positively influence household nutrition.

Source of energy and manure production: Livestock interventions, such as the use of animal manure for biogas production and organic fertilizer, contribute to improved soil fertility and crop yields. This indirectly supports food security and diverse diets.

Social capital and community resilience: Livestock interventions can strengthen social networks, build community resilience, and contribute to a supportive environment for nutrition-related interventions and behavior change.

Climate change adaptation: Livestock interventions that enhance the resilience of farming systems to climate change can contribute to stable agricultural productivity. This stability supports food availability and accessibility, impacting nutrition.

Education and knowledge transfer: Livestock interventions that include educational components and knowledge transfer to communities can lead to improved awareness of nutrition, hygiene, and health practices.

Access to animal source foods (ASFs) has been postulated to contribute positively to child nutritional outcomes, as a source of essential micro- and macronutrients (Allen, 2003). Seasonal and climatic variations can affect the availability and access of animal source foods among livestock dependent communities, impacting on the nutritional status of children and women especially during drought period. Over the years, drought emergencies have shown an increasing trend in magnitude, complexity, frequency and economic impact (Matere et al., 2020). The resultant effects of these drought emergencies has been acute shortage of food, feed, fodder and drinking water which adversely affects the health and nutrition of both human and livestock (Bakshi et al., 2018).

Arid and Semi-arid lands especially in northern Kenya are particularly vulnerable to drought emergencies due to their unique social, ecological and climate variability drivers including a very fragile ecosystem (Carabine et al., 2015; Nicholson, 2014). The majority of the households in pastoral drylands are dependent on livestock for their food and nutrition requirements (Randolph et al., 2007), and therefore, during critical dry periods and/or drought, these livestock-dependent households' access to food is constrained by livestock migrations, livestock morbidity and mortality, and a decrease in production (Chotard et al., 2011). Pastoral communities are nutritionally highly vulnerable, especially pastoralist children, and pregnant and lactating women mostly during critical dry periods or drought as they depend on livestock for their nutrition.

Animal milk is considered a highly nutritious food for children (Fratkin et al., 2004), and particularly children in pastoral communities who depend on milk for their food and nutritional requirements (Galvin et al., 2000; Sadler et al., 2010). However, the seasonal lack of access to animals and animal products associated with dry or drought periods results in seasonal spikes in cases of child malnutrition in these pastoral communities. Therefore, addressing the challenge of undernutrition requires multi-sectoral strategies and approaches employing both nutrition-specific and nutrition-sensitive interventions (Ruel & Alderman, 2013; United Nations Economic and Social Council, 2016). For this to happen, there is need to accelerate the improvement of nutritional outcomes, and shift focus to building more resilient, equitable, and sustainable food systems (Development Initiatives, 2020).

Animal source foods (ASFs) are rich in highly bioavailable nutrients, including iron, zinc, calcium, vitamins B12 and D, choline, and essential amino acids that are essential for child growth and development and which are not readily available in plant source foods (Beal et al., 2023; Neumann et al., 2002; Zhang et al., 2016). Livestock and by extension ASFs play a critical role in supporting livelihoods and nutrition security for many communities in sub-Saharan Africa. This role is even more critical for pastoralist communities who inhabit arid and semi-arid areas, which have limited potential for crop agriculture due to frequent climatic shocks. The impact pathways through which livestock interventions may influence human nutrition have been previously studied (Kabunga et al., 2017). These impact pathways include increased production and consumption of ASFs. This pathway is associated with ability to meet minimum dietary diversity at household and individual levels. The second impact pathway is the increased household level income through sale of livestock and livestock products which in turn translates into diet improvement (Ruel et al., 2018). Livestock interventions such as dairy programs, small livestock rearing, backyard poultry production, breed improvement, fisheries, livestock transfer programs, livestock feed improvement, and livestock value chain programs have the potential to positively influence improved dietary diversity at household level and possibly impact the individual nutritional outcome.

These Livestock interventions are implemented either alone or incorporate nutrition and health social behaviour change communication (SBCC) strategies. Social behaviour change communication interventions have an impact on increasing consumption of ASFs, however consumption is influenced by the production and food security situation (Flax et al., 2021). Effective and impactful SBCC interventions need to be tailored on how to increase production diversity, influence decision making around retention of animal source products for home consumption and influence on how proceeds from sale of animal source products could be used for household nutrition.

Seasonality has an effect on nutrition sensitive livestock interventions and seasonality should be considered when the outcomes of the intervention vary by season such as food availability, dietary intake, child morbidity and wasting (Sassi, 2019).

Although nutrition-sensitive livestock interventions may have a positive effect on child nutritional outcomes, the effect may be modified by diseases. A bi-directional relationship between malnutrition and infection has been established, where, malnourished children are at increased risk of infection, while chronic, repeat, or recurrent infections often contribute to malnutrition (Walson & Berkley, 2018). Childhood infections such as diarrhoea and acute respiratory infections may be a risk factor for child undernutrition (Tickell et al., 2020). Infections may cause acute malnutrition in addition to chronic undernutrition. Diarrhoea can lead to impaired weight gain due to reduced nutrient uptake and/or malabsorption, and malnutrition can lead to increased susceptibility to or severity of diarrhoea leading to a vicious cycle of undernutrition and infectious disease (Guerrant et al., 1992). Furthermore, zoonotic diseases, particularly chronic and debilitating zoonoses such as brucellosis and Q fever may influence child nutritional status. However, the nexus between malnutrition-environment-infection axis is complex and evidence particularly on the effect of infectious zoonotic diseases on child nutrition status is limited (Schaible & Kaufmann, 2007).

Although the number of livestock interventions or programs being conducted with a nutrition objective incorporated are on the increase, high quality evidence on the effectiveness and cost-effectiveness of nutrition-sensitive livestock interventions on nutrition outcomes is scanty (Ruel et al., 2018). This is attributed to poor program design and implementation, where most of the studies are observational and do not allow for temporal relationships in pathways from livestock interventions to nutrition outcomes to be characterised or are poorly powered to differentiate causal inferences. Furthermore, most of the programs have been implemented within short durations, mostly following donor funding cycles, hence do not provide enough time for the impact and impact pathways to be realised. Some of the nutrition-sensitive program components such as behaviour change communication strategies may take more time to adapt materials, training, and optimal use of inputs and services. Nutrition-sensitive programs also have long pathways from the project inputs to biological effects on nutritional status. The effect on nutritional outcomes such as anthropometry may require up to 1000 days of programme implementation for impact to be realised. Nutrition-sensitive interventions or programs are complex as they span different sectors such as health, agriculture (crop or livestock farming), and education and are integrated in nature hence leading to variability in delivery of the program by implementers. This makes attribution of impact to different program components difficult and may require multiple study arms to disentangle their relative contribution to overall program impact.

Nutrition-sensitive livestock interventions have the potential to improve child dietary and nutritional status outcomes; however, the paucity of well-designed studies implemented within a sufficient time frame to realise intervention effects has limited researchers' ability to determine and infer causal relationships (Ruel et al., 2018; Leroy et al., 2016; Pandey et al., 2016). Furthermore, studies focusing on nutrition-sensitive livestock interventions that improve child diet and nutrition outcomes and prevent seasonal variations in child nutrition outcomes due to climatic variability and climatic shocks in Africa's drylands are scarce (Marshak et al., 2021). Nutrition-sensitive livestock interventions could be effective in preventing undernutrition. Increasingly, livestock interventions are being used in humanitarian response and there is growing interest among governments and other development agencies in the cost-effectiveness of nutrition-sensitive livestock interventions in preventing undernutrition. However, determining the cost-effectiveness of nutrition-sensitive interventions in preventing undernutrition has attracted little attention (Carletto et al., 2015; Ruel et al., 2018). Despite the consensus on the need to invest in nutrition-sensitive livestock interventions which aim at preventing undernutrition by addressing underlying causes of undernutrition and not just treating cases of malnutrition, the evidence on their effectiveness, pathways to impact and the cost-effectiveness of livestock interventions in addressing undernutrition is limited. Thus, providing a strong body of evidence from well designed and implemented experimental studies is essential to provide guidance on which interventions have an impact on nutrition outcomes and at what cost.

1.1 Problem statement

Kenya's drylands inhabited by pastoralist communities are prone to frequent climate variability shocks such as drought emergencies that affect their food security, nutrition, and livelihoods. Humanitarian drought emergency responses by government and partners have included livestock interventions such as providing supplementary livestock feeds in addition to treatment of malnourished persons. However, most of these interventions have different components (integrated in livelihood projects) and are not targeted at milking animals for sustaining milk production during critical drought periods. Further, evidence on the cost-effectiveness of these interventions in preventing acute malnutrition is limited. The difficulty associated with conducting field trials in such challenging environments in arid and semi-arid regions with poorly developed infrastructure has limited the conduct of well-designed randomized trials to provide good estimates on their effectiveness and cost-effectiveness.

During drought emergencies, herds migrate in search of pasture and water leaving behind women and children with little access to milk. Although, pastoral communities leave behind some milking animals to provide milk to the households as other herds migrate in search of water and pasture, as the drought period progresses these milking animals stop lactating due to a lack of feed and water limiting access to milk to women and children. This limited access to milk and other animal source foods for the livestock dependent communities leads to spikes in cases of acute malnutrition in children below five years, as well as pregnant and lactating women, who are some of the most nutritionally vulnerable groups. Some of the responses to drought emergencies include the provision of livestock feed. However, the feed distribution is provided during the drought or late into the drought period when most of the milking animals have stopped lactating. This low availability of milk to the households is associated with increased cases of acute malnutrition.

Diseases can play a significant role in the impact pathways between livestock and nutrition, both directly and indirectly. The relationship between livestock diseases and human nutrition is complex and multifaceted. Diseases affecting livestock can impact the quality and safety of animal source foods (ASFs) such as meat, milk, and eggs. For example, zoonotic diseases can be transmitted from animals to humans through contaminated food products, affecting human health. Livestock diseases can lead to reduced productivity, including lower milk yields, decreased meat production, and impaired reproductive performance. This can directly affect the availability of nutrient-dense foods for human consumption. Livestock diseases can contribute to malnutrition in humans by affecting the overall nutritional status of the livestock. For example, diseases may lead to weight loss, reduced milk production, and poor-quality meat, impacting the nutritional value of the food products. Diseases that are transmissible between animals and humans (zoonoses) can have direct health implications for humans. For example, brucellosis, bovine tuberculosis, and salmonellosis are examples of zoonotic diseases that can affect both livestock and humans. Diseases in livestock can contribute to the spread of foodborne pathogens, leading to foodborne illnesses in humans who consume contaminated ASFs. Proper hygiene and disease control measures are critical to reduce this risk. Livestock diseases can impact the economic well-being of households dependent on livestock for income. Economic losses may result from reduced productivity, increased veterinary costs, and the loss of animals. Livestock diseases can limit access to ASFs by reducing the availability and affordability of these foods. This can have consequences for the diversity and quality of diets in communities dependent on animal products.

Pastoral populations are at high risk of exposure to brucellosis and other zoonoses due to close interaction with animals and practices such as consumption of unpasteurized milk and handling infected aborted materials without personal protective equipment (PPE). Further, childhood infections such as diarrhea and acute respiratory infections (ARI) are highly prevalent in pastoral areas due to hygiene and sanitation challenges. Taken together, these factors increase the risk of acute malnutrition among children in pastoral communities, especially during dry periods. Nutrition-sensitive livestock interventions that aim at increasing production diversity, access and consumption of nutrient-dense animal source foods may have the potential to improve child dietary and nutrition outcomes.

Incorporating a training component or a social behaviour change communication (SBCC) component in the nutrition-sensitive livestock programming could be beneficial in improving nutritional outcomes. These could be through increasing production of animal source foods and influencing retention of animal source foods for home consumption and therefore improving the effectiveness of livestock interventions in addressing undernutrition in children. However, there remains a dearth of evidence on the effectiveness and cost-effectiveness of nutrition-sensitive livestock interventions and nutrition and health behavior change communication (BCC), especially in the pastoral context. This is attributed to design and implementation challenges of most livestock interventions that aim to prevent malnutrition. Generally, gaps in design, sample size calculations and implementation timeframe limit the effectiveness of nutrition-sensitive livestock interventions in addressing malnutrition. Furthermore, most of the programs are integrated making it difficult to disentangle the net effect of the livestock intervention on nutrition outcomes. Better designed randomised controlled trials are required to better determine the effectiveness of livestock interventions on diets and nutrition outcomes of stunting, wasting and underweight. Such studies should be designed from the onset with nutrition objectives and should be powered to determine treatment effects on dietary diversity, stunting, wasting and underweight.

Exposure to infectious zoonotic pathogens and childhood illness symptoms could modify a child nutrition outcome. However, data on the effect of exposure to zoonotic diseases and reported childhood illness symptoms on child nutrition outcomes is scarce, particularly in the pastoral context. For nutrition-sensitive livestock interventions to be adopted as a strategy for preventing acute malnutrition among children during dry periods, their cost-effectiveness will need to be determined. Evidence on the cost-effectiveness of nutrition-sensitive livestock interventions in preventing undernutrition is scarce especially in pastoral context.

These gaps hinder our understanding on the possible benefits of livestock interventions that may improve maternal and child nutritional status through sustained or increased milk yield, access to and consumption of animal source foods during critical dry periods or drought and if such interventions are cost-effective. Laisamis sub-county within Marsabit County is one of the Kenya's drylands which experiences frequent droughts, leading to spikes in acute malnutrition which consistently surpasses the emergency threshold of 15%. The sub-county also has very high burden of zoonotic diseases such as brucellosis which may also exacerbate the challenge of acute malnutrition among children and women. However, there is very limited data on the effect of livestock interventions in preventing acute malnutrition in women and children.

This thesis addresses this knowledge dearth by assessing the effectiveness and cost-effectiveness of provision of livestock feeds and regular nutrition counselling during drought emergencies in preventing acute malnutrition in women and children under five years of age among pastoralist communities in northern Kenya. To account for relationships between malnutrition and illnesses including zoonotic disease, the study determines exposure to zoonotic diseases (brucellosis and Q fever) and measures of child health based on reported syndromes of fever, diarrhea, and acute respiratory infection (ARI).

1.2 Study objectives

1.2.1 General objective

To determine the effectiveness and cost-effectiveness of livestock interventions (providing livestock feeds to milking animals during drought periods) and nutrition counselling in preventing acute malnutrition in women and children below five years of age among pastoralist communities of northern Kenya, to inform nutrition-sensitive programming and policy decisions on responses to drought emergencies.

1.2.2 Specific objectives

i) To quantitatively assess impact of livestock interventions on maternal and child nutritional outcomes in sub-Saharan Africa.

ii) To determine the effect of providing livestock feeds to milking animals during drought periods and nutrition counselling on milk yield, milk consumption and undernutrition in women and children below five years in Marsabit County, Kenya.

iii) To establish the burden and effect of zoonoses (brucellosis & Q-fever), childhood illness syndromes (diarrhea, fever & acute respiratory infections) and their association with undernutrition in children below five years in Marsabit County, Kenya.

iv) To determine the cost-effectiveness of providing livestock feeds to milking animals during drought periods and nutrition counselling in preventing undernutrition in children below five years in Marsabit County, Kenya.

1.3 Specific research questions

a) What is the effect of livestock interventions on maternal and child nutritional outcomes in sub-Saharan Africa?
b) What is the effect of providing livestock feeds to milking animals during drought periods and nutrition counselling on milk yield, milk consumption and undernutrition in children below five years in Marsabit County, Kenya?
c) What is the burden and effects of zoonoses (brucellosis & Q-fever) and childhood illness syndromes (diarrhea, fever, and acute respiratory infections) on undernutrition in children below five years in Marsabit County, Kenya?
d) Are providing livestock feeds to milking animals during drought periods and nutrition counselling a cost-effective way of preventing undernutrition in children below five years in Marsabit County, Kenya?

1.4 Significance of the study

The findings of this study provide evidence on the role of livestock interventions in preventing undernutrition among women and children below five years. This may be more useful during dry seasons in northern Kenya and other drylands in Africa where communities experience seasonal spikes in levels of acute malnutrition during dry periods. The findings on the burden of zoonotic diseases (brucellosis and Q fever) and childhood illness syndromes of diarrhea, fever, and acute respiratory infection (ARI) and their effect on child undernutrition could promote awareness creation on their prevention and control strategies. Further, findings on the cost-effectiveness of livestock interventions in preventing undernutrition in children could be used to refine policies and programs aimed at addressing undernutrition among women and children below five years in livestock dependent communities in Kenya and other countries with similar settings.

1.5 Thesis structure

This thesis is structured as a monograph with the methods, results, and discussion sections for each of the study objectives clearly outlined as part of each of the respective sections. Were results have been published, the publications are provided as a footnote. The thesis starts with chapter one which is the general introduction. Chapter one focuses on the background of the thesis and explores the problem the thesis intents to solve and specifies the objectives of the study. Overall, the thesis is focused on determining the effectiveness and cost-effectiveness of providing livestock feeds to milking animals during drought periods and nutrition counseling in preventing acute malnutrition in women and children particularly in pastoral communities during dry periods. Specifically, this dissertation addressed four objectives. The first objective made a quantitative assessment of available evidence on the impact of nutrition-sensitive livestock interventions on maternal and child nutritional outcomes in sub-Saharan Africa and identified the data gaps.

The second objective assessed the effect of providing livestock feeds to milking animals during drought periods and regular nutrition counselling on household milk yield, milk consumption and undernutrition in women and children below five years in Marsabit County during critical dry periods or drought. A 3-arm cluster randomized control trial (cRCT) was conducted in Laisamis area of Marsabit County in northern Kenya. Household eligibility included ownership of livestock, having at least one child below three years of age at recruitment, or a pregnant woman, and consent to participate in the follow-up study. Consented households were randomized into the three study arms. Households in arm 1 received livestock feeds sufficient to maintain two tropical livestock units (equivalent to two cows or 2 camels or 20 sheep or goats) of milking animals for 3 months during the critical dry period. Households in arm 2 received similar amounts of livestock feed and regular nutritional counseling delivered by trained community healthcare volunteers. While households in control group did not receive any of the study interventions. Key data including livestock numbers and types kept, total household milk production, food consumption patterns and amounts by children and women, anthropometric measures of nutritional status for children and women, health data for people and their animals, were collected every six weeks for the entire 2-year study period that covered four dry seasons. Statistical analysis followed the intention-to-treat principle and employed linear mixed effects models and mixed-effects logistic regression models to compare three key outcomes [household milk yield; milk consumption by children; and measures of undernutrition (stunting, wasting, underweight)] between the three study arms while controlling for multiple factors including household socio-economic status, husbandry practices and disease episodes in livestock and people. Data was analyzed using R statistical software.

In the third objective, biological samples were collected from both people and their livestock and tested for exposure to brucellosis and Q-fever using ELISA test kits. Brucellosis and Q-fever are among top ten priority zoonotic diseases in Kenya and could be transmitted through consumption of contaminated animal source foods. Syndromic data in children on reported fever, diarrhea and acute respiratory infections were collected during data collection visits. Data analysis was carried out to determine burden of brucellosis and Q-fever among people and their livestock as well as the associations between undernutrition and health status of children, and exposure to the zoonotic infections.

The fourth objective assessed the cost-effectiveness of providing livestock feeds to milking animals during critical dry periods and nutrition counselling in preventing undernutrition in children below five years. Costs were analysed from a provider perspective. These included costs incurred to procure and deliver the livestock feeds, and to provide nutrition counselling service to the beneficiaries. Programme costs data were obtained through review of project financial documents and interviews with programme staff. An activity-based costing approach was applied by determining main programme activities within each of the two interventions and allocating costs to these activities. Aggregated costs were organised into main cost centres based on the intervention arm and type of cost. All costs are expressed in US dollars. Cost-effectiveness analysis was conducted as cost per case of wasting and stunting averted. Incremental cost effectiveness ratios (ICERs) were calculated for each intervention, estimating additional costs incurred by each intervention to avert cases of wasting and stunting, relative to the control group.

Chapter two is the literature review. Briefly, this was achieved through a systematic review and meta-analysis of published articles reporting on the effect of livestock interventions on maternal and child nutrition in Africa and available in PubMed, Web of Science and Scopus databases. Evidence synthesis followed PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines. Estimation of pooled effects (meta-analysis) was undertaken for experimental studies with nutritional outcomes of consumption of animal source foods (ASFs) and minimum dietary diversity (MDD). Fixed effects regression models and pooled effect sizes were computed and reported as odds ratios (ORs) together with their 95% confidence intervals (CI). The methods used for the systematic review and meta-analysis were published in a peer reviewed journal (Muema et al., 2021)

Chapter three is the materials and methods. Methods for each objective are exhaustively described and published together with results as journal articles for the different objectives. Chapter four provided a detailed description of the study results for each objective. Results of three papers published are described in the results section. The results for the systematic review and meta-analysis were published and are available (Muema et al., 2023). Two more publications describing results for the burden of brucellosis and Q-fever in people and their livestock were published (Muema et al., 2022). Chapter five provides the general discussion of the thesis. Key findings of the study and their significance are discussed. The results are interpreted in the context of research questions. Further, the results are compared with existing literature and the contribution of the results to the topic explored and the study limitations are acknowledged. Finally, in chapter six, this thesis draws the study conclusions based on the findings and highlights key recommendations from this work and suggests areas of future research.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Undernutrition is categorized into three forms: wasting (indicated by a person with low weight compared to his/her height), stunting (low height for his/her age) and underweight (low weight compared to his/her respective age). These undernutrition indicators are determined based on the number of standard deviations (SD) units from the WHO Multicenter Growth Reference Study standards published in 2006 (WHO, 2006). Based on the global burden of disease estimates, 20% of deaths are attributable to malnutrition (Afshin et al., 2019). Poverty and malnutrition have been identified to be responsible for over 250 million children being at risk of not meeting their full developmental potential later in life (Black et al., 2017) Undernutrition is associated with increased morbidity and mortality in children and affects their cognitive development, especially in the first 1000 days of a child's life (Black et al., 2017).

Africa's children continue to be at a high risk of undernutrition (stunting, wasting and underweight) and this is a serious public health concern in the majority of countries on the continent (WHO, 2017). Despite some progress in combating all forms of malnutrition globally, an estimated two out of every five, and one of every four children under 5 years in Africa are stunted and affected by wasting respectively (UNICEF/WHO/WORLD BANK, 2021). Therefore, combating the challenge of undernutrition may contribute to progress in attaining the Sustainable Development Goal (SDG) 2 and 3 (ending hunger and all forms of malnutrition; and good health and well-being). However, for this to happen, there needs to be multi-sectoral strategies and approaches employing both nutrition-specific and nutrition-sensitive interventions across communities while building more resilient, equitable and sustainable food systems for improved nutrition outcomes (Development Initiatives, 2020; Ruel & Alderman, 2013; United Nations Economic and Social Council, 2016).

For a majority of rural households in sub-Saharan Africa, agriculture (including livestock) is a key source of livelihoods, food and nutrition security in sub-Saharan Africa (FAO, IFAD, UNICEF, WFP and WHO, 2022; OECD/FAO, 2016). This is supported by previous reviews that have assessed the contribution/impact of general agricultural interventions focusing on home gardening for fruits and vegetables, aquaculture, livestock production and health, cash crops and biofortified crops on nutrition (Berti et al., 2004; Fiorella et al., 2016; Girard et al., 2012; Grace et al., 2018; Harvey et al., 2014; Leroy & Frongillo, 2007; Margolies et al., 2022; Pandey et al., 2016; Randolph et al., 2007; Ruel, 2001; Webb & Kennedy, 2014). These reviews have highlighted the growing evidence of the role of nutrition-sensitive agriculture interventions in improving nutrition and documented some pathways through which agriculture can contribute to nutrition. The same can be said of animal source foods (ASFs) that provide highly bioavailable nutrients that are vital for child growth (Neumann et al., 2002; Zhang et al., 2016).

Livestock and by extension ASFs play a critical role in supporting livelihoods and nutrition security for many communities in sub-Saharan Africa. This role is even more critical for pastoralist communities who inhabit arid and semi-arid areas which have limited potential for crop agriculture due to frequent climatic shocks. Livestock interventions have been documented to influence human nutrition through a number of pathways (Kabunga et al., 2017). These include a) increasing the production diversity and consumption of ASFs associated with the ability to meet minimum dietary diversity at household and individual levels; and b) increasing household income levels through trade in livestock products leading to improved household diets. Therefore, livestock interventions targeting dairy, small livestock husbandry, backyard poultry production, breed improvement, aquaculture, livestock transfer, livestock feed improvement and livestock value chains programs, among others, have the potential to improve production diversity, availability, and access to ASFs, dietary diversity at individual and household levels and impact human nutritional outcomes. However, empirical data on the net contribution of livestock intervention on the nutritional status of vulnerable people in Africa is scanty.

Africa's drylands are mainly arid and semi-arid lands (ASAL) characterised by extreme climatic variability and frequent shocks. Primarily, the drylands in Africa are inhabited by pastoralists and agro-pastoralist communities who over time have adapted to the environmental and climatic variability which influences the availability of water, pasture and performance of crops for those practicing dryland farming (Krätli, 2015). Over the years, drought and other shocks have increased both in magnitude and frequency in these dry lands, directly affecting household food security and livelihoods (FAO, 2018). Due to the harsh climatic conditions, crop agriculture is limited and thus, more than 80% of these communities depend on livestock for their livelihood, where they practice seasonal mobility in search of water and pasture as a coping strategy (FAO, 2018; Randolph et al., 2007; Watson & van Binsbergen, 2013).

The seasonal lack of adequate pasture and water has resulted in these communities being among highly nutritionally vulnerable groups, with an increase in cases of acute malnutrition among children under five years of age (Sadler et al., 2012). Further, zoonotic infections which are highly prevalent, particularly in pastoral communities due to their close interaction with infected livestock (Welburn et al., 2015), and this may also influence child nutrition outcomes. Childhood infections manifested through diarrhea, fever and acute respiratory infections have the potential to impact child growth and development including their nutritional status (Walson & Berkley, 2018). Malnutrition and infectious diseases occur in a vicious cycle of malnutrition, infection, and disease. Malnutrition increases susceptibility to infections, while infections may lead to malnutrition due to reduced dietary intake, decreased nutrient absorption, and increased nutrients and calories needed to fight infection.

Livestock are an important asset in the humanitarian context. Strategic livestock interventions are vital in mitigating the effects of disasters such as drought. Targeted livestock interventions implemented based on early warning systems can prevent the effects of drought-induced malnutrition in children. In the humanitarian context, particularly in a pastoral context, one of the drought responses is usually the provision of livestock feed which is made to safeguard the livestock assets and to ensure sustained milk production. These livestock interventions such as dry season livestock feed provision may have the potential to prevent acute malnutrition in children. However, the effectiveness and cost-effectiveness of livestock interventions in preventing undernutrition have not been well studied (Carletto et al., 2015; Puet 2019; Ruel et al., 2018). This literature chapter focuses on collating, synthesizing, and documenting all available evidence on the linkages between livestock interventions and nutrition outcomes in Kenya and the rest of Africa.

The chapter addresses thematic areas including the effect of livestock interventions on child nutrition outcomes, the burden of zoonoses and childhood health syndromes including diarrhoea, fever and acute respiratory infection, their effects on child nutrition status, and the cost-effectiveness of livestock interventions in preventing malnutrition.

This is completed through a systematic review and meta-analysis of the literature on studies conducted in Africa on the impact of livestock interventions on maternal and child nutrition outcomes. The protocol followed to study this has been published elsewhere (Muema et al., 2021).

2.2 Burden and Consequences of Malnutrition

Global estimates indicate that 22% (149.2 million) of children below five years were stunted and 6.7% (45.4 million) suffered from wasting, with most of the affected children being from Africa and Asia (UNICEF/WHO/WORLD BANK, 2021). Malnutrition is associated with increased ill health and mortality. Of all the deaths among children below five years in developing countries, 45% are associated with undernutrition (Black et al., 2013). Globally, health effects associated with overweight and obesity account for 7.1% of all deaths as well as 120 million healthy years of life lost and account for 4.9% of all DALYs among adults (Afshin et al., 2017). The socioeconomic impact of malnutrition on society is estimated at US$3.5 trillion annually, with overweight and obesity being responsible for US$500 billion (Beddington et al., 2016). The majority of malnutrition cases are in low- and middle-income countries with Africa and Asia bearing the greatest burden of all forms of malnutrition.

In Kenya, on average, 18% of children under five are stunted, 5% wasted, while 10% are underweight (KNBS and ICF, 2023). In terms of socio-economic impact, undernutrition costed Kenya Ksh 373.9 Billion in 2014, which represented 6.9 per cent of GDP in 2014 according to the cost of hunger study in Kenya and will cost Kenya approximately US$38.3 billion in GDP by the year 2030 (USAID, 2014). Malnutrition increases the risk of childhood mortality, morbidity, and future adult disability. Additionally, malnutrition is associated with increased susceptibility to diseases and socioeconomic costs (Arthur et al., 2015). Determinants of child malnutrition are varied with biological, economic, and social factors playing a key role in causing child malnutrition. Food, care, and health are important determinants of good nutrition. Most growth failure occurs within the first 1000 days of life.

There exists an interrelationship between child malnutrition, morbidity and mortality with the odds of dying being higher in severely malnourished children compared to non-malnourished children (Ho, 2015). Consequently, malnourished children have more severe and frequent infections compared to non-malnourished children. Improving nutritional status ensures better defenses against infection and lowers the risk of severe malnutrition (Correia & Waitzberg, 2003).

Poor dietary intake and infectious diseases are the main causes of poor nutritional status. Infectious disease episodes particularly diarrheal diseases and respiratory infections have a negative effect on child nutritional status and nutrition interventions should target preventing infectious diseases in addition to providing adequate and quality food. The nutrition of children in the period from conception to 2 years of age is critical for both child development and adult health (Schwarzenberg & Georgieff, 2018). Nutrition deficits in the first 1000 days of life may result to lifelong impaired development and even with good nutrition later in life, it may be difficult to reverse these negative effects (Danese et al., 2007; Galobardes et al., 2008; Senese et al., 2009). It is therefore necessary to understand the relationship between micro- and macronutrient intake and neurodevelopment so as to optimize the delivery of essential nutrients for child development, especially during the first two years of a child's life (Galobardes et al., 2008; Ngure et al., 2014). Research has shown that children affected by early childhood malnutrition exhibit poor intelligence quotient (IQ) scores, cognitive development as well as school achievements, consequences which have negative effects on society for future generations (Scott, 2020). Maternal nutrition is therefore very important, especially during pregnancy for child nutrition and health (Likhar & Patil, 2022).

2.3 Animal source foods and child nutrition

Animal source foods (ASFs) including milk, meat and eggs are an important source of both macronutrients (protein & essential fatty acids) and micronutrients (vitamins and minerals) and are nutritionally beneficial due to their high bioavailability and digestibility compared to other food sources (Black et al., 2013; Gupta, 2016). Animal source foods are also a very critical source of vitamin B12 and their lack may lead to vitamin B12 deficiency (Allen, 2008). Milk has a positive impact on linear growth in children due to highly available amino acids, calcium and zinc (Dror & Allen, 2011), while meat is important for cognitive development due to iron content (Gupta, 2016).

Animal source foods are critical especially for children as well as pregnant and lactating mothers who have high micronutrient requirements as even the consumption of small quantities of ASFs can be enough to achieve adequate nutrition. The challenge, especially in resource-poor settings, is that mostly the diets of children, pregnant and lactating mothers are mainly grains and cereals (Allen, 2003). This is particularly so in critical dry periods, especially in pastoral areas when livestock migrate in search of water and pasture leaving the women and children in households without access to animal source foods such as milk and meat. Interventions that improve access to animal source foods for children, pregnant and lactating women may be beneficial to the maternal and child nutritional status.

2.4 Drought emergencies and undernutrition

Drought emergencies are associated with loss of livelihoods, especially in households heavily dependent on livestock for their food and nutrition security (Delbiso et al., 2017). These drought emergencies impact negatively on food security and nutrition by limiting access to food, health services and disrupting the societal care structure (FAO, 2015). The extent of the effect of drought on child health and nutritional status largely depends on the population context and vulnerability especially socio-economic status (United Nations, 2011).

Seasonal variations have an effect on child nutritional status, especially on wasting which depicts recent and severe weight loss due to inadequate dietary intake (Miller et al., 2013). Seasonal variations in dietary intake and disease susceptibility may contribute to the development of severe acute malnutrition among children and hence seasonality may represent a significant risk factor for child health and survival (Shell-Duncan, 1995). Pastoral areas are particularly highly vulnerable to undernutrition especially during critical dry periods due to reduced milk production, high temperatures and increased workload related to search for pasture and water for livestock. Children in pastoral areas exhibit high levels of wasting compared to other regions. This is particularly so in the horn of Africa countries were the average prevalence of wasting is high in pastoral production systems compared to crop-based agricultural production systems and mixed livelihood systems (Sadler et al., 2009). Drought negatively affects both maternal and child nutritional status with implications on growth and development in children (Hoddinott & Kinsey, 2001).

In recent years, drought emergencies have been on an increasing trend both in frequency and magnitude which has impacted negatively on pastoral livelihoods due to their fragile ecosystem (Nicholson, 2014). The cycle of droughts which was previously every ten years, has increased to every five years, 3-5 years, and in the last decade it has become extremely unpredictable (Matere et al., 2020). In order to cope with the ever-increasing extreme weather shocks, pastoralists have developed traditional coping strategies to survive the effects of droughts. These coping strategies include diversification of livelihood sources, seasonal livestock mobility in search for pasture and water and diversification of herd composition adapting livestock, which are relatively adaptable to drought and disease challenges (Opiyo et al., 2015). However, most of these coping mechanisms have resulted in increased work load for women and adversely affected both maternal and child nutritional status. This is particularly true for seasonal livestock migration which results in women and children being left in households to rely mainly on non-nutritious cereals with no access to milk and meat which are critical sources for both macro-and micronutrients, a phenomenon that may be the cause of seasonal spikes in acute malnutrition in pastoral areas.

2.5 Malnutrition and disease

In most of developing countries food shortage and disease have been shown to occur in a vicious cycle and account for the high morbidity and mortality. Food shortage, poor child care practices, poor health services and harmful environment are factors associated with inadequate dietary intake and infectious diseases occurrence in resource-poor setting (Schaible & Kaufmann, 2007). Nutritional interventions should therefore target to address the root causes of malnutrition and disease at household and community levels. Malnutrition increases the susceptibility to infectious diseases and accounts directly or indirectly for over 50% of all deaths in children below five years (Scrimshaw & SanGiovanni, 1997). Infections, on the other hand, can also lead to malnutrition due to reduced dietary uptake, malabsorption especially due to diarrheal diseases and increased energy requirements leading to a cycle of malnutrition, infection and disease (Ambrus & Ambrus, 2004).

In addition to diarrheal illnesses and respiratory infections which have been shown to have a major effect on child nutritional status, zoonotic infections such as brucellosis, Q fever, and bovine tuberculosis, which are transmitted through the consumption of infected animal source foods may also have an impact on nutritional status, especially in pastoral areas where households are heavily dependent on livestock (Schelling, 2002). The burden of these zoonotic infections mostly lies with the poor households and negatively impacts their livelihoods but data on the true burden is scarce as these diseases are neglected (Mableson et al., 2014).

2.6 Prevention of undernutrition

Several interventions have been implemented with the goal of improving the nutritional outcomes of individuals in households. These interventions include agricultural crop-based interventions, supplementation for specific nutrients, surveillance and treatment of clinical malnutrition, and livestock based interventions.

Agricultural crop-based interventions can impact nutritional outcomes through pathways such as improving food availability and access, dietary quality and income. Most agriculture crop-based intervention have included kitchen/micro-gardening, crop bio-fortification, production of nutrition-rich crops, and irrigation projects targeting mainly fruits and vegetables. Most of the studies conducted to evaluate the link between agriculture and nutritional outcomes have shown that agricultural interventions can potentially improve nutrient intake and nutritional outcomes but women's empowerment and nutritional education are essential ingredients for this goal to be achieved (Pandey et al., 2016). However, empirical evidence on how they contribute to nutrition outcomes is scanty (Ruel et al., 2018). Additionally, these crop-based interventions are only applicable in agrarian areas and difficult to implement in pastoral areas.

Micronutrient supplementation programs targeting micronutrients such as vitamin A, iron, iodine, and folic acid have been implemented in children as a tool to prevent or reduce the risk of malnutrition and disease. However, data on the impact of these supplementation programs and their cost-effectiveness is scanty (Warthon-Medina et al., 2015). Management and treatment of acute malnutrition is often conducted through programs such as integrated management of acute malnutrition (IMAM) or community-based management of acute malnutrition (CMAM). These programs focus mainly on high-quality infant and young child feeding (IYCF) and disease prevention and treatment programs. These programs are linked to health system delivery platforms which in most cases the health care delivery infrastructure is not well developed and needs strengthening particularly in rural resource-poor settings. Additionally, data on the effectiveness and cost-effectiveness of these programs is limited (Black et al., 2016). Most of the livestock-based interventions which have been implemented have targeted improved livestock production through livestock breed improvement, feed, and livestock distribution to poor households with sheep and goats, or poultry. Most of these interventions have been implemented within other livelihood programs, making quantifying the net effect of livestock interventions on nutrition a difficult task (Leroy & Fragillo 2007; Ruel et al., 2018).

2.7 Research gaps and what remains to be known

Although several reviews assessing the contribution/impact of agricultural interventions (home gardening for fruits and vegetables, aquaculture, livestock production, cash crops and biofortified crops) on nutrition and pathways through which such interventions can contribute to nutrition have been conducted (Berti et al., 2004; Fiorella et al., 2016; Girard et al., 2012; Grace et al., 2018; Harvey et al., 2014; Leroy & Frongillo, 2007; Pandey et al., 2016; Randolph et al., 2007; Ruel, 2001; Webb & Kennedy, 2014), empirical data on the net contribution of livestock and the impact of livestock interventions on human nutrition is scanty. Many of the integrated livelihood studies have suffered design and methodological challenges by not being designed to address a nutrition objective. The result is that quantifying the effect of livestock intervention on child nutrition outcomes becomes difficult (Ruel et al., 2018).

The second challenge is where the studies have been designed with a nutrition objective, cross-sectional study designs have been dominant, making the determination of the spatial-temporal effects of the livestock interventions on child nutrition outcomes difficult (Aiga et al., 2009; Headey & Hirvonen, 2016; Hoorweg et al., 2000; Kabunga et al., 2017; Kidoido & Korir, 2015; Lambrecht et al., 2021; Lenjiso et al., 2016; Mosites et al., 2016; Mosites et al., 2015; Muleta, Haddinott et al., 2015; Hailu, Stoecker, et al., 2021).

Finally, for the few well designed experimental studies that have been implemented to provide evidence on the influence of livestock interventions on child nutritional outcomes, a majority of them are conducted over a short period that is insufficient to observe changes in nutritional indicators that take time to change such as stunting (Ruel et al., 2018). This lack of well-designed livestock intervention studies with clear nutrition objectives may be limiting guiding policies on nutrition programming, specifically on how to leverage livestock interventions to reduce the burden of undernutrition.

Zoonotic diseases such as brucellosis and Q-fever are endemic in most of Africa, and highly prevalent particularly in pastoral communities in Kenya. In Kenya, brucellosis and Q-fever are among top ten priority zoonoses (Munyua et al., 2016). Brucellosis is mainly transmitted through consumption of infected dairy products while Q-fever transmission is mainly through inhalation of infected aerosols from infected animals or the environment making the two diseases highly prevalent in pastoral communities. The close interaction between people and livestock in pastoral communities increases the risk of exposure to zoonotic diseases. These zoonotic diseases may be chronic and debilitating and affect the growth and development of children exposed to the diseases. However, the burden of these zoonotic diseases and the effect on child nutrition outcomes has not been well characterised. Further, due to poor hygiene conditions and water challenges in pastoral communities, childhood infections are highly prevalent and manifest mainly through diarrhoea, fever, and acute respiratory infections. These disease syndromes may have the potential to adversely affect child nutrition, child growth and development. However, data on the effect of childhood illness syndromes such as diarrhoea, fever, and ARI on child nutrition in Marsabit county, Kenya is scarce which limits the design of prevention and control strategies.

Livestock interventions such as the dry season livestock feed provision have the potential to address the underlying causes of undernutrition including poverty, lack of access to food, disease, and climate variability. These interventions may be both effective and cost-effective in preventing the drought induced seasonal spikes in acute malnutrition in children, particularly in pastoral communities that are dependent on livestock for their diets. However, economic evaluation studies on these interventions focusing on the cost and cost-effectiveness of these interventions are limited. The lack of evidence on the cost-effectiveness of livestock interventions in preventing undernutrition may be limiting on informing policy and programming decisions to identify interventions which are both effective in addressing undernutrition but also cost-effective.

Finally, experimental studies evaluating the effectiveness and cost-effectiveness of livestock interventions in preventing undernutrition and quantifying the burden of select zoonotic diseases, childhood disease syndromes, and their effect on undernutrition in children below five years particularly in the pastoralist setting are very scarce. Hence, there was an absolute necessity to undertake a well-designed experimental study to generate evidence to inform future policy and programming decisions on nutrition-sensitive livestock programs in the context of pastoralist communities living in arid and semi-arid areas in Kenya.

2.8 Key methodological issues

From the literature reviewed, key methodological issues in the design, and implementation of nutrition-sensitive livestock interventions were identified and needs to be addressed in the future design of such intervention for them to be effective in improving diets and nutrition outcomes. First, most of the studies were impact evaluations of livestock programs which were initially designed as integrated livelihood programs and without a clear nutrition objective at the design stage (Dumas et al., 2018; MacDonald et al., 2010; Rawlins et al., 2014). Furthermore, these studies were implemented as part of integrated livelihood programs making it difficult to disentangle the net contribution of livestock interventions in improving child nutrition outcomes. Secondly, many of the livestock-oriented studies were designed as observational studies which hinders us from inferring a cause-effect relationship between the program and observed changes in diet and nutrition outcomes (Aiga et al., 2009; Kabunga et al., 2017; Kidoido & Korir, 2015; Lenjiso et al., 2016; Mosites et al., 2016; Mosites et al., 2015; Haddinott et al., 2015; Stoecker, et al., 2021).

For the few available experimental studies reviewed, the main challenge is the timeframe for implementation. Most of the experimental studies were implemented for 12- months on average which is a short time for the livestock interventions to have an impact on child nutrition outcomes such as stunting which may require a longer implementation period (Bierut et al., 2021; Flax et al., 2021; Lutter et al., 2021; Marquis et al., 2018; McKune et al., 2020; Passarelli et al., 2020; Prado et al., 2020; Stewart et al., 2019).

Better designed randomised controlled trials are required to better determine the effectiveness of livestock interventions on nutrition outcomes of stunting, wasting and underweight. Such studies should be designed from onset with these nutrition objectives and should be powered to determine treatment effects on stunting, wasting and underweight. Further, none of the studies reviewed explored the cost-effectiveness of the livestock intervention programs nor the effect of zoonotic diseases and childhood disease syndromes on nutrition outcomes. These are the gaps that this research study sought to address.

2.9 Conceptual framework

The study conceptual framework for this study was based on a literature review on the effect of nutrition-sensitive livestock interventions on undernutrition. The framework is applicable to the Kenyan pastoral context where causes of acute malnutrition and food insecurity are complex and are normally compounded by frequent shocks such as drought. Livestock interventions such as the provision of livestock feed during dry periods, breed improvements, livestock donation programs, and animal health interventions when implemented alone or together with nutrition and health training programs influence child dietary and nutritional outcomes.

The effect of livestock interventions such as dry season livestock feed provision on nutrition outcomes such as acute malnutrition is through the pathways of increased/ sustained milk production and milk consumption among children. However, climate variability, socio-economic and demographic variables are modifying factors in this relationship. Further, herd dynamics including livestock species owned and herd structure, as well as herd health including zoonotic diseases in animals such as brucellosis and Q-fever may affect household milk production. Although livestock interventions may improve or sustain milk production at household level, cultural norms, and taboos as well as household and caretaker characteristics may affect milk consumption and influence the child nutrition outcomes. Zoonotic infections such as brucellosis and Q-fever which are highly prevalent in pastoral settings and may be passed to humans through consumption of contaminated milk and close interaction with animals may have a direct effect on child nutritional status. Additionally, childhood infections such as diarrhea, acute respiratory infections (ARIs) and fever may influence child nutrition through increased susceptibility to infections, and malabsorption of nutrients making children to be at a high risk of being malnourished.

This study identified provision of livestock feed and nutrition counselling during dry seasons to livestock dependent households in pastoralist communities as independent variables influencing child nutrition outcome of acute malnutrition. Climate variability such as drought emergencies and household socio-economic and demographic characteristics such as household income, household food access and food security were identified as modifying variables in the effect of livestock interventions on child nutrition outcomes. Intervening variables such as household milk yield and child milk consumption were identified as the pathways through which livestock interventions could influence nutrition. Zoonotic infections and childhood infections were considered independent variables which could affect child nutrition outcomes (Figure 2.1).

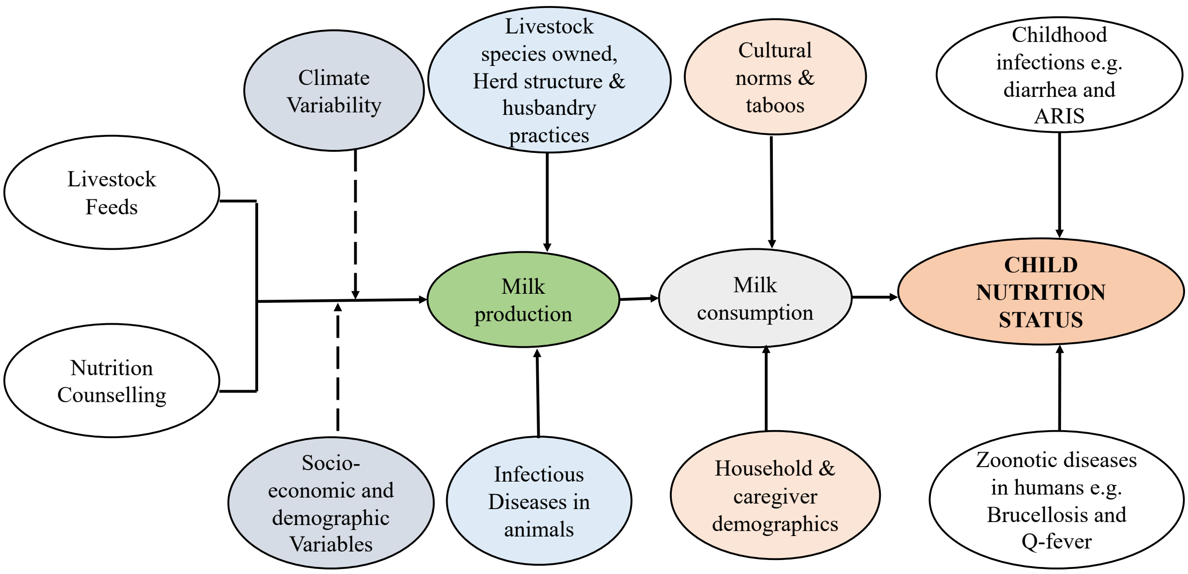

Figure 2.1: Study conceptual framework on the impact of nutrition-sensitive livestock interventions on child nutritional outcomes.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Methods for study objective 1: Quantitative assessment of impact of livestock interventions on maternal and child nutritional outcomes in sub-Saharan Africa

This review aimed at assessing the available evidence on the impact of livestock interventions on child nutritional outcomes in sub-Saharan Africa and identify data gaps. The systematic review and meta-analysis protocol was registered in PROSPERO with ID: CRD42020203843; https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42020203843. Detailed methods for this review have been published elsewhere (Muema et al., 2021). The review follows guidelines provided from PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) statement (Moher et al., 2009).

3.1.1 Literature search and study selection

Major electronic databases including PubMed, Scopus and Web of science were searched, and the relevant peer-reviewed publications and reports identified by two independent reviewers. All the reference lists of all papers identified through the database searches and relevant papers and reports considered were reviewed and "forward citation" tool in Google Scholar was applied to find papers that cited these studies to complement the search. Reference lists of previous systematic reviews conducted on similar study themes were also reviewed. The search strategy was based on keywords formulated according to the population/patient/problem, intervention/indicator/exposure, comparison/control, outcome (PICO) format. These keywords were generated through a preliminary general search in major electronic databases to identify the most used keywords in the publications. Medical Subject Headings (MeSH) terms will be used to identify potential key wards and choose appropriate terms. Boolean operators' terms "AND", "OR" and "NOT" were used to connect the search terms to either narrow or broaden the search. Truncation/wildcard symbol (*) was used for words where variations was possible. The key words and search terms used in the database searches are provided in **Table 2.1** below.

Table 2.1:Key words and search terms used in the database searches.

Indicator	Description
Population	Child OR Infant OR Pediatric OR "young adult" OR Preschool OR Pregnant OR Woman OR Women OR Lactating OR Breastfeeding OR Adolescent OR toddler
Intervention	Trial OR Programme OR Intervention OR Experiment OR Supplementation OR Implementation OR Feed OR Consumption OR "Livestock production" OR "livestock ownership" OR Pastoral OR Livestock OR Cattle OR Camel OR Goat OR Sheep OR Small ruminant OR Poultry OR Chicken OR Fish OR Aquaculture OR fish pod OR Pig OR Meat OR Beef OR mutton OR Pork OR dairy OR egg OR honey OR "animal source food" OR "animal products" OR "foods of animal origin" OR "nutrition sensitive agriculture" OR value chain OR Beekeeping OR "animal health care" OR water OR shelter OR training Or extension services
Outcome	Nutrition OR nutrition status OR nutrition outcome OR Growth OR Linear Growth OR Malnutrition OR Undernutrition OR Stunting OR Wasting OR underweight OR Micronutrient OR micronutrient status OR anemia OR hemoglobin OR hemoglobin OR folate OR vitamin OR Vitamin A OR Vitamin B12 OR iron OR Ferritin OR zinc OR calcium OR MUAC OR anthropometric OR Height-for-age OR Weight-for-height OR Weight-for-age OR dietary diversity
Geographical location	Developing Countries OR Africa OR Africa, Northern OR Africa South of the Sahara OR Sub-Saharan Africa OR Africa, Central OR Africa, Eastern OR Africa, Southern OR Africa, Western OR Algeria OR Angola OR Benin OR Botswana OR Burkina Faso OR Burundi OR Cameroon OR Cape Verde OR Central African Republic OR Chad OR Comoros OR Congo OR "Cote d'Ivoire" OR Djibouti OR "Democratic Republic of the Congo" OR Egypt OR Eritrea OR Ethiopia OR Gabon OR Gambia OR Ghana OR Guinea OR Guinea-Bissau OR Kenya OR Lesotho OR Liberia OR Libya OR Madagascar OR Malawi OR Mali OR Mauritania OR Mauritius OR Morocco OR Mozambique OR Namibia OR Niger OR Nigeria OR Rwanda OR Senegal OR Seychelles OR Sierra Leone OR Somalia OR South Africa OR Sudan OR Swaziland OR Tanzania OR Togo OR Tunisia OR Uganda OR Zambia OR Zimbabwe

MUAC – mid-upper arm circumference

Search results were uploaded to Rayyan QCRI (https://www.rayyan.ai/) to facilitate collaboration among reviewers during the study selection process. Duplicates were removed and studies were screened by two independent reviewers based on inclusion criteria. Titles and abstracts were examined for eligibility for inclusion in the review and full-text articles were searched when abstracts did not provide sufficient information for decision-making.

3.1.2 Inclusion and exclusion criteria

Studies were screened against the inclusion and exclusion criteria to access if they met the conditions to be included in the review. Studies were included if they were published in Africa, the study population was children below five years or pregnant and lactating women and involved livestock interventions contributing to the production or consumption of animal source foods. The outcome of interest in the included studies was nutrition outcomes including anthropometry (weight-for-age z-score, height-for-age z-score, weigh-for-height z-score, mid upper arm circumference (MUAC)), micronutrient status and health related outcomes. Pear reviewed articles and online reports published up to 9th December 2021 were included. Experimental, quasi-experimental and observational studies, cross-sectional longitudinal intervention-control comparisons and randomized field trials were included while literature reviews, studies conducted in other continents, studies with crop agriculture interventions, biofortification, home gardening and irrigation programs were excluded as shown in **Table 2.2** below.

Table 2.2: Inclusion and exclusion criteria used to assess study eligibility.

Criteria	Include	Exclude
Location	Studies conducted in Africa	Studies conducted in other continents
Population	Children below 5 years, OR pregnant women OR Lactating women	
Intervention	Livestock interventions contributing to production and consumption of animal source foods (milk, meat, eggs and fish) and livestock value chains	Crop agriculture Biofortification Home gardening Irrigation programs
Outcome	Nutrition outcomes including; anthropometry (weight-for-age z-score, height-for-age z-score, weigh-for-height z-score, MUAC, micronutrient status and health related outcomes	Health outcomes not directly related to nutrition
Publication date	Studies published up to 9th December 2021	
Publication type	Peer reviewed articles and online reports	Unpublished reports
Study designs	Experimental, quasi-experimental and observational studies, cross-sectional longitudinal intervention-control comparisons and randomized field trials	Literature reviews
Publication language	English	Other languages

A two-stage screening process was employed in all the retrieved articles from the database searches. First, titles/abstracts were screened by two independent reviewers to check for relevance to the review question. Secondly, full texts of possible relevant articles were reviewed by two independent reviewers to ascertain if the methods used in the studies selected at stage one adhered to the set inclusion criteria. This included ascertaining whether, the studies reported on nutrition-sensitive livestock interventions, were implemented in Africa, and had an objective of improving nutrition status in children under 5 years of age or pregnant and lactating women and were published in the English language up to 9th December 2021. Studies that did not meet these set criteria were excluded. All articles selected by both reviewers were included for review and data extraction. For articles where there were disagreements between the two reviewers, discussions were carried out with a third reviewer and consensus sought.

3.1.3 Data abstraction and synthesis

The selected articles went through a full-text review, and data were abstracted from relevant articles after full-text review by two independent reviewers. Decisions on articles that would be included in the meta-analysis were made independently by each reviewer and discussed between them before arriving at a consensus. Data abstraction included variables on study author(s), year and country, study title, study design, study participants and sample size, intervention type, study outcome measured, the effect of intervention on nutrition, statistical significance, study findings, study limitations and conclusion. Data were synthesized both qualitatively and quantitatively and key outcomes presented.

3.1.4 Qualitative evidence synthesis

Qualitative data synthesis involved presenting summary of key outcomes in the form of summary tables together with a narrative description of the relevant studies.

3.1.5 Effect size determination (Quantitative synthesis)

Meta-analysis was carried out using the statistical software Review Manager (RevMan version 5.4.1). The outcome measures included were consumption of animal source foods (ASFs) and minimum dietary diversity (MDD). Meta-analysis was not performed on the outcome of nutritional status measured by anthropometry (stunting, wasting and underweight) as there was significant heterogeneity in reporting metrics for these indicators. The pooled effect of livestock interventions on consumption of ASFs and meeting MDD was measured by using odds ratios (OR) with their 95% confidence intervals. The statistical heterogeneity between studies and its effect on the meta-analysis was determined using the statistical measure of heterogeneity (I^2 statistic), classified as I^2 statistic (I^2 = 0%: no heterogeneity; I^2 =>0 – ≤25%: low heterogeneity; I^2 =>25 – ≤50%: moderate heterogeneity; I^2

$=>50 – \leq 75\%$: high heterogeneity and $I^2 =>75 – \leq 100\%$: very high heterogeneity). Fixed and random effects models were used to estimate the OR (95% CI) based on the level of heterogeneity of the studies included. The results were presented graphically using forest plots indicating point estimate and 95% confidence interval of observed effect for each individual study together with a summary estimate and its confidence interval.

3.1.5 Validity/risk of bias assessment

Individual studies were assessed for study validity/risk of bias using the Grades of Recommendations, Assessment, Development and Evaluation (GRADE) guidelines (Guyatt et al., 2011). Studies were scored as either low, medium and high quality based on five criteria; counterfactual analysis, sample size and power calculations, nutrition outcome assessment, intermediate outcome assessment and confounding bias assessment. Overall assessment of risk of bias for each study was determined through a weighted judgement of the established criteria.

3.2 Methods for study objective 2: Determination of the effect of providing livestock feeds to milking animals during drought periods and nutrition counselling on milk yield, milk consumption and undernutrition in women and children below five years in Marsabit County, Kenya

3.2.1 Study area

The study was conducted in Marsabit County. The county is one of the arid and semi-arid counties in northern Kenya with high rates of acute malnutrition (Wayua, 2017) and high prevalence of brucellosis (Osoro et al., 2015). The county is predominantly pastoral, with households heavily depended on livestock for their livelihoods. The communities practice seasonal mobility to access livestock pasture and water. The study was conducted specifically in Laisamis Sub-county, see **Fig.3.1** below. The sub-county was purposively selected following consultations with local government officials and communities. The aim was to select the study area having similar environmental patterns, households dependent on pastoral livelihoods characterized by seasonal mobility of livestock in search for pasture and water, and having high levels of acute malnutrition in children (Government of Kenya, 2017).

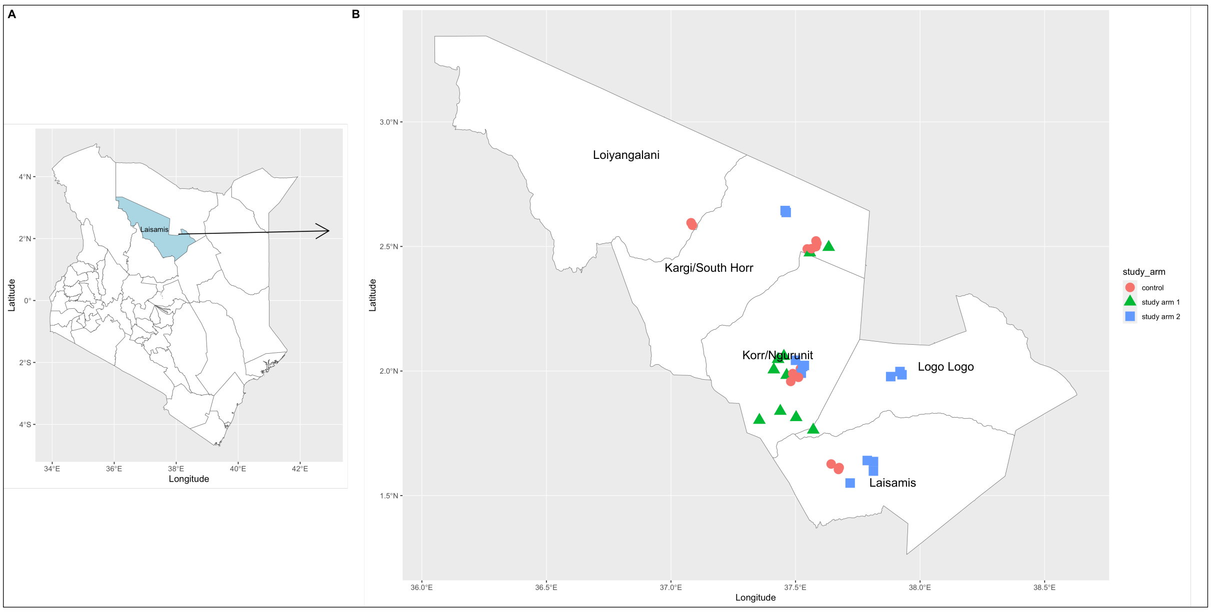

Figure 3.1: Map of Kenya showing Laisamis sub county study area, the regions of Laisamis selected for the study and the distribution of villages assigned to the different arms of the study. *Source: author's own work*

3.2.2 Study population

Children below five years and pregnant or lactating mothers from households within Laisamis Sub- County that kept livestock. The domestic animals eligible for inclusion in the study were cattle, goats, sheep and camels which were used as sources of milk for the households.

3.2.3 Study design

The study was a cluster randomized control trial with two intervention arms and one control arm. The study was conducted for a period of 28 months (from September 2019 to December 2021) covering four dry seasons in the study region. Households in Arm 1 received livestock feed sufficient to maintain two tropical livestock units (equivalent to two cows or 2 camels or 20 sheep or goats) of milking animals during the critical dry period. Households in Arm 2 received similar amounts of livestock feed and regular nutritional counseling delivered by trained community healthcare workers on a weekly basis while households in the control arm did not receive any of the interventions and served as the comparison group.

3.2.4 Sample size estimation

Sample size calculation was done using the formulae for sample size determination for cluster randomized controlled trials (cRCTs) for comparison of means in a two – arm trial with equal cluster sizes. The study was restricted to 36 villages that met the minimum study eligibility criteria while also considering logistics and cost. A design effect (DE) was used to account for similarities within study clusters and to increase the statistical power of the study (Ribeiro et al., 2018; Rutterford et al., 2015). The sample size calculation was based on a comparison of the risk of acute malnutrition among children in the intervention arm (households with lactating animals and receiving livestock feeding) and in the control arm (not receiving any of the interventions). The difference in change in the weight for age z-score (WAZ) between children in the intervention and control arms was the outcome measure as per the equation below.

$$m = \frac{(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta})^2 \, 2\delta^2}{\Delta^2} (1 + (n-1)p)$$

Where:

DE = design effect; $DE = 1 + (n - 1) \times \rho$

n = cluster size (i.e. number of participants per cluster)

p = intracluster correlation coefficient (ICC)

Z = the x'th percentage point of the standard normal distribution;

Δ = delta – clinically important difference between groups for the primary outcome measure

σ^2 = variance of primary outcome measure.

α = significance level.

β = power.

Assumptions:

α = significance level to be set at 95% CI = 0.05

β = study to be powered at 80%

Δ = delta – the mean difference between intervention and control groups hypothesized to be = 0.25 points based on a similar study, the milk matters studies in the Somali region of Ethiopia (Sadler, Mitchard, Abdi, Shiferaw, Bekele, et al., 2012).

p = A low ICC of 0.02 for undernutrition within villages was assumed in the study county as observed in a similar study (Fenn et al., 2004).

σ^2 = sigma = 1

n = 50 households per village

The sample size calculation formula above was implemented in R statistical software (R Core Team, 2019), using package "cluster Power" and function cluster.R1 <- crtpwr.2mean (alpha = 0.05, power = 0.8, m=NA, n=50, cv=0, d=0.25, varw = 1, icc =0.02). Assuming 50 households per village (cluster) with statistical significance of 0.05, power of 0.80, and an intra-cluster correlation coefficient of 0.02. This sample size provided the ability to detect minimum differences between treatment arms of a change of 0.25 in mean WHZ.

Based on the above assumptions, a total of 12 villages were required per study arm (each village has an estimated 50 households with at least 1 child 3 years and below per household at recruitment). Allowing for 10% drop-out (approximately 50 households per arm), a sample of 600 households per study arm (50 households per village meeting the recruitment criteria) and total of 1800 households for the three arms were required for this cluster randomized control trial.

3.2.5 Sampling strategy

Stratified multi-stage cluster sampling was used. All the five wards in Laisamis Sub-County, namely, Laisamis. Korr/Ngurnit, Logologo, Kargi/South Horr, and Loyangalani were included in the study. From the five wards, fifteen sub-locations with similar climatic conditions were selected to form a sampling frame from which twelve sub-locations were randomly selected for the study. Treatment arms were randomly allocated to the selected sub-locations with four sub-locations per treatment arm. Villages within the selected sub-locations were eligible for inclusion in the study. Approximately 12 villages each with 50 households per study arm were randomly selected. All households that meet the inclusion criteria in each of the selected villages were recruited into the study until the required sample size was achieved. To minimize "contamination" between intervention arms and control arms, all participating households at any given sub-location were assigned to the same study arm, see the flow diagram in **Figure 3.2** below.

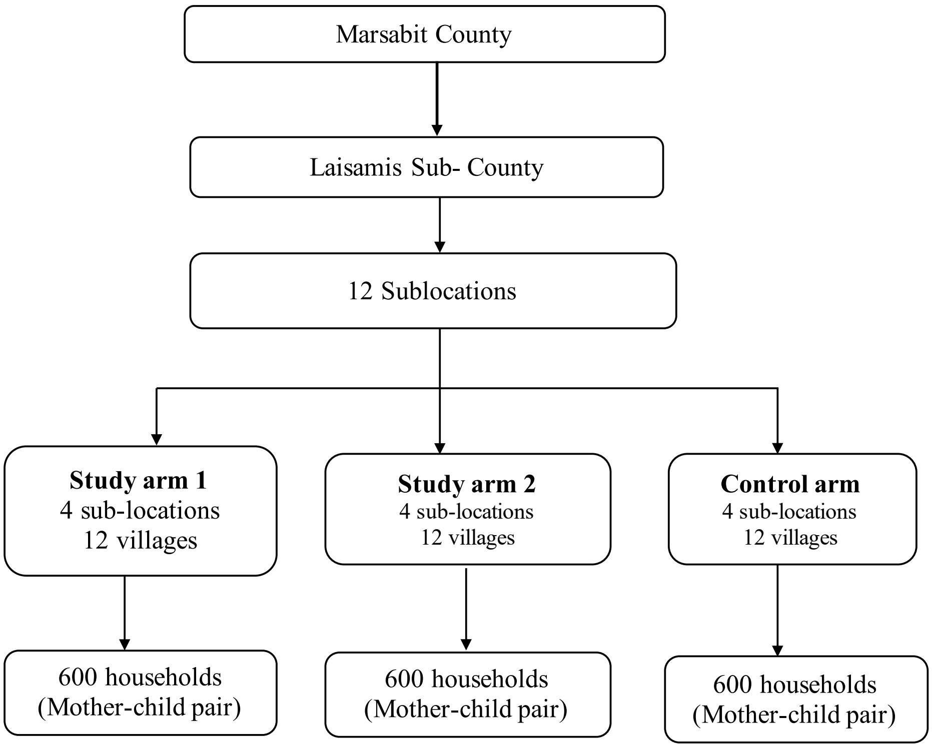

Figure 3.2: Study sampling strategy flow diagram indicating the stratified multi-cluster sampling process used to select study households and the allocation of the households to different study arms.

3.2.6 Recruitment Procedure

The longitudinal study commenced with a recruitment visit, which took place at the beginning of the study. Informed consent was obtained at the time of household recruitment. A total of 1903 households were consented to participate in the study. Each household had at least a child < 3 years (recruited at < 3 years to allow for follow up of up to 24 months) and either a pregnant or lactating mother at the time of recruitment. Children born from the recruited pregnant women were also recruited into the study forming a mother-child pair in each household. The study period ran from September 2019 to December 2021. Following the recruitment visit, each study household was visited every six weeks for a period of 24 months making a total of 15 visits.

3.2.7 Nutrition counselling

Households in intervention arm 2 received enhanced nutritional counselling and education based on the Maternal Infant and Young Child Nutrition programme (Government of the Republic of Kenya Ministry of Health, 2013) This was accompanied by information on benefits of consuming milk, hygienic handling and storage, and milk preservation and preparation, in the form of a milk utilization card co-designed with the Ministry of Health. The enhanced counselling was offered weekly by trained community health workers drawn from the same study community.

3.2.8 Study variables

3.2.8.1 Outcome variable

The main outcome variables (dependent variables) for this study were household average milk yield (litres/day), milk consumption (frequency & amount) for children and mothers nutritional status (stunting, wasting and underweight).

3.2.8.2 Independent variables

The main independent variables (predictor variables) were the treatment arm (received livestock feed and nutrition counselling or control), individual households and the village. The treatment arm was treated as fixed effects, while individual households and villages were treated as random effects. Other covariates which were controlled for included rainfall (seasonality), livestock ownership and herd structure, species and numbers of milking animals, herd health, herd management and veterinary interventions, household demographics and socio-economic status, and illness of household members.

3.2.9 Data collection process

3.2.9.1 Data collection tools

In all households that met the inclusion criteria, household-level and individual-level data questionnaires were administered. The household level data questionnaire collected information on the household demographics, the health of the animal herd, milk, livestock illness (2-week livestock illness data, human illness (2-week recall human syndromic data, and household socio-economic data (assets, livestock ownership, milk production).

The individual-level data questionnaire was administered to a mother and child pair and/ or pregnant woman. The questionnaire collected information on the demographic data of the respondent, dietary diversity, syndromic surveillance data (fever, diarrhea and respiratory signs/cough) and anthropometric measures.

3.2.9.2 Data collection procedure

Data collection was completed electronically using mobile phones on CommCare® data collection platform. Research assistants were trained on how to electronically capture data from household visits and interviews. A relational database containing all data collected during the household visits, and data obtained from laboratory analysis of samples was designed and utilized for data storage and querying. Data collected during the visits was uploaded from the mobile phones to the relational database, and a backup copy was immediately generated and stored in a restricted drive. Daily checks were carried out to identify and correct any errors. Since possible electricity power failure and low internet coverage and connectivity was anticipated, the mobile phones were supplied with power banks. The CommCare® mobile platform allows for offline data collection and storage, and uploading of the data to the server when internet connection was available.

Data on average amount of milk produced per day by species (cattle, camels, goats and sheep), milk intake (yes/no), frequency of milk intake, average milk intake (litres/day) and child nutritional status (height-for-age, weight-for-height and weight-for-age) was collected. Data on household milk yield and consumption was determined through administration of questionnaires capturing both household level- and individual level data .

Anthropometric measures were collected to determine the nutritional status. These data include child height-for-age (stunting), weight-for-height (wasting), weight-for-age (underweight) and middle upper arm circumference for both mother and child. Weight was measured using standardized seca 872 electronic scales (with tare function), and height was determined using height/length boards (ShorrBoard®). MUAC tapes were used to measure mother and child nutritional status. In cases where children enrolled in the study were acutely malnourished, they were referred to the nearest health facility for further review and management.

3.2.10 Quality assurance and quality control

3.2.10.1 Recruitment and training of research assistants

The research assistants were recruited through an equal-opportunity mechanism. Adverts were made and recruitment done targeting individuals with experience in field data collection. The nine (9) selected assistants were trained on the study's objectives, procedures, and ethics.

3.2.10.2 Pre-testing

A one-week study pilot was conducted to authenticate the validity and reliability of the study tools. This process aimed to ensure that the tools were easily and consistently understandable among participants. Based on the pilot results, the tools were adjusted accordingly.

3.2.11 Data management and analysis

3.2.11.1 Data Management

For this study, field questionnaire administration, anthropometric measurements and collection of biological samples in both human and animals were used to provide data to answer the different study questions. For the households enrolled in the study, both questionnaire data, anthropometric measurements, and biological samples data were collected during the recruitment visit and the subsequent follow-up visits within the 24 month follow-up period.

3.2.11.2 Data analysis

Data analysis for this cluster randomized controlled trial was carried out using the intention-to-treat principle. All randomized study participants were included in the study and analysis was conducted based on the group originally assigned (McCoy, 2017). Initially, descriptive analyses were performed to determine the distribution of the study independent variables in relation to the outcome. Based on the data type and objective of analysis, linear mixed effects models, mixed-effects logistic regression, and random coefficient Poisson models were performed to test the study hypotheses. Odds ratios and their 95% confidence intervals were reported. All analyses were performed using R statistical software (R Core Team, 2019). For each statistical technique employed, respective R packages were used and are summarized in Table 3.2.The analysis were done for each main outcome data for the objective.

3.2.11.2.1 Main outcome data: Household milk yield (litres/day)

The primary analysis used linear mixed effect models to compare mean change in household average daily milk yield (litres) over study time by the intervention and control study arms. The dependent variable was the household milk yield (litres). The treatment group was treated as fixed effects and individual households and villages as random effects. The analysis controlled for other covariates including forage condition indices, rainfall (seasonality), livestock ownership and herd structure, species and numbers of milking animals, herd health, herd management and veterinary interventions, household demographics and socio-economic status, illness of household member. The estimated differences in mean daily milk yield between the treatment arms and their corresponding confidence intervals were presented.

3.2.11.2.2 Main outcome data: Milk consumption (amount and frequency)

The dependent variables were a categorical value of milk intake (Yes/No) by children < 5 years, daily frequency of milk intake by children < 5 years and average daily milk intake by children below 5 years. The initial analysis focused on the binary outcome (whether or not study participants consumed milk) compared across the three study arms. Mixed effects logistic regressions models were used to model the binary outcome, with individual and village incorporated as the random effects. To model the frequency of milk intake data, random coefficient Poisson models were used to account for repeated measures from study participants and clustering within villages to determine the differences between participants in the three study arms.

The primary analysis compared the average daily milk intake for children participating in the study between the three study arms. Linear mixed-fixed effects models with average daily milk intake as the outcome variable, the treatment arm of the study as the fixed term, and individual and village as the random effects were used. The analysis controlled for covariates including gender, education level, marital status, primary occupation and age of the household head, household demographics and socioeconomic status (household size, wealth index), livestock ownership, herd structure and herd dynamics, herd health (frequency of disease events, disease events), milking animals and household milk production, milk storage practices, household consumption and expenditures on meat, eggs, plant proteins, carbohydrates, vegetables and fruits), terms of trade between livestock, livestock products and staples, exposure to nutritional education and counselling.

3.2.11.2.3 Main outcome data: Child nutritional status

The dependent variables were undernutrition (wasting, stunting and underweight). Anthropometric measures from children (MUAC, weight, height) and mothers (MUAC and weight) were collected every six weeks and the following nutritional status indices were calculated.

Height for age z score (stunting): This was calculated using the height and age of the child in days. The sex of the child was used to classify their nutrition status. A z-score of ≤ -3 was categorized as severe stunting, while a score between ≤ -2 and ≥ -3 was categorised as moderate stunting. The rest was normal.

Weight for height z score (wasting): This was calculated using weight (in kgs) and height (in cms), while sex was used to classify their nutrition status. Children with a z score ≤ -3 were categorized as having severe acute malnutrition while the ones with a score between ≤ -2 and ≥ -3 were categorised as having moderate acute malnutrition. Children with a score of ≥-2 and ≤2 were normal while those with >2 and ≤ 3 were overweight, and ones with >3 were obese.

Weight for age z score (underweight): This was calculated using weight and age of child in days. Sex was also used to classify the nutrition status. A z-score of ≤-2 was categorised as underweight while a score between ≥ 2 was categorised as overweight. The rest was categorised as normal.

MUAC for age z score (Global acute malnutrition): This was calculated using child MUAC and the age of the children (in days). A z-score of <-3 was categorised as severe acute malnutrition while a score between ≤-2 and ≥-3 was categorised as moderate acute malnutrition. The rest was normal.

The initial analysis was descriptive of the measures of nutritional status (wasting, stunting, under-weight) among the study participants. A nutritional status value for each study individual was calculated and established for each data point (study visit). To compare the risk of children with undernutrition indices of wasting, stunting and underweight (binary outcome - Yes/No), between the three study arms, mixed-effects logistic regressions to account for the multiple measurements per individual over the study period were used. Since the data on weight-for-height, height-for-age, and weight-for-age were available as continuous variables, linear mixed-effect models were used to compare these values between the three study arms. The treatment arms were treated as fixed effects, and the individual and village variables as random effects.

To account for possible confounders, the following variables (covariates) were included in the models as fixed effects: mother's age, education level, occupation, marital status; caregiver hygiene status (washing hands,), exposure to nutritional education and counselling (binary - Yes/No, frequency of exposure, content taught); breast-feeding (status, frequency); the age of the child; dietary intake (type, frequency and amounts) in the last 24 hours (animal source foods - milk, eggs, meat, and plant proteins, carbohydrates, vegetables); health status in the two weeks preceding the visit (fever, diarrhea, runny nose/cough); household demographics and socioeconomic status.

3.2.11.2.3.1 Dietary diversity indicators

Dietary diversity indices including Household Dietary Diversity Score (HDDS), Minimum Dietary Diversity for Women (MDD-W) and Minimum Dietary Diversity for Children (MDD-C) were calculated. The following 12 food groups were used to calculate the HDDS indicator. Cereals, roots and tubers, vegetables, fruits, meat/poultry/offal, eggs, fish and seafoods, pulses/legumes/nuts, milk and milk products, oil/fats, sugar/honey, and Miscellaneous. Each food group was assigned a score of 1 (if consumed over the previous 24 hours) or 0 (if not consumed in the last 24 hours). The household score ranges from 0 to 12 and is equal to the total number of food groups consumed by the household. The average household dietary diversity score for the population of study is calculated using this formula; Sum (HDDS) / Total number of households surveyed

For the Minimum Dietary Diversity for Women (MDD-W), ten food groups (Grains, white roots and tubers, and plantains, Pulses (beans, peas and lentils), Nuts and seeds, Dairy, Meat, poultry and fish, Eggs, Dark green leafy vegetables, other vitamin A-rich fruits and vegetables, other vegetables and other fruits were considered. The total number of food groups consumed were summed and the MDD-W score calculated using the equation below.

$$\frac{\text{Women } 15-49 \text{ years of age who consumed foods from 5 food groups the previous day}}{\textit{Total number of women } 15-49 \textit{ years of age who were surveyed}}$$

Minimum Dietary Diversity for children (MDD-C) was calculated to determine whether children 6-23 months have achieved minimum dietary diversity, their consumption of food and beverages from at least five out of the eight specified food groups in the past 24 hours was considered. The eight food groups considered included breast milk, grains, roots, tubers and plantains; pulses (beans, peas, lentils), nuts and seeds; dairy products (milk, infant formula, yogurt, cheese); flesh foods (meat, fish, poultry, organ meats); eggs; vitamin-A rich fruits and vegetables; and other fruits and vegetables. The MDD-C was then calculated as the proportion of children who achieved this minimum dietary diversity, divided by the total number of children using the equation below.

$$\frac{\text{Number of children } 6-23 \text{ months who consumed foods from 5 or more food groups}}{\textit{Children } 6-23 \textit{ months of age whom data on breastfeeding amd diet were collected}}$$

3.3 Methods for study objective 3: Establishing the burden and effect of zoonoses (brucellosis & Q-fever), childhood illness syndromes (diarrhea, fever & acute respiratory infections) and their association with undernutrition in children below five years in Marsabit County, Kenya

Biological samples were collected from both women and children in the same households where nutrition status data was collected. Additionally, animals providing milk to these households including goats, sheep and camels provided blood samples for analysis for exposure to brucellosis and Q-fever. Brucellosis and Q-fever are among top ten priority zoonotic diseases in Kenya and could be transmitted through consumption of contaminated animal source foods and living in close proximity to infected animals.

3.3.1 Study population

The study population for the cluster randomized controlled trial investigating the effectiveness and cost-effectiveness of providing livestock feed and nutrition counselling during dry periods on maternal and child nutrition status constituted the study population for this sub-study.

This population was chosen because women of childbearing age, especially pregnant and lactating women, and children <5 years of age are the most nutritionally vulnerable group and are a good indicator of household nutritional status. The study investigated the burden of brucellosis and Q-fever in these same population since high prevalence of brucellosis have been reported in similar pastoral production systems in Kenya (Osoro et al., 2015) and also due to the severe, debilitating and chronic nature of brucellosis (A. Dean et al., 2012), the study sought to determine if it is associated with the high rates of malnutrition reported in women and children in this setting. Consequently, the sampling population did not include the whole population.

3.3.2 Study design, Sample Size and Sampling Strategy

For this objective, a cross-sectional study was conducted. Multi-stage cluster sampling was conducted to select potential enrollees. A list of all sub-locations within the five wards was generated and 12 sub-locations were randomly selected. A list of all villages within each sub-location was then generated and used as a sampling frame to randomly select three villages per sub-location. In each village, households with a lactating animal, a child less than five years and a woman of reproductive age were identified for possible inclusion in the study.

Households were the primary sampling units while individuals (children, women, or lactating animals) were secondary sampling units. A household herd was defined as aggregate flocks (cattle, goats, sheep, and camels) managed under the same household. The study assumed that household herds share common risk factors for disease and that disease distribution within the herd was homogenous. Sample size calculation was based on the formula for sample size determination when herds, flocks or other aggregates of animals are the sampling units and taking into account herd effects to achieve high herd level sensitivity and specificity while also accounting for test imperfections as the ELISA kits used had less than 100% sensitivity and specificity (Humphry et al., 2004; Thrusfield, 2008).

$$n = (1.96/d)^2 \text{ X } \frac{[(Se_{\text{agg}} \text{ x } P_{exp}) + (1 - Sp_{\text{agg}})(1 - P_{exp})][(1 - Se_{\text{agg}} \text{ x } P_{exp}) - (1 - Sp_{\text{agg}})(1 - P_{exp})]}{(Se_{\text{agg}} + Sp_{\text{agg}} - 1)^2}$$

The study applied an expected herd prevalence (*P_{ex}*) of 50%, a desired absolute precision (*d*) of 5%, and aggregate test sensitivity (Se_{agg}) and specificity (Sp_{agg}) of 95% and 99%, respectively, to obtain a minimum sample size of 960 households. The 50% prevalence was chosen because it provides the largest sample size for given values of absolute error.

In each household herd, up to three lactating animals per species were chosen by systematic random selection. A sampling interval number was obtained by dividing the total number of lactating animals per species by number of animals to be sampled within the herd. The first animal was then randomly selected followed by every n^{th} animal until the sample size was attained. In each household herd, all lactating animals per species were grouped together and numbered using animal marker pens and random numbers assigned by dividing the total number of lactating animals per species by three (3) to create the interval of selection. Animals bearing the random number were selected for blood sample collection. For human participants, children and women within households that consented to participate in the study were enrolled for blood collection. The sample collection sampling strategy flow diagram is shown in **Figure 3.3** below.

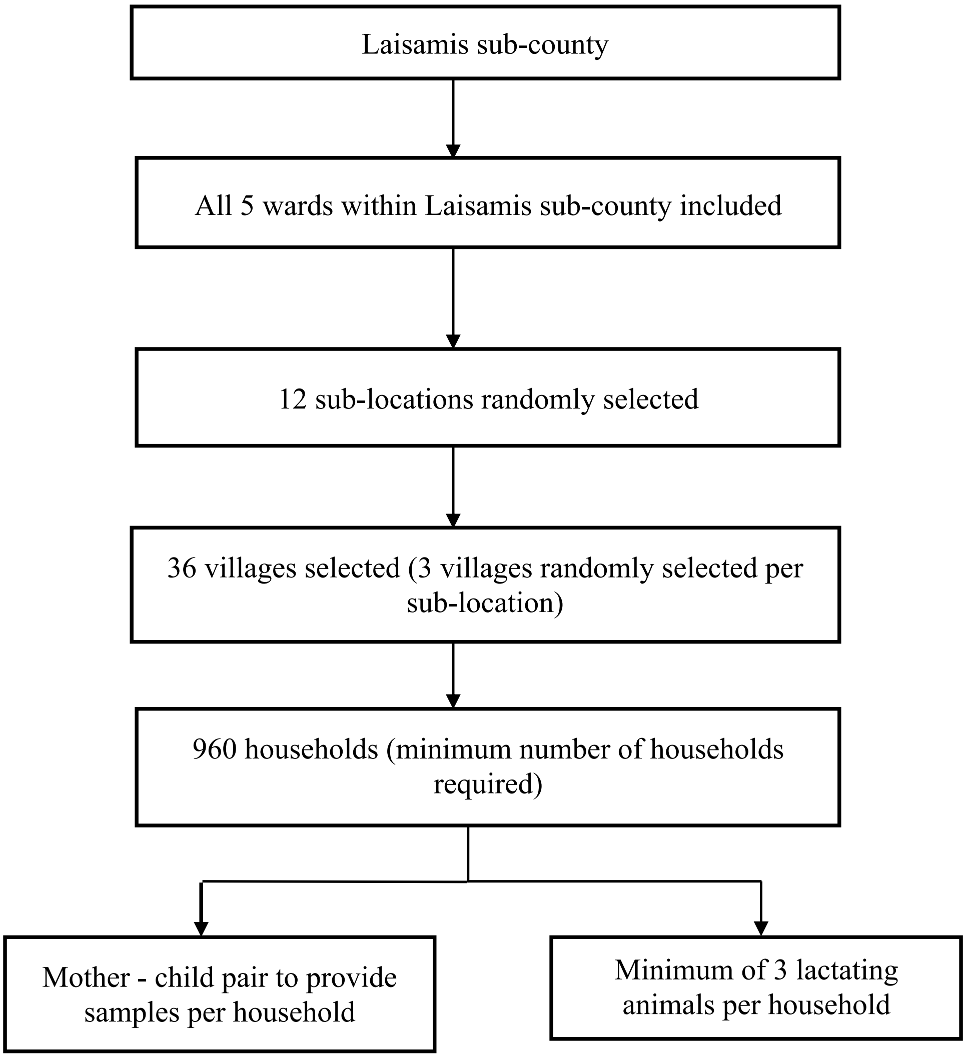

Figure 3.3: Sample collection sampling strategy flow diagram indicating recruitment and allocation of study participants for blood sample collection.

3.3.3 Data collection

Individual-level factors (animal and human) were collected using a structured questionnaire, which was administered to an adult household respondent (≥18 years). These factors included species, age, sex, physiological status, history of reproductive disorders for animals, and participant type (mother or child), age, sex, and physiological status for humans. Data on reported child illness data was extracted from the questionnaire data collected from the same children in the cluster randomized controlled trial.

3.3.3.1 Human and animal biological samples collection

Human and animal blood specimens were collected via venipuncture by trained nurses and animal health technicians, respectively. Human samples were collected in plain 5 mL serum separation tubes while animal samples were collected in 10 mL vacutainers. For the human samples, 2.5 mL of blood was collected from children and 4 mL from women while for the animal samples, 8 mL of blood was collected from goats, sheep, and camels. The blood collection tubes were barcoded and allowed to stand for 15 min to allow for clot separation. Clotted samples were then transported to a field laboratory in cooler boxes within 6 hours of collection. Both human and animal biological samples were used to test for infection status with brucellosis and Q fever.

3.3.3.2 Human blood sample collection, processing, and testing

Briefly, with new sterile gloves, sterile, single-use needles and vacutainer tubes, the study participant was allowed to sit comfortably with the arm from which blood was to be collected being supported. Blood was collected from the median antecubital or basilica vein. A tourniquet was used to apply pressure on the arm to distend the vein. Once the vein had been located, the phlebotomy site was disinfected with a 70% alcohol swab. The appropriate vacutainer needle gauge (21G for adult and 23G for child) was selected and the needle's protective case opened and screwed in the blood-drawing device without uncovering the needle. The quality seal was broken in front of the participant and aseptically, the vacutainer needle was inserted into the vein and blood drawn to the required capacity. The tourniquet was then released, needle removed from the vein and the puncture site covered with cotton swab for 30 seconds. Venous blood (4 mLs in adults and 2-3mLs in participant's children) was collected for serological testing using appropriate vacutainer tubes. Once the the correct volume of blood had been collected, each tube was labeled with a barcode label. The vacutainer tube containing the blood sample was labeled using scannable pre-printed labels with the unique sample ID. The samples were kept in a cool box for transportation to the field processing site/laboratory in Marsabit. Samples were shipped to the field laboratory in Marsabit for temporary storage before shipping to the University of Nairobi Institute of Tropical and Infectious Diseases (UNITID) laboratories for brucellosis and Q fever testing. Brucellosis and Q fever serology were performed using ELISA commercial kits. Indirect ELISA kits—PrioCHECK™ Brucella Ab 2.0 Strip Kit, (Thermo Fisher Scientific, UK) and IBL-America Brucella IgG ELISA (Immuno-Biological Laboratories Inc, USA) were used to screen for *Brucella* spp IgG antibodies in animal and human sera, respectively.

3.3.3.3 Animal blood sample collection, processing, and testing

Blood samples were collected from the jugular vein of 2-3 randomly selected milking animals (small ruminants or camels) at each study household. Briefly, the study personnel donned the minimum Personal Protective Equipment (PPE) for livestock sample collection (overalls, gumboots and gloves). The animal was restrained manually in a crush or a halter was used for proper and humane restraint and to protect the animal and study personnel. Using the halter, the animal's head was placed in a slightly elevated position but drawn to the opposite side of the jugular vein to where blood was to be collected. The venipuncture area was disinfected using gauze with 70% alcohol and the vein occluded by applying pressure using the thumb figure in the jugular groove located in the lower neck. The vacutainer needle attached to a vacutainer holder was placed into the distended jugular vein at a 45°angle cranial to the jugular groove. Once the needle was in position in the vein, a vacutainer tube was inserted into the needle to collect the blood. The occluding pressure was then removed from the vein once the desired volume had been collected and the tube detached from the needle and the needle from the jugular vein withdrawn.

The vacutainer tube was labeled with the unique sample ID and placed in a vacutainer rack and the vacutainer needle was placed in the sharp's container. The sample was then stored in a cool box with frozen ice packs for transportation to the field laboratory in Marsabit for sample processing. Once in the field laboratory, the samples were centrifuged for 15 minutes and 2 mL of serum collected using plastic transfer pipettes into a cryovial tube. The cryovial was labeled with the same label information used in the vacutainer tube and frozen until testing. Indirect ELISA kits—PrioCHECK™ Brucella Ab 2.0 Strip Kit, (Thermo Fisher Scientific, UK) was used to screen for *Brucella* spp IgG antibodies in animals and IBL-America Brucella IgG ELISA (Immuno-Biological Laboratories Inc, USA) used for screening for *Brucella* spp IgG antibodies in humans. Samples were tested for *Coxiella burnetti* antibodies using indirect ELISA test kits. Human sera were tested using the SERION ELISA Classic *Coxiella burnetii* phase 2 IgG (SERION Diagnostics, Würzburg, Germany) kit. Animal sera were tested using the PRIOCHECK™ Ruminant Q Fever IgG (ThemoFisher Scientific, UK) ELISA kit. Testing was done following the manufacturer's instructions.

3.3.4 Data analysis

Data analysis was carried out to determine burden of brucellosis and Q-fever among people and their livestock as well as the associations between undernutrition and health status of children, and exposure to the zoonotic infections. The initial analysis was descriptive of the burden of brucellosis and Q fever among the study participants both human and domestic animals. The primary analysis was to compare the risk of brucellosis and Q fever infection status (yes/no) in study participants, using mixed effects logistic regression. The main outcome variable was brucellosis infection status (yes/no) by children < 5 years and pregnant and lactating women or Q-fever infection status (yes/no) by children < 5 years and pregnant and lactating women. The analysis focused on the binary outcome (infection status, yes/no) and used mixed effects logistic regressions to model the binary outcome, with individual households and the village incorporated as the random effects. Other variables (covariates) included in the models' as fixed effects were mother's age, education level, occupation, marital status, exposure to nutritional education and counselling (binary - yes/no, frequency of exposure), age of the child, household demographics and socioeconomic status.

Logistic regression models were used to identify individual- and household/herd-level factors associated with and brucella and *C. burnetii* (Q fever) antibody seropositivity. A univariable model was used to explore the relationship between brucellosis and Q-fever seropositivity and independent predictor variables. The independent predictor variables assessed for human models included age, sex, physiological status, occupation, education level, geographical location (ward) and nutritional status. For the animal models, the independent variables assessed included species, geographical location (ward), reproductive disorders, household head occupation, household head education level and grazing distance. All predictor variables were added to a multivariable model and a variable selection for the final model was carried out using the stepwise Akaike Information Criterion algorithm. Odds ratios and corresponding 95% confidence intervals were calculated to identify the strength of identified associations. The fitted models were evaluated by including household/herd as a random effect to adjust for possible clustering of *C. burnetii* or brucella seropositivity within households/herds. Model diagnostics included calculating scaled residuals, mapping residuals, and testing for dispersion and spatial autocorrelation of residuals. Model building assumed family binomial with logit link functions. The associations between exposure to brucellosis and Q-fever among the study participants and measures of nutritional status were evaluated using a mixed effects logistic regression model. Further, a mixed effects multivariable model was used to test the association between reported child illness syndromes of fever, diarrhoea, and acute respiratory infection (ARI) and child nutritional status (undernutrition). All analyses were performed using R version 3.6.2 (R Core Team, 2019).

3.4 Methods for objectives 4: Determination of the cost-effectiveness of providing livestock feeds to milking animals during drought periods and nutrition counselling in preventing undernutrition in children below five years in Marsabit County, Kenya

The cost-effectiveness of proving livestock feeds to milking animals during critical dry periods and nutrition counselling in preventing undernutrition in children below five years was assessed. The main outcome variable was cost-effective ratio of $/WHZ.

3.4.1 Estimation of program costs

Program costs were estimated based on a provider perspective and included costs incurred to procure and deliver the feed and nutrition counselling service to the beneficiaries. Direct and indirect costs such as transport costs incurred by the beneficiaries to the feed distribution centres and time for participating in the feed distribution and nutrition counselling were not included. Programme costs data were obtained from review of project financial documents and interviews with programme staff. Costs were assessed over the entire implementation period of two years, January 2020 – December 2021. An activity-based costing approach was applied by determining main programme activities within each of the two interventions and allocating costs to these activities. Aggregated costs were organised into main cost centres based on the intervention arm and type of cost. All costs were expressed in US dollars.

3.4.2 Cost-effectiveness estimation

The outcomes of this study were cases of wasting and stunting averted by the nutrition-sensitive livestock intervention of providing livestock feeds and nutrition counselling. Cost-effectiveness was assessed as cost per case of wasting and stunting averted. Cases averted by the two interventions relative to the control group for each of the two outcomes were calculated. A point estimate and 95% confidence interval (CI) for the numbers of cases of wasting and stunting averted by the interventions were calculated using odds ratios and associated confidence intervals from the nutrition-sensitive livestock intervention cluster randomized controlled trial providing livestock feed and nutrition counselling relative to the control arm.

Incremental cost-effectiveness ratios (ICERs) were calculated for each intervention, estimating additional costs incurred by each intervention to avert cases of wasting and stunting relative to the Control Group. ICERs were calculated only for statistically significant differences in nutrition outcomes between the interventions and the control group as measured by the cRCT study trial. Incremental cost-effectiveness ratios (ICERs) were calculated as the change in costs/change in benefits comparing intervention and control groups ("Do Nothing").

The effectiveness outcome was measured as changes in the proportion of children wasted (Weight-for- Height Z scores (WHZ) and the proportion of children stunted (Height-for-age Z scores) among children enrolled in the study between each of the study arms. Cost-effectiveness analysis (CEA) was calculated as Incremental Cost Effectiveness Ratio (ICER) = (Changes in the total cost of interventions by arm)/ (Changes in acute malnutrition (WHZ) or stunting (HAZ) by arm). The ICER was used to determine the most effective strategy under the cost-effectiveness threshold. The cost-effectiveness threshold was determined using the WHO guidelines on the cost-effectiveness of health interventions where , interventions costing less than 1 GDP per capita are considered very cost-effective while those costing less than 3 GDP per capita are considered cost-effective.

3.5 Dissemination of study findings

The dissertation was submitted to the Faculty of Health Sciences, University of Nairobi, as a partial requirement for the award of the Doctorate in Tropical and Infectious Diseases.

Secondly, dissemination sessions were held with the communities in Laisamis Sub-county in the villages were the data was collected to discuss the findings and recommendations. Dissemination sessions were also held with key partners working around nutrition programming in Kenya as well as technical officers in government from the Ministry of health and Ministry of Agriculture, Livestock and Fisheries both at the county and national levels. In addition, three (3) manuscripts were published in peer-reviewed scientific journals. Lastly, some of the findings were disseminated at scientific conferences.

3.6 Summary of research methods used

The methods above have been summarized as shown in **Table 3.2**.

Table 3.2:Summary of methods, variables, and statistical analysis and tests carried for each of the study objectives

Study design, population and	**Data collection**	**Main outcome data**	**Statistical analysis and tests carried out**
Objective I: systematic review and meta-analysis of published literature on impact of livestock interventions on child nutrition outcomes in sub-Saharan Africa.	Systematic review and meta-analysis following PRISMA guidelines	Summary evidence of key outcomes from publications and reports	Evidence synthesis both qualitative and quantitative synthesis
Objective II: A cluster randomized controlled trial to test the association between livestock interventions and household milk yield, milk consumption and child nutritional status	Interviews using structured questionnaires	• Household milk yield • Milk consumption (amount & frequency) • Child nutritional status	• Descriptive frequencies and proportions • Linear mixed effects models employing the “lme4” package, specifically lmer () function in R • Mixed-effects logistic regression model employing the “lme4” package, specifically glmer () function in R

			• Random coefficient Poisson model using glm () and family = poisson
Objective III: Cross sectional study to estimate the burden of brucellosis, Q -fever and reported human health syndromes in children < 5 years and their effects on child nutritional status	Interviews using structured questionnaires, Biological samples collection and laboratory testing of samples for exposure to brucellosis and Q fever.	• Brucellosis infection status • Q fever infection status • Reported health syndromes (fever, diarrhea, and ARI)	• Indirect ELISA tests carried out to determine exposure to brucellosis and Q-fever • Descriptive frequencies and proportions • Mixed effects logistic regression employing the "lme4" package, specifically glmer () function in R
Objective IV: Economic evaluation study on the costs and cost-effectiveness of livestock interventions in preventing undernutrition in children < 5 years.	Project costs data collected in a provider perspective	Cost-effective ratio of $/WHZ	• Descriptive frequencies and proportions • Cost-effectiveness analysis

3.7 Ethical considerations

3.7.1 Ethics review and ethical conduct

The study protocol, including consent forms and data collection tools, was approved by the University of Nairobi - Kenyatta National Hospital Ethics Review Committee *REF: P850/10/2019* and National Commission for Science, Technology and Innovation (NACOSTI), *License No: NACOSTI/P/23/23513.* Administrative permission to conduct the field study was also sought and obtained from the county government of Marsabit. The ethical principles of scientific research were strictly adhered to, as well as national laws and regulations that applied to this study.

3.7.2 Participant information and consent

All the participants were given full and adequate oral and written information about the nature, purpose, possible risks, and benefits of the study. Participants were notified that they were free to discontinue or leave the study at any time. They were given an adequate opportunity to ask questions and were allowed time to consider the information provided. The study participants signed informed consent was obtained before conducting this study. The study kept the original signed informed consent form, and a copy was given to the participant. All animal owners provided written informed consent before specimen collection. Animal restraint and sampling were conducted in a manner to minimize discomfort to animals and enhance personal safety and were conducted by trained animal health technicians and veterinary surgeons following the World Organization for Animal Health (WOAH) guidelines for use of animals in research and education.

3.7.3 Participant data protection

The study data were stored in a computer database while maintaining confidentiality. Unique enrolment numbers were used to identify participants in this database. The participant identification list was stored separately and included their unique codes, full names, and the latest known addresses.

CHAPTER FOUR: RESULTS

4.1 Results for Objective I: Quantitative assessment of impact of livestock interventions on maternal and child nutritional outcomes in sub-Saharan Africa

Results from this objective have been published and are available in the citation below[1].

4.1.1 Selection of studies

Following the search criteria, a total of 29,450 published articles were retrieved from three databases, PubMed (12,990), Web of Science (16,315), and Scopus (145). A total of 4,799 articles were excluded as duplicates. An additional 24,651 articles were excluded after review of the title and abstracts, and 66 articles after full-text review. Three articles identified from the reference lists of the selected papers were included in the full review. In total, 29 articles were included for qualitative synthesis and their results summarized and presented in summary tables alongside a narrative summary. After assessing homogeneity in reporting metrics, 4 studies qualified for inclusion for quantitative synthesis (meta-analysis). **Figure 4.1** below is a PRISMA flow diagram summarising the study selection process.

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[1] *Muema, J., Mutono, N., Kisaka, S., Ogoti, B., Oyugi, J., Bukania, Z., Daniel, T., Njuguna, J., Kimani, I., Makori, A., Omulo, S., Boyd, E., Osman, A.M., Gwenaelle, L., Jost, C., Thumbi, S., 2023. The impact of livestock interventions on nutritional outcomes of children younger than 5 years old and women in Africa: a systematic review and meta-analysis. Front. Nutr. 10, 1166495. https://doi.org/10.3389/fnut.2023.1166495.*

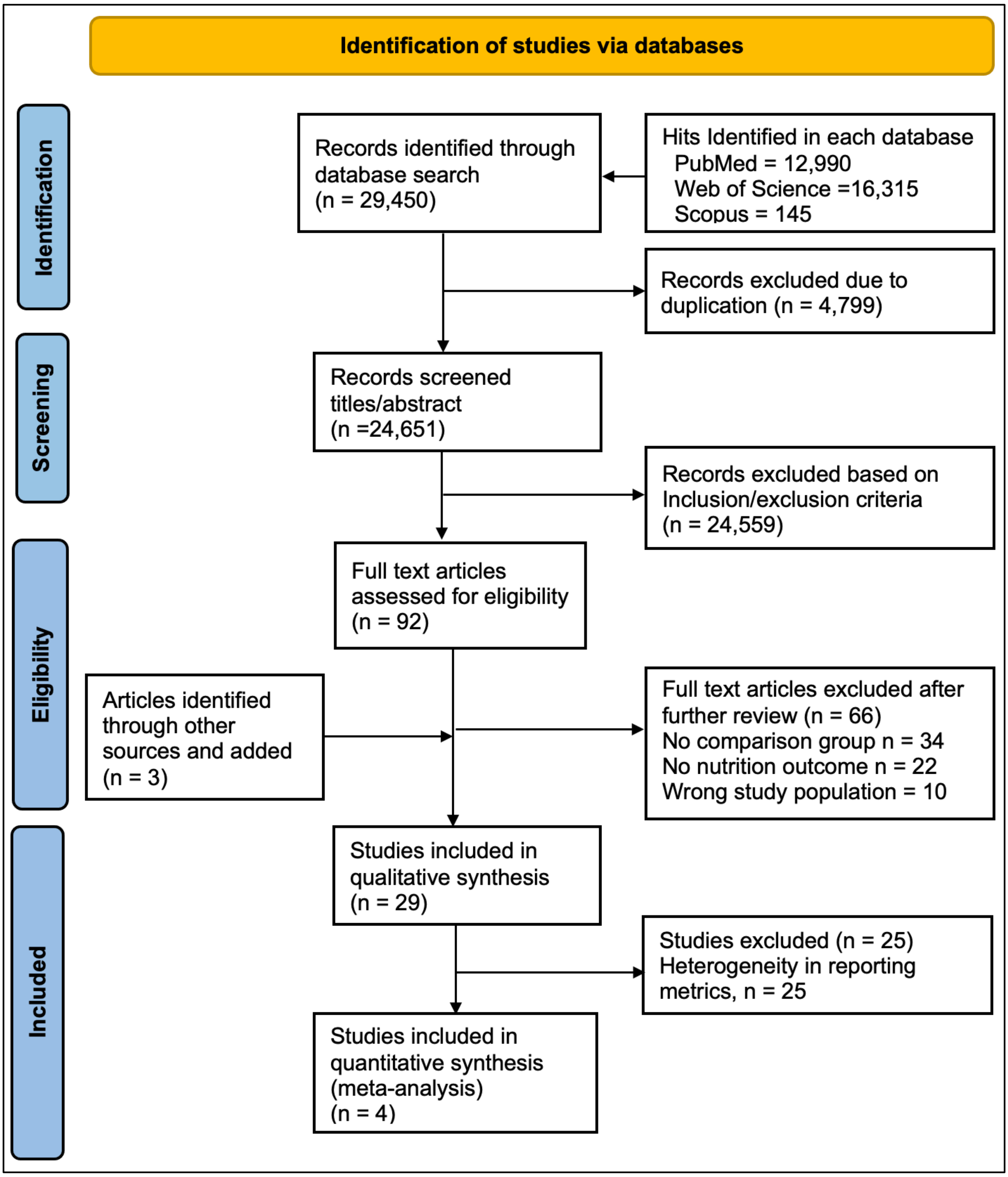

Figure 4.1: PRISMA flow diagram for inclusion of articles (adapted from (Moher et al., 2009)).

4.1.2 Characteristics of selected studies

4.1.2.1 Spatial distribution of publications

The selected publications were on studies conducted in ten African countries. Majority of studies were conducted in Ethiopia (n=8), Malawi (n=7), Kenya (n=5), Uganda (n=3), Rwanda (n=2), Ghana (n=2) and one study each from Zambia, Senegal, Tanzania, and Burkina Faso (Figure 4.2)

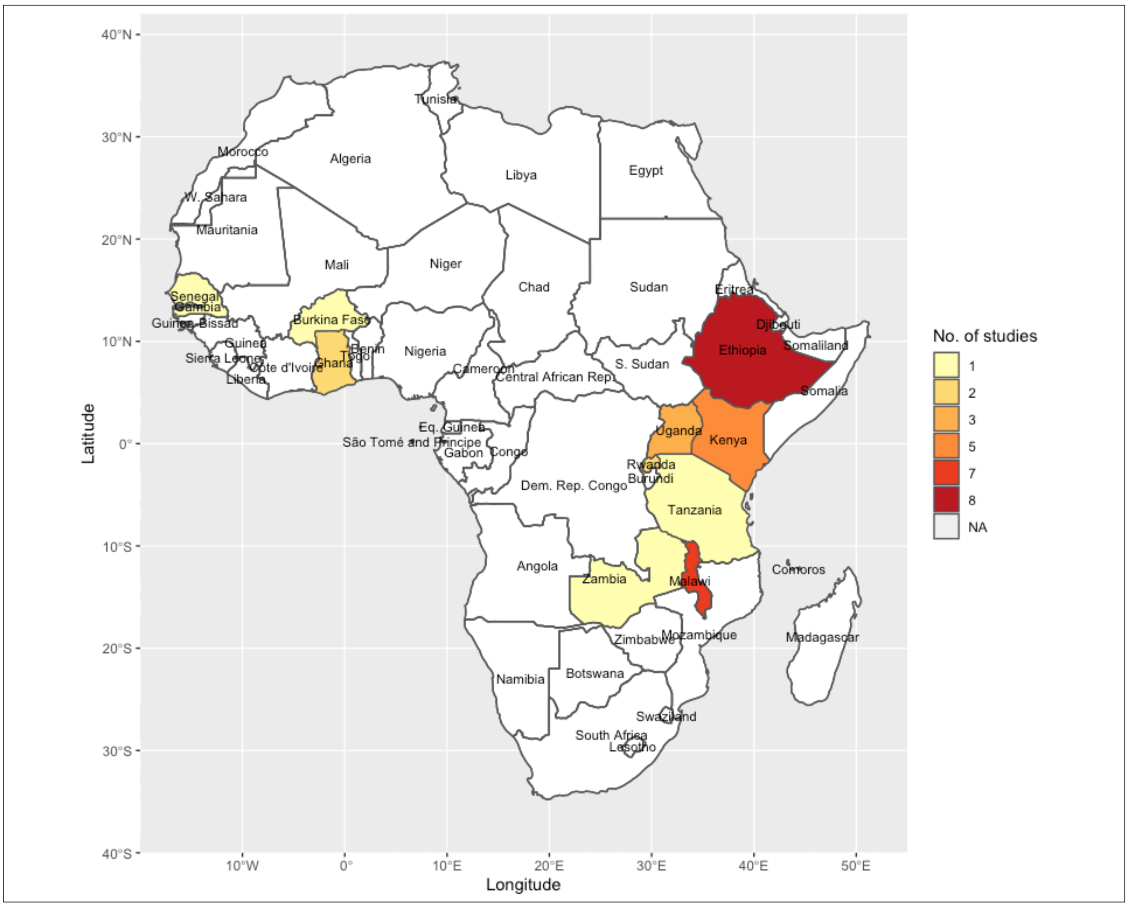

Figure 4. 2: A map of Africa showing the countries where the studies included in the review were conducted and the number of studies in each country.

4.1.2.2 Summary of key study characteristics

Here, a summary of available evidence on the effect of nutrition-sensitive livestock interventions on various nutritional outcomes and the proportion of studies that reported them is provided. Further, a summary of the type of livestock interventions and various study designs employed by the various studies is provided. The key nutritional outcomes identified in the studies reviewed were dietary diversity, consumption of animal source foods (ASFs), haemoglobin concentration and prevalence of anaemia, stunting or HAZ z-scores, wasting or WHZ z-scores, and underweight or WAZ z-scores, with some studies having multiple outcomes. When the reviewed studies were stratified by nutritional outcome measured, 9% (n=5) of the studies reported dietary diversity outcomes (Flax et al., 2021; Lenjiso et al., 2016; Lutter et al., 2021; Marquis et al., 2018; Rawlins et al., 2014), 18% (n=10) measured consumption of animal source foods (Caswell et al., 2021; Dumas, Lewis, et al., 2018; Flax et al., 2021; Hoddinott et al., 2015; Kabunga et al., 2017; 2021; MacDonald et al., 2010; McKune et al., 2020; Otiang et al., 2022; Rawlins et al., 2014; Stewart et al., 2019), 7% (n=4) evaluated HB concentration and prevalence of anaemia (Lambrecht et al., 2021; Le Port et al., 2017; MacDonald et al., 2010; Muleta, Hailu, & Belachew, 2021), 33% (n=18) reported stunting or HAZ z-scores (Argaw et al., 2018; Bierut et al., 2021; Dumas, Lewis, et al., 2018; Headey & Hirvonen, 2016; Hoddinott et al., 2015; Kabunga et al., 2017; Kidoido & Korir, 2015; Lenjiso et al., 2016; Long et al., 2012; MacDonald et al., 2010; Marquis et al., 2018; McKune et al., 2020; E. Mosites et al., 2016; E. M. Mosites et al., 2015; Otiang & Yoder, 2022; Passarelli et al., 2020; Rawlins et al., 2014; Stewart et al., 2019), 15% (n=8) reported on wasting or WHZ z-scores (Kabunga et al., 2017; Kidoido & Korir, 2015; Lenjiso et al., 2016; MacDonald et al., 2010; McKune et al., 2020; Otiang et al., 2022; Rawlins et al., 2014; Stewart et al., 2019) while 18% (n=10) reported on underweight or WAZ z-scores (Aiga et al., 2009; Kabunga et al., 2017; Kidoido & Korir, 2015; Lenjiso et al., 2016; MacDonald et al., 2010; Marquis et al., 2018; McKune et al., 2020; Passarelli et al., 2020; Rawlins et al., 2014; Stewart et al., 2019).

The studies were designed as livestock-oriented programs impact evaluation, nutrition-sensitive dairy value chain interventions, observational studies, and experimental studies. Of the 29 nutrition-sensitive livestock intervention studies reviewed, four papers on livestock-oriented programs and one article on nutrition-sensitive dairy value chain were identified. The programs included interventions to promote and increase access to and consumption of animal source foods. Majority of the livestock-oriented studies involved the evaluation of the impact of livestock donations programs which had been implemented with an aim to increase consumption of nutrient dense animal source foods, improve both household and individual dietary diversity and child nutritional status outcomes in most cases measured by anthropometric indices. Four impact evaluations were reviewed including Heifer international's livestock transfer program in Rwanda (Rawlins et al., 2014), the distribution of small animals through small animal revolving funds in Malawi (MacDonald et al., 2010), the establishment of small-scale egg production centres in Zambia (Dumas, Lewis, et al., 2018) and a dairy goats donation program by Farm Africa in Ethiopia (Kassa et al., 2003).

The search documented only one published study reporting results on the impact of a nutrition-sensitive dairy value chain on child nutrition (Le Port et al., 2017). The study was designed as a cluster randomized controlled trial (cRCT) impact evaluation aimed at testing the effect of using a dairy value chain to distribute micronutrient-fortified yogurt to improve haemoglobin levels (Hb) and reduce iron deficiency anaemia among children from participating dairy farmer households contracted to supply milk to a local dairy firm. Intervention group farmers received micronutrient-fortified yogurt for their children (24 – 59 months-old) and a BCC strategy to improve child Hb concentration and reduce prevalence of anaemia while the control group received BCC only.

Twelve (12) observational studies providing data on the linkages between livestock ownership, consumption of animal source foods and child nutritional outcomes were identified in this review. Of these studies, 4 studies focused on the dairy cow ownership (Hoddinott et al., 2015; Hoorweg et al., 2000; Kabunga et al., 2017; Kidoido & Korir, 2015), 3 studies focused on livestock ownership and health (Headey & Hirvonen, 2016; Lambrecht et al., 2021; Mosites et al., 2016), 2 studies on animal source foods consumption (Muleta, Hailu, & Belachew, 2021; Stoecker, et al., 2021), one study each focused on fish farming (Aiga et al., 2009), analysis of national datasets (Mosites et al., 2015), and milk market participation (Lenjiso et al., 2016).

The search identified 12 experimental studies designed as randomised controlled trials (RCTs) presenting results on the effect of livestock interventions on child nutrition and health outcomes (Table 4.1). Of these studies, seven 7 studies were on the provision of animal source foods in diets (Argaw et al., 2018; Bierut et al., 2021; Caswell et al., 2021; Long et al., 2012; Lutter et al., 2021; Prado et al., 2020; Stewart et al., 2019), 3 studies involved poultry interventions coupled with a training program (Marquis et al., 2018; McKune et al., 2020; Passarelli et al., 2020), 1 study on SBCC intervention on the consumption of animal source foods (Flax et al., 2021) and 1 study was an animal health intervention involving vaccination of chicken against Newcastle disease (Otiang et al., 2021). All the studies were judged as high-quality evidence as they were all randomised controlled trials with counterfactual analysis. The studies were implemented either as livestock intervention only or as livestock intervention and a training program. Training programs were either husbandry training or nutrition and health education. The outcomes of interest evaluated in these studies were mainly animal source foods consumption, dietary diversity, and nutritional status (stunting, wasting and underweight). Some of the studies had more than one intervention component as shown in **Table 4.2** below.

Table 4.2: Summary of key livestock intervention studies on linkages between livestock interventions and nutrition outcomes in children <5 years of age

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
Studies evaluating impact of livestock-oriented programs					
Got Milk? The Impact of Heifer international Livestock donations programs in Rwanda on nutritional outcomes Rawlins et al., 2014, Rwanda.	Cross sectional impact evaluation study in HHs with children < 5 years	Dairy cow and meat goat donation program	• Dietary diversity • Child anthropometry (weight, height/length)	• Increased individual dietary diversity for dairy cow beneficiary HHs. • Increased milk consumption for dairy cow beneficiaries and higher meat consumption for goat beneficiaries.	• Receiving a dairy cow was associated with an average increase of 1.17 food groups consumed. • Marginally statistically significant reductions in WHZ z-scores and WAZ z-scores of about 0.4 SDs for meat goats recipients, and reductions in HAZ z-scores of about 0.5 SDs dairy cows recipients.
Small-animal revolving funds: An innovative programming model to increase access to and consumption of	Cross – sectional surveys to evaluate program effectiveness	Distribution of small animals (goats, rabbits, chickens, and guinea fowls) to rural households accompanied by training on animal	Nutritional status and prevalence of anaemia	Increased access to and consumption of ASFs for the intervention households.	•Egg consumption - increased from 28% at baseline to 52% at endline •Chicken meat consumption increased

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
animal-source foods by rural households in Malawi. MacDonald et al., 2010, Malawi.		husbandry and intensive nutrition education to promote consumption of animal products			from 33% to 58% and goat meat consumption from 13% to 26%. •Stunting reduced from 56% to 40%, underweight from 29% to 13% and wasting from 8% to 2%. •Reduction in anaemia prevalence in pregnant women from 59% to 48%.
Small scale egg production centres increase children's egg consumption in rural Zambia. Dumas et al., 2018, Zambia.	•Repeated cross-sectional design	Establishment of egg production centres – select farmers were given 40 layer hens.	•Children egg consumption •Children nutritional status measured by stunting (HAZ)	•Increased egg consumption in the project area compared to control •No impact on child HAZ	Significant increase in child egg consumption (OR 5.53 95% CI (2.90 - 10.58).
Enhancing the role of livestock production in improving nutritional status of farming families: Lessons from a dairy goat development project in Eastern Ethiopia. Kassa et al., 2003.	•Cross-sectional survey for an intervention – control comparison	Donation of goats (crossbreeds and local breeds) to project beneficiaries in the dairy goat project by Farm Africa in Ethiopia compared to control group	• Nutritional status of children <5years of age	• Increased dairy goat production was not accompanied with better utilisation of foods of animal origin, especially milk.	• No statistically significant differences in the consumption of animal source foods and nutrition status between intervention and control group

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
Ethiopia.					
Nutrition-sensitive value chain interventions					
Delivery of iron-fortified yoghurt, through a dairy value chain program, increases haemoglobin concentration among children 24 to 59 months old in Northern Senegal: A cluster randomized control trial. Le port et al., 2017, Senegal.	•Cluster Randomized control trial (cRCT)	Provision of micronutrient fortified yoghurt (MNFY) and BCC to the intervention group compared to control receiving only BCC. Intervention group: received 1 sachet of MNFY per day for each child 24-59 months old for 7 days. Control group: received BCC only. messages on essential nutrition action (ENA) delivered through group sessions, home visits, community meetings, radio spots).	• Child HB concentration and prevalence of anaemia	• The nutrition-sensitive dairy value chain approach proved to be an effective way to improve Hb in pre-school children.	• Non – significant decrease in anaemia prevalence • Statistically significant greater increase in Hb (+0.55g/dl) in intervention group compared to control group; larger in boys (+0.72) than in girls (+0.38) not significant.
Summary of evidence from observational studies					
Cows, Missing Milk Markets, and Nutrition in Rural Ethiopia. Hoddinott, Headey, and Dereje 2015, Ethiopia.	Cross-sectional	Test the association between cow ownership and child dietary intake and anthropometry comparing HHS owning cows & those without.	•Dairy intake (7-day recall in children 6 - 24 months old). •Child (6-59 months old) anthropometry: HAZ, WHZ stunting.	•Cow ownership associated with greater milk consumption, increased linear growth, and reduces stunting.	Cow ownership associated with greater milk consumption, increase in Height-for-age z-score (HAZ) scores of between 0.25 and 0.47 standard deviations and

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
					reduced probability of stunting by between 6% to 13% for children 12 - 18 moths old but not with WHZ
Does ownership of improved dairy cow breeds improve child nutrition? A pathway analysis for Uganda. Kabunga et al., 2017, Uganda.	Cross-sectional analysis of data from Uganda 2009/2010 national Panel Survey (UNPS).	Breed improvement. Assess the association between adoption of improved dairy cows, milk consumption and child anthropometry	•Nutrition outcome indicators (stunting (HAZ), wasting (WHZ) and underweight (WAZ)). •Milk yield, Own produced milk intake and milk sales	•Improved dairy cow adoption associated with increased milk consumption and reduced stunting (HAZ) but not with underweight (WAZ) and wasting (WHZ).	No quantitative data provided
Do low-income households in Tanzania derive income and nutrition benefits from dairy innovation and dairy production?. Kidoido and Korir 2015., Tanzania.	Cross-sectional analysis of Tanzania LSMS-ISA household panel data of 2008/2009 and 2010/2011.	Test the association between improved dairy production, household income, and child anthropometry	• Child nutritional status - Height-for-age (HAZ), Weight-for-height (WHZ) and Weight -for -age (WAZ) for children 0-60 months old	• Dairy consumption improved child nutritional status (HAZ, WAZ, and WHZ)	• Dairy consumption positively associated with HAZ, WAZ, and WHZ in low-income HHs
Is Exposure to Poultry Harmful to Child Nutrition? An	Cross-sectional exploratory analysis of	Test the associations between household poultry ownership,	• Length or height-for-age Z-scores (HAZ)	• Poultry ownership was associated with	• Poultry ownership is positively associated with child HAZ [β =

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
Observational Analysis for Rural Ethiopia. Headey and Hirvonen 2016, Ethiopia	observational data	exposure of children to poultry in the home, and child anthropometry [child height for-age Z-scores (HAZ)].	• Intermediate outcomes: Dietary diversity and exposure to diseases	improved child height-for – age Z scores (HAZ)	0.291, SE = 0.094]. • Corralling poultry in the household dwelling overnight is negatively associated with HAZ [β = -0.250, SE = 0.118].
The Relationship between Livestock Ownership and Child Stunting in Three Countries in Eastern Africa Using National Survey Data. Mosites et al., 2015, Ethiopia, Kenya, and Uganda	Cross-sectional, analysis of Demographic and Health Survey (DHS) datasets from Ethiopia (2011), Kenya (2008–2009), and Uganda (2010).	Test association between livestock ownership and child stunting. Compare stunting status across levels of livestock ownership.	• Stunting	• Livestock ownership was associated with reduced child stunting prevalence.	• Significant association between livestock ownership with lower stunting prevalence in Ethiopia (Prevalence Ratio [PR] 0.95, 95% CI 0.92–0.98) and Uganda (PR 0.87, 95% CI 0.79–0.97), but not Kenya (PR 1.01, 95% CI 0.96–1.07).
Relations between Household Livestock Ownership, Livestock Disease, and Young Child Growth. Mosites et al., 2016, Kenya.	•Prospective cohort study.	Comparison of child growth (stunting) among households owning livestock and those that didn't own any livestock Test association of livestock ownership, livestock disease, or	• Stunting (HAZ), Wasting (WHZ), annualized child growth rate (cm/year), and mean monthly growth rate	• The study found no association between ownership of livestock and child growth status. However, disease episodes	• Livestock ownership not associated with HAZ, WHZ, or growth rates • Livestock disease associated with growth rates only in some months (June–

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
		both with child anthropometry.		in household livestock may be related to a lower child growth rate in some groups	November) and among children 0–23 months old.
Camel milk consumption is associated with less childhood stunting and underweight than bovine milk in rural pastoral districts of Somali, Ethiopia: a cross-sectional study. Muleta et al., 2021, Ethiopia	•Cross sectional study	To compare the prevalence of growth failures between Camel milk and bovine milk consumers	• child nutritional status - height-for-age, weight-for-age, and weight-for-height z – scores.	• Camel milk consumption was associated with lower prevalence of stunting and underweight than bovine milk.	• Higher proportion of pre-schoolers consuming bovine milk were stunted (72 vs. 28 %; P < 0·001) and underweight (70·1 vs. 29·9 %; P < 0·001) compared with camel milk consumers but not wasting • Severe stunting (76 vs. 24 %; P =0·002), severe wasting (66 vs. 34 %; P = 0·048) and severe underweight (78 vs. 22 %; P <0·001) were observed in bovine milk consumers
Associations between livestock ownership and lower odds of anaemia among	•Cross-sectional study with comparison	Assess the association between household livestock ownership and child anaemia and	• Child anaemia, defined as Hb < 11.0 g/dL for children 6–59	• Livestock ownership was associated with reduced	• Children from households owning cattle, small livestock (goats, sheep, or pigs)

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
children 6–59 months old are not mediated by animal-source food consumption in Ghana. Lambrecht et al., 2021. Ghana	between households who owned livestock and those who didn't	examine whether this relationship is mediated by child ASF consumption or by child morbidity and inflammation	months old	prevalence of anaemia in children. • Consumption of ASFs did not mediate the observed association between livestock ownership and child anaemia	and poultry, had lower odds of anaemia compared with those owning no livestock (OR [95% CI]:0.32 [0.14, 0.71]).
Camel milk consumption was associated with lower prevalence of anaemia among preschool children in rural pastoral districts of Somali, eastern Ethiopia. Muleta et al., 2021 Ethiopia	•Cross-sectional study	Children were selected from random households with lactating camels or cattle.	• Hemoglobin (Hb)	• Camel milk consumption was associated with lower prevalence of anaemia compared with consumption of bovine milk.	•Anaemia (Hb <11 g/dL) was found in 59.8% of the overall sample, whereas it was 42.7% and 75.4% among CaM and BM consumers, respectively. • Children who consumed BM and had intestinal parasites were 3.1 and 3.3 times more likely to be anaemic (aOR 3.12; 95% CI, 1.27-7.66) and (aOR,3.32; 95% CI, 1.39-7.91), respectively, from their counterparts.

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
Malnutrition among children in rural Malawian fish-farming households. H. Aiga et al.,2009 Malawi	•Cross-sectional study	Compare the prevalence of stunting, underweight and wasting among children 6—59 months of age between fish-farming and non-fish-farming households	• Prevalence of malnutrition (stunting, underweight and wasting	• Overall, a lower prevalence of malnutrition was detected among the children in fish-farming households than those in non-fish-farming households in all the malnutrition indicators, i.e., stunting, underweight and wasting	•Significant difference between fish-farming and non-fish farming households was confirmed only in the prevalence of severe underweight (<-3 WAZ) (P = 0.045) and global underweight (<-2 WAZ) (P = 0.042)
Nutrition in agricultural development: Intensive dairy farming by rural smallholders. Hoorweg, Leegwater & Veerman, 2000 Kenya	•Cross-sectional study	comparison of nutrition status among children from dairy farmers, dairy customers, and a rural population children group (not practising dairy farming).	• Nutritional status (height-for-age, weight-for-age, and weight-for-height)	A positive relation between milk consumption and nutritional status of children, independent of household income, energy intake and level of education was confirmed.	•Better Nutritional status (height-for-age, weight-for-age, and weight-for-height) of pre-school children among dairy farmers and dairy customers than in children from the rural population.
Smallholder milk market participation, dietary diversity, and nutritional status among young	Quasi - experimental analysis of survey data for households	Comparison of nutritional status among children from households Participating in smallholder milk	• Dietary diversity • Child anthropometry (wasting, stunting	• Milk market participant households have significantly	• Milk market participant households have a mean dietary diversity

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
children in Ethiopia. Lenjiso et al., 2016 Ethiopia.	participating in smallholder milk markets and non-participants in children < 5 years	market compared to non -participant households	& underweight)	higher levels of dietary diversity of young children • Better child nutritional status in milk market participant households • Milk market participation is associated with higher milk production and household income.	score of 5.3 while non-participants have a score of 4.3. • Children from non-participant households had 11.3 % more likelihood to be wasted, 35% more likelihood to be stunted and 19.8% more likely to be underweight compared children from milk market participant households.
Summary of evidence from experimental studies					
Meat and milk intakes and toddler growth: a comparison feeding intervention of animal-source foods in rural Kenya. Long et al., 2012 Kenya	Cluster randomised controlled trial	Comparison feeding intervention of three groups to examine effect of ASFs on toddlers' growth. Intervention groups included, Plain millet porridge (Plain group), Porridge with milk (Milk group) and porridge with beef (meat group). Red meat in porridge (370 g/day).	• Linear growth (HAZ), MUAC, MAFA, MAMA • Anthropometry (MUAC) measurements	• Better linear growth in milk group • Better nutrition status (MUAC) in milk group than meat group	• Linear growth was significantly greater for the milk group than the meat group (p=0.0025). • Slope of growth of mid -arm muscle area of the plain group was significantly greater than in the meat group (p=0.0046).

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
		Milk in porridge (360 gr/day). Given 5 days/week for 5 months			• Greater MUAC growth rate in milk group than the meat group (p=0.0418).
Effects of n–3 long-chain PUFA supplementation to lactating mothers and their breastfed children on child growth and morbidity: a 2 X 2 factorial randomized controlled trial in rural Ethiopia. Argaw et al., 2018 Ethiopia.	Randomized, double-blind, placebo controlled trial	•Fish oil supplementation. Four different arms. •MCI - lactating mothers and child received fish oil intervention, •MI - lactating mother received fish oil supplementation and child received placebo control. •CI - child received fish oil intervention and mother received placebo control. C - both mother and child received placebo supplement or control	• Linear growth • morbidity and systemic inflammation	Fish oil supplementation had no benefits on linear growth or morbidity.	• No significant intervention effect was found on linear growth, morbidity, or systemic inflammation. • Supplementation given directly to children moderately increased relative weight gain (effect size:0.022/mo 95% CI 0.005 - 0.039/mo)
An agriculture–nutrition intervention improved children's diet and growth in a randomized trial in	Cluster randomized controlled trial	Provision of chicken for egg production and training sessions on poultry production compared to control	• Dietary diversity • Child nutritional status (HAZ, WAZ, WHZ)	Improved dietary diversity and better nutritional status for children in the intervention group	Compared to children in the control group, children in the intervention group met minimum diet diversity

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
Ghana. Marquis et al.,2018 Ghana.		group	• consumption of eggs		(AOR 1.65, 95% CI 1.02 - 2.69) and had higher LAZ/HAZ β=0.22 95% CI 0.09, 0.34) and WAZ (β=0.15 95% CI 0.00 - 0.30)
Impacts of an egg complementary feeding trial on energy intake and dietary diversity in Malawi. Lutter et al., 2021 Malawi.	A randomized controlled trial	Provided an egg a day for 6 months or assigned to a control group	•Dietary diversity •Energy intake	•The intervention resulted in higher dietary diversity and increased percentage of children attaining a minimum dietary diversity cut-off.	80% of children in the egg group met minimum dietary diversity compared to 60% at endline in the control group At midline and endline, usual energy intake from eggs was about 30 kcal/day higher in the egg group compared with controls ($p < 0.0001$ •Egg consumption was more than 9 times in egg group compared to control
The effect of bovine colostrum/egg supplementation compared with corn/soy flour in young Malawian children: a	Prospective, randomized, blinded, placebo controlled clinical trial	•The intervention group received a daily nutritional supplement of BC/egg, and the control group received an isoenergetic supplement of corn/soy	•Primary outcomes were change in length-for-age z-score (Δ LAZ)	•Intervention associated with less linear growth faltering	•Reduced linear growth faltering in intervention group (difference = 0.12 z-scores; P = 0.0011) •Lower prevalence of stunting observed in intervention group (n =

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
randomized, controlled clinical trial. Bierut et al., 2021 Malawi		flour from the ages of 9 to 12 months Both groups received multiple micronutrients			47/137) compared to control group (n = 62/127) at 17 months (RR = 0.70; 95% CI: 0.52, 0.94).
Animal Source Food Social and Behaviour Change Communication Intervention Among Girinka Livestock Transfer Beneficiaries in Rwanda: A Cluster Randomized Evaluation. Flax et al., 2021 Rwanda.	A Cluster Randomized trial	•SBCC intervention to promote the consumption of ASFs, especially cow's milk, in households that had received a cow from the Girinka program.	•Dietary diversity - minimum dietary diversity (consumption of ≥4 food groups in the past 24 hours) • Milk consumption in the past 24 hours	•No significant differences between intervention and control group on diet diversity •Increased milk consumption in children in intervention group compared to control	• Increased milk consumption in intervention compared to control group (OR 2.1, 95%CI 1.1, 3.9)
Early Child Development Outcomes of a Randomized Trial Providing 1 Egg Per Day to Children Aged 6 to 15 Months in Malawi. Prado et al., 2020 Malawi	Individually randomized controlled trial	•Provision of 1 egg per day for the intervention group child during twice-weekly home visits for 6 months. •Control group visited twice per week and received messages about hygiene and handwashing during food preparation but	Effect of intervention on child development	The provision of 1 egg per day had no overall effect on child development in this population of children	Intervention and control groups did not significantly differ in any developmental score, with the exception that a smaller percentage of children were delayed in fine motor development in the intervention group (10.6%) compared with

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
		did not receive eggs or any other foods during the study period.			the control group (16.5%; prevalence ratio: 0.59, 95% CI: 0.38–0.91).
A Chicken Production Intervention and Additional Nutrition Behaviour Change Component Increased Child Growth in Ethiopia: A Cluster-Randomized Trial. Passarelli et al.,2020. Ethiopia	•A cluster randomized control trial	Provision of genetically improved chicken and nutrition-sensitive behaviour change communication. Control group received no intervention.	•Height-for-age z scores (HAZ), weight-for-age z scores (WAZ), and weight-for-height z scores (WHZ)	•The intervention improved HAZ and WAZ compared to control •Improved dietary diversity	The intervention group had higher HAZ (MD: 0.28; 95% CI: 0.05, 0.50) and WAZ (MD: 0.18; 95% CI: 0.01, 0.36) compared to control but not statistically significant.
Burkina Faso. Behaviour Change, Egg Consumption, and Child Nutrition: A Cluster Randomized Controlled Trial. McKune et al., 2020.	Cluster randomized controlled trial	•Each child in the full intervention arm received 4 chickens (3 gifted by community champion & 1 from child family), and mothers received the 10-month behaviour change package •Participants in the partial intervention arm received only the behaviour change package	•Primary outcome: Child egg consumption •Secondary outcome: poultry production, women empowerment, and anthropometric indices	•Both full and partial interventions Significantly Increased egg consumption compared to control group •Intervention had no statistically significant effect on child stunting	•Full intervention significantly increased poultry production (β= 11.6; 95% CI 8.3–15; P =1.1 3 1025) and women's decision-making about eggs (β = .66; P = .02), and significantly decreased wasting ((β = .58; P = .03) and underweight ((β = .47; P =0.02).
The effect of eggs on early child growth in	Individually randomized	Provision of one egg per day or assigned to	Child linear growth	•Increased egg consumption in	•No intervention effect on length-for-age,

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
rural Malawi: The Mazira Project randomized controlled trial. Stewart et al., 2019 Malawi	controlled trial	control group. Eggs were provided during twice-weekly home visits for 6 months. Control households were visited at the same frequency		intervention group compared the control group •The provision of 1 egg per day to children in rural Malawi had no overall effect on linear growth	weight-for-age, or weight-for-length z scores •Significantly higher head circumference for age z score of 0.18 (95% CI: 0.01, 0.34) in intervention compared to control group.
Impacts of an egg intervention on nutrient adequacy among young Malawian children Impacts of an egg intervention on nutrient adequacy among young Malawian children Impacts of an egg intervention on nutrient adequacy among young Malawian children. Caswell et al., 2021 Malawi.	a randomized controlled trial	Provision of an egg per day to children 6 – 15 months	•Nutrient intake adequacy and micronutrient density.	•Higher Nutrient intake adequacy and micronutrient density in the intervention group.	
Vaccination of household chickens results in a shift in	Randomized controlled trial	Quarterly Vaccination of chickens against Newcastle Disease Virus	•Consumption of ASFs •Child growth	•The intervention increased consumption of	•Increased consumption of ASFs (24% increase) by children in the

Study tile/Author(s), country	Study design	Livestock intervention/study objective	Main outcome measure(s)	Key qualitative findings	Key quantitative findings (effect sizes)
young children's diet and improves child growth in rural Kenya. Otiang et al 2022 Kenya		(NDV) plus parasite control for the intervention arm while the control arm received parasite control only		ASFs and improved children's HAZ and WHZ	intervention households compared to control group •Overall increase in both HAZ and WHZ z-scores in the intervention group relative to control group.

4.1.2.3 Summary of quantitative results (meta-analysis)

Four (4) nutrition-sensitive livestock interventions articles were included in the meta-analysis. Majority were poultry related livestock interventions and included additional component of training on either health and nutrition behaviour change communication or livestock husbandry training as shown in **Table 4.3** below.

Table 4.3: Intervention components of nutrition-sensitive livestock interventions included in the meta-analysis.

Study, Country(reference)	**Study design**	**Intervention component**			
		Inputs		Training	
		Poultry/eggs	Livestock	Health/nutrition BCC	Livestock husbandry
Marquis et al.,2018 Ghana	cRCT	X		X	X
Flax et al., 2021 Rwanda	cRCT		X	X	
Stewart et al., 2019 Malawi	RCT	X		X	
Lutter et al., 2021 Malawi	RCT	X			

cRCT – cluster randomized controlled trial, BCC – behavior change communication.

4.1.2.3.1 Pooled effect estimates

Pooled effects of nutrition-sensitive livestock interventions on consumption of ASFs and MDD outcomes in children <5 years of age were estimated. Nutrition–sensitive livestock interventions have a significantly positive effect on consumption of ASFs when compared to controls (OR = 5.39, 95% CI = 4.43 - 6.56). However, a substantial heterogeneity between the studies was detected $I^2 = 98\%$, $p = <0.00001$ as shown in **Figure 4.3** below.

Study or Subgroup	Livestock Intervention Events	Livestock Intervention Total	Control Events	Control Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Flax 2021	91	223	80	219	51.6%	1.20 [0.82, 1.76]
Lutter 2021	205	290	22	305	6.8%	31.02 [18.78, 51.26]
Marquis 2018	78	247	41	181	34.9%	1.58 [1.02, 2.45]
Stewart 2019	206	290	22	305	6.7%	31.55 [19.09, 52.14]
Total (95% CI)		**1050**		**1010**	**100.0%**	**5.39 [4.43, 6.56]**
Total events	580		165			

Heterogeneity: $Chi^2 = 183.36, df = 3 (P < 0.00001); I^2 = 98\%$
Test for overall effect: $Z = 16.80 (P < 0.00001)$

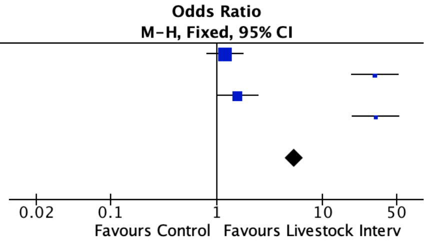

Figure 4.3: Forest plot showing effect of nutrition–sensitive livestock interventions on consumption of ASFs in children <5years of age

Additionally, nutrition-sensitive livestock interventions were associated with an 89% increase in the likelihood of children aged < 5 years attaining minimum dietary diversity (OR = 1.89, 95% CI = 1.51 - 2.37). Moderate heterogeneity was reported for this sub-group with the I^2 proportion being 74% as indicated in **Figure 4.4** below.

Study or Subgroup	Livestock Intervention Events	Livestock Intervention Total	Control Events	Control Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Flax 2021	105	223	88	219	42.4%	1.32 [0.91, 1.93]
Lutter 2021	233	290	182	305	31.5%	2.76 [1.91, 4.00]
Marquis 2018	198	247	126	181	26.1%	1.76 [1.13, 2.75]
Total (95% CI)		**760**		**705**	**100.0%**	**1.89 [1.51, 2.37]**
Total events	536		396			

Heterogeneity: $Chi^2 = 7.57, df = 2 (P = 0.02); I^2 = 74\%$
Test for overall effect: $Z = 5.55 (P < 0.00001)$

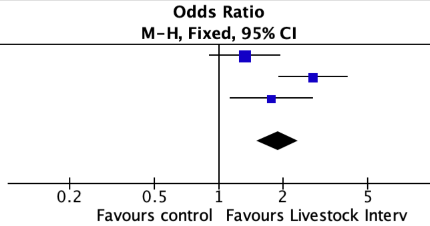

Figure 4.4: Forest plot showing effect of nutrition–sensitive livestock interventions on attaining Minimum Dietary Diversity in children <5 years of age

4.1.2.3.2 Rating quality of evidence

Based on GRADE quality of evidence assessment approach, the overall quality of evidence of this review was rated low, mainly due to limitations of performance, inconsistency, and selection biases, for more details see **Table 4.4**.

Table 4.4: GRADE rating of the quality of evidence

Certainty assessment							№ of participants		Effect		Certainty	Importance
№ of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**Livestock interventions**	**Control**	**Relative (95% CI)**	**Absolute (95% CI)**		
ASFs consumption (follow-up: mean 12 months)												
4	randomised trials	not serious	serious[a]	not serious	serious[b]	not serious	580/1050 (55.2%)	165/1010 (16.3%)	**OR 5.39** (4.43 to 6.56)	**349 more per 1,000** (from 300 more to 398 more)	⊕⊕◯◯ Low	IMPORTANT
Minimum Dietary Diversity (MDD) (follow-up: mean 12 months)												
3	randomised trials	not serious	serious[c]	not serious	serious[b]	not serious	536/760 (70.5%)	396/705 (56.2%)	**OR 1.89** (1.51 to 2.37)	**146 more per 1,000** (from 98 more to 191 more)	⊕⊕◯◯ Low	IMPORTANT

CI: confidence interval; **OR:** odds ratio
Explanations
a. High levels of heterogeneity of the study results
b. Small sample sizes and wide confidence intervals
c. Moderate level of heterogeneity in study results

4.2 Results for Objective II: Determination of the effect of providing livestock feeds to milking animals during drought periods and nutrition counselling on milk yield, milk consumption and undernutrition in women and children below five years in Marsabit County, Kenya

4.2.1 Baseline household socio-demographic characteristics

4.2.1.1 Study population demographic characteristics

A total of 1734 households were recruited and participated in the baseline survey. The average household size was 6 people, with 49% of the household members being female and a majority of the households (87%) being headed by males. Only 7% of the household heads reported having had formal education. The main occupation for most household heads (88%) was livestock herding as shown in Table 4.5.

Table 4.5: Study population baseline household socio-demographic characteristics

Variable	Overall N	Intervention Arm 1, n%	Intervention Arm 2, n%	Control, n%
No. of households recruited	1734	639	585	510
Study participants recruited				
Children	1748	599	564	585
Women	1734	639	585	510
Age distribution (child)				
< 6 months	272 (16%)	102 (17%)	92 (16%)	78 (13%)
6 – 23 months	1009(58%)	361 (60%)	346 (61%)	302 (52%)
24 – 36 months	367 (21%)	136 (23%)	126 (22%)	105 (18%)
Gender (child)				
Female	858 (49%)	312 (52%)	278 (49%)	268 (46%)
Male	890 (51%)	287 (48%)	286 (51%)	317 (54%)
Household head Gender				
Female	234 (13%)	70 (11%)	92 (16%)	72 (14%)
Male	1500 (87%)	569 (89%)	494 (84%)	438 (86%)
Household head formal education				
Yes	127 (7%)	25 (4%)	43 (7%)	59 (12%)
No	1607 (93%)	614 (96%)	542 (93%)	451 (88%)
Household head education status				
Not completed primary school	46 (3%)	10 (2%)	19 (3%)	17 (3%)
Primary school	18 (1%)	4 (1%)	5 (1%)	9 (2%)
Secondary school	40 (2%)	8 (1%)	10 (2%)	22 (4%)
College graduate	23 (1%)	3 (1%)	9 (2%)	11 (2%)
Household head main occupation				
Livestock herding	1533 (88%)	595 (93%)	509 (87%)	429 (84%)
Employment	74 (4%)	19 (3%)	19 (3%)	36 (7%)
Casual labour	56 (3%)	8 (1%)	25 (4%)	23 (5%)
Trader/ business	67 (4%)	16 (3%)	30 (5%)	21 (4%)
Firewood/charcoal	4 (0%)	1 (0%)	2 (0%)	1 (0%)

4.2.1.2 Household livestock ownership demographics

Households owned cattle, goats, sheep, camels, donkeys, and chicken. All households owned at least one livestock species with ownership of goats at 96%, sheep (92%), camels (68%), cattle (43%), donkeys (60%) and chicken (13%). On average, the households had three camels, seven goats, six sheep and three cattle. Participants under the three study arms had similar average number of animals by species owned with no statistical differences in ownership by study arms, see details in **Table 4.6** below.

Table 4.6: Household livestock ownership per species and study arm at baseline

Species	**All species N (%)**	**Intervention Arm 1 n (%)**	**Intervention Arm 2 n (%)**	**Control n (%)**
Cattle	5,294 (43%)	2,027 (47%)	2,456 (47%)	811 (32%)
Goats	30,723 (96%)	12,710 (97%)	10,564 (96%)	7,449 (95%)
Sheep	27,477 (92%)	11,238 (95%)	9,796 (92%)	6,443 (89%)
Camels	10,113 (68%)	4,612 (82%)	3,249 (59%)	2,252 (61%)
Donkeys	1,490 (60%)	625 (66%)	515 (61%)	350 (52%
Chicken	760 (13%)	237 (11%)	301 (15%)	222 (13%)

4.2.1.3 Household average amount of milk produced per species and hygiene practices at baseline

All study households had milking animals. A majority of them had milking goats (81%) while 24% had sheep, 19% camels and 2% cows. The average milk produced per animal was highest among cows and camels at 1.16 and 1.14 litres/day respectively. Goats and sheep produced 0.22 and 0.2 litres per animal/day respectively, see **Table 4.7**. Nearly all the households (99%) produced milk for home consumption, with 19% of the households also selling milk. No statistically significant differences were found in milk production per species between the study arms (p value > 0.05). The main practice in storing milk was the use of gourds (99%) of the households, with the remaining proportion reporting the use of aluminium cups and plastic containers. Before milking, 65% of the participants reported that they washed hands, 27% washed the milking container and 1% washed the animal teats. Some of the participants did not report conducting any hygiene practices before the milking process (14%). On average, the households stored milk for six hours and was stored in form of fresh raw milk (95%), boiled milk (5%) and sour milk (<1%).

Table 4.7: Average amount of milk produced per species per day at recruitment

	All recruited households			
	Species			
Parameter	Cows	Camels	Sheep	Goats
No. of animals being milked	88	2024	3600	6220
Proportion of households with animals being milked	2%	19%	24%	81%
Average milk produced (litres/animal)	1.16	1.14	0.20	0.22

4.2.1.4 Study participants' consumption of animal source foods at baseline

In 24 hours prior to administering the study questionnaire, 96% and 58% of the women and the children <3 years had consumed milk, respectively. The women consumed milk mainly in form of tea (86%), or fresh raw milk (16%), or boiled milk (12%). For children <3 years, 71% had consumed milk in tea, 24% fresh raw milk, and 20% boiled milk. For children below 6 months, 90% were exclusively breastfed, with the rest receiving complementary feeding with animal milk (4%), and non-milk liquids (6%). The average daily milk intake was 693ml and 553ml for women and children < 3 years respectively as shown in **Table 4.8** below. Consumption of meat and eggs was low with only 8% and 1% of the women, and 4% and 1% of children reporting to have consumed meat and eggs respectively.

Table 4.8: Milk consumption from a 24-hour recall survey for study participants at baseline survey stratified by study arm

Indicator	Total N	Intervention arm 1	Intervention arm 2	Control
Milk intake by children <3 years				
Yes	1021 (58%)	333 (56%)	344 (61%)	344 (59%)
No	727 (42%)	266 (44%)	220 (39%)	241 (41%)
Milk intake by pregnant/lactating women				
Yes	1673 (96%)	607 (95%)	573 (98%)	493 (97%)
No	61 (4%)	32 (5%)	12 (2%)	17 (3%)
Frequency of milk intake per day				
Children <3 years	2	2	2	2
Pregnant/lactating women	2	2	2	2
Average daily milk intake (ml)				
Children <3 years	553	570	535	552
Pregnant/lactating women	693	708	707	652
Forms of milk consumed by children <3 years				
Boiled milk	203 (20%)	99 (30%)	55 (16%)	49 (14%)
Fresh (raw) milk	424 (41%)	123 (37%)	151 (44%)	150 (43%)
Tea	724 (71%)	219 (66%)	225 (65%)	280 (81%)
Forms of milk consumed by pregnant/lactating women				
Boiled milk	211 (12%)	142 (23%)	48 (8%)	21 (4%)
Fresh (raw) milk	271 (16%)	84 (13%)	83 (14%)	104 (21%)
Tea	1440 (86%)	447 (74%)	515 (90%)	478 (97%)

4.2.1.5 Nutrition status of women and children at baseline

The nutrition status of women was monitored through measurement of the mid-upper arm circumference (MUAC). The study did not collect height measurements for the women. Of the 1734 women recruited in the study, the prevalence of moderate acute malnutrition was 14% (236 women) and that of severe acute malnutrition was 0.1% (2 women). Among the 1748 children recruited into the study, 459 (26%) had global acute malnutrition (GAM) with 424 (24%) of the children having moderate acute malnutrition (MAM) and 35 (2%) having severe acute malnutrition (SAM). The prevalence of stunting was high with 265 (15%) and 362 (21%) of the children in the study classified as moderately and severely stunted respectively. The prevalence of underweight was 29% (505 children). The summary baseline nutritional status data is provided in **Table 4.9** below.

Table 4.9: Baseline nutritional status of the women and children recruited into the study by gender and study arm

		Intervention arm 1			Intervention arm 2			Control		
Outcome	Total N(%)	Female	Male	Total n (%)	Female	Male	Total n (%)	Female	Male	Total n (%)
Children <3 years	1748	312 (52%)	287 (48%)	599	278 (49%)	286 (51%)	564	268 (46%)	317 (54%)	585
Weight-for-Height (Wasting)[1]										
Moderate acute Malnutrition[2]	424 (24%)	88 (28%)	65 (23%)	153 (26%)	74 (27%)	65 (23%)	139 (25%)	66 (25%)	66 (21%)	132 (23%)
Severe acute Malnutrition[3]	35 (2%)	6 (2%)	10 (3%)	16 (3%)	2 (1%)	4 (1%)	6 (1%)	5 (2%)	8 (3%)	13 (2%)
Height-for-age (stunting)										
Moderate stunting[4]	265 (15%)	55 (18%)	55 (19%)	110 (18%)	38 (14%)	46 (16%)	84 (15%)	26 (10%)	45 (14%)	71 (12%)
Severe stunting[5]	362 (21%)	68 (22%)	53 (18%)	121 (20%)	59 (21%)	70 (24%)	129 (23%)	53 (20%)	59 (19%)	112 (19%)
Weight-for-Age (underweight)[6]	505 (29%)	67 (21%)	99 (34%)	172 (29%)	81 (29%)	86 (30%)	167 (30%)	67 (25%)	99 (31%)	166 (28%)
PLW moderate malnutrition[7]	236 (14%)	96 (31%)		96 (16%)	79 (28%)		79 (14%)	61 (23%)		61 (10%)
PLW severe malnutrition[8]	2 (0%)	1 (0%)		1 (0%)	1 (0%)		1 (0%)	0		0

[1] <=2SD of the WHO child growth standards median
[2] <=3 SD of the WHO child growth standards median or MUAC of <=11.5 cm
[3] <=2 SD of the WHO child growth standards median or MUAC of >11.5 AND <=12.5 cm
[4] <=2 SD of the WHO child growth standards median
[5] 2 SD to 3 SD of the WHO child growth standards median
[6] <=3 SD of the WHO child growth standards median
[7] <= 2 SD of the WHO child growth standards median
[8] MUAC of 17.0 cm to 21.0 cm
[9] MUAC of <17.0 cm

4.2.2 Longitudinal follow - up results on the effect of providing livestock feed and nutrition counselling on milk yield, milk consumption and undernutrition in children <5 years

4.2.2.1 Number of milking animals (TLUs) retained at the household level

The animals selected by the households comprised goats (98%, 1597 TLUs), sheep (66%, 733 TLUs), cows (5%, 141 TLUs) and camels (1%, 28 TLUs). Some households combined species for the TLU's selection, with the highest combination comprising of small ruminants (sheep and goats), followed by sheep and cows as shown in **Figure 4.5** below.

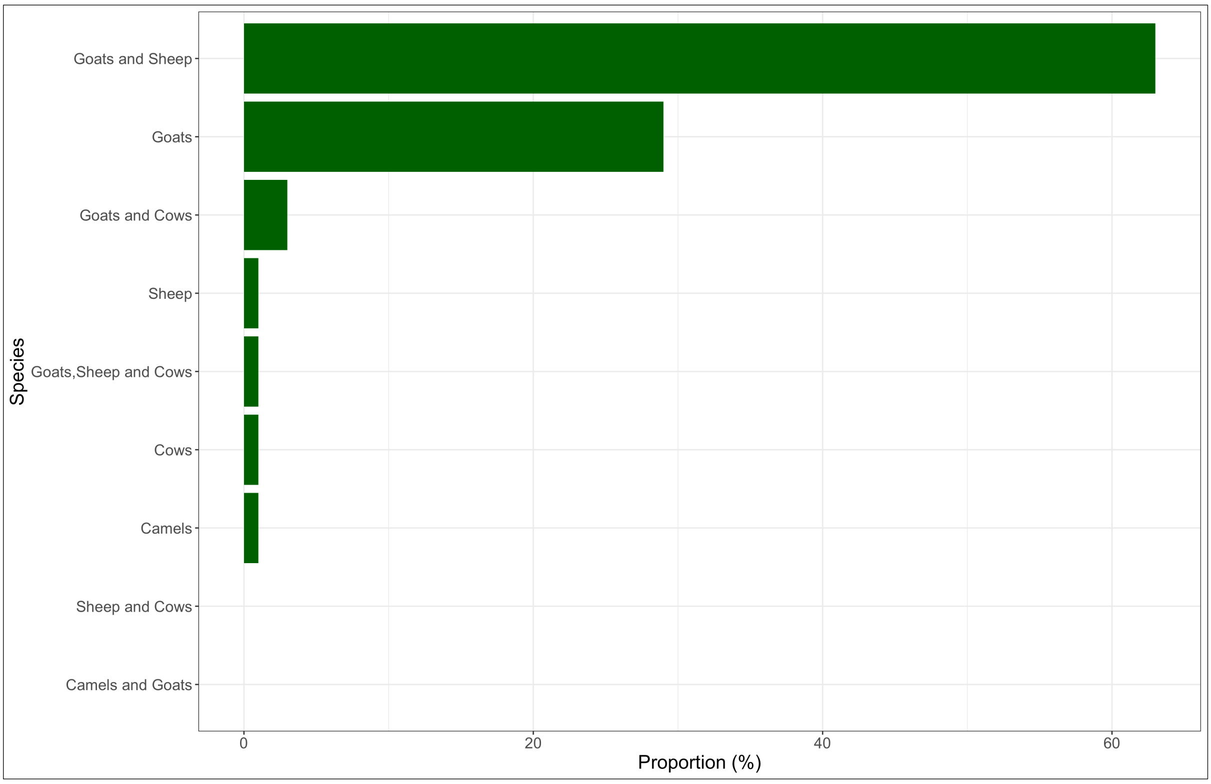

Figure 4.5: Proportion of animal species selected by the study households for the intervention

Although the study required each household to retain two tropical livestock units, the number of milking animals retained at the household to provide milk to the households varied by study intervention arm. At baseline, there was no statistically significant difference in the number of milking animals retained at the household level (p value = 0.095). Intervention arm households sustained more milking animals; 1.4 and 0.6 more TLUs) for arm 1 and 2 respectively compared to control as shown in **Table 4.10** below.

Table 4.10: Average number of tropical livestock units of milking animals maintained at household level

Season of the year	Intervention arm 1	Intervention arm 2	Control	*P value*
Season 1 (Baseline)	3.6	3.3	3.3	0.095
Non-dry season	3.5	2.4	2.4	<0.001
Dry season	3.4	2.6	2.0	<0.001
Average	3.4	2.5	2.3	<0.001

4.2.2.2 Average household milk yield per intervention arm

While controlling for herd sizes, births, veterinary interventions, household incomes, provision of livestock feeding during dry periods was consistently associated with higher milk production at the household level both during the dry season and non-dry season when compared to the control group. Compared to the control group, intervention households recorded higher milk yield per day (1.6L vs 0.7L, $p < 0.001$), representing 129% more milk production as shown in **Table 4.11** below.

Table 4.11: Average household milk production per day stratified by study arm

Season of the year	Intervention Arm 1	Intervention arm 2	Control	*P value*
Non-dry season	1.5	1.3	0.9	<0.001
Dry season	1.6	1.3	0.7	<0.001

4.2.2.3 Factors associated with average household milk yield

The results of the multivariable model assessing determinants of household milk yield indicated household milk yield was significantly associated with receiving livestock feeds (β=0.20, 95% CI [0.12, 0.31]), milking TLUs maintained (β=0.60, 95% CI [0.59, 0.61]), seeking veterinary care for sick animals (β=0.19, 95% CI [0.15, 0.24), and number of livestock births (β=0.07, 95% CI [0.06, 0.80]) as shown in **Table 4.12** below.

Table 4.12: Factors associated with average household milk yield

Parameter	Univariate analysis (95% CI)	Multivariate analysis (95% CI)
Household size	0.15 (0.10 – 0.20)	0.03 (-0.03 – 0.09)
Cash transfer program	-0.88 (-1.22 - -0.53)	-0.12 (-0.52 – 0.29)
Milk TLU's maintained	0.62 (0.61– 0.63)	0.60 (0.59– 0.61)
Number of livestock births	0.23 (0.21 – 0.24)	0.07 (0.06 – 0.80)
Number of non-milked TLUs maintained	0.005 (0.004 – 0.005)	0.001 (0.001 – 0.001)
Received livestock feeds	0.63 (0.42 – 0.84)	0.20 (0.12 – 0.31)
Received feeds + nutrition counselling	0.19 (-0.14 – 0.51)	
Sought veterinary care	0.97 (0.90 – 1.04)	0.19 (0.15 – 0.24)
Socio-economic Index		
Quantile 1 (Richest)	-0.29 (-3.91 - 3.34)	
Quantile 2	-0.32 (-3.94 - 3.31)	
Quantile 3	-0.27 (-3.89 – 3.52)	
Quantile 4	-1.28 (-4.92 – 2.34)	
Quantile 5 (Poorest)	Ref	
Household head main occupation		
Livestock herding	1.37 (1.02 -1.72)	0.09 (-0.20 - 0.22)
Non-livestock herding	Ref	

4.2.2.4 Average daily milk consumption by children <5 years and mothers

Nutrition counselling was provided to households in intervention arm 2 by trained community health volunteers. At any point during the follow-up data collection visits, on average, 40% of the households in intervention arm 2 reported having received nutritional counselling, see **Figure 4.6** below.

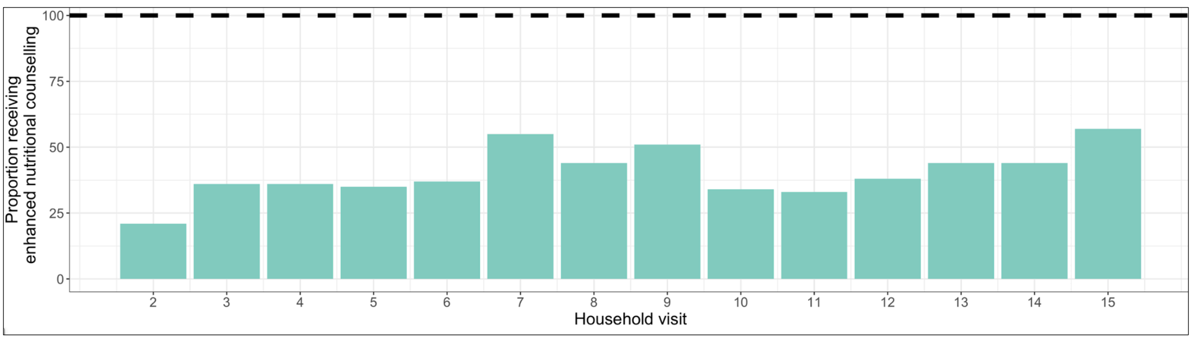

Figure 4.6: Proportion of households in intervention arm 2 who received nutritional counselling at any given data collection follow-up visit

The targeted counselling followed Maternal, Infant, and Young Child Nutrition (MIYCN) guidelines. Most of the households received counselling on hygiene (29%), followed by breastfeeding (21%), maternal nutrition (18%) while the least was on iron folic acid supplementation where only 3% of the households received the counselling as shown in **Figure 4.7** below.

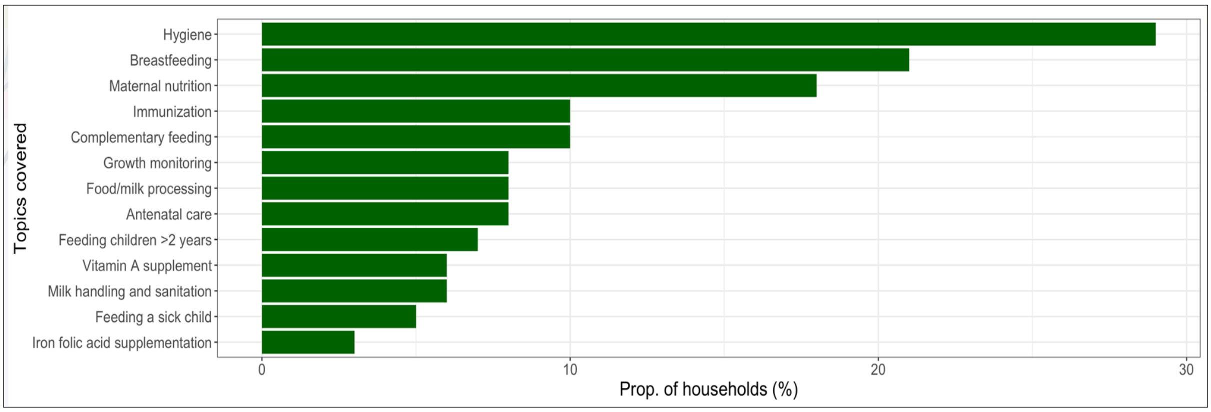

Figure 4.7: Topics covered during nutrition counselling sessions and proportion of households received per topic.

While controlling for household milk TLUs, milk yield (in litres), milk storage, household size and the socio-economic index children and mothers in households receiving livestock feed during dry seasons and enhanced nutritional counseling consistently consumed more milk compared to those in the control arm. Households that receive livestock feeds, maintained milk consumption during both dry and non-dry seasons. Compared with children in control group, children in intervention arm 1 (received livestock feeds) consumed an average of 200mL (58%) more milk per day while those from intervention arm 2 (received livestock feeds and nutrition counselling) consumed an average of 240mL (70%) more milk per day. Mothers in households receiving livestock feeding consumed an average of 210 mL (133%) more milk per day, compared to those in the control arm.

4.2.2.5 Factors associated with milk consumption (amount and frequency) among children < 5 years.

Milk consumption in children was significantly associated with, receiving livestock feeds (β=0.20, 95% CI [0.12, 0.28]), enhanced nutrition counselling (β=0.04, 95% CI [0.01, 0.07]), number of milking TLUs maintained at the household (β=0.08, 95% CI [0.01, 0.15]), and household milk yield (β=0.05, 95% CI [0.04, 0.06]) as shown in **Table 4.13** below.

Table 4.13: Factors associated with milk consumption among children <5 years

Parameter	Univariate (95% CI)	Multivariate (95% CI)
Feed received	0.31 (0.26 – 0.35)	0.20 (0.12 – 0.28)
Enhanced counselling	0.11 (0.04 – 0.18)	0.04 (0.01 – 0.07)
Milk TLU	0.20 (0.19– 0.22)	0.08 (0.01 – 0.15)
Milk yield (litres)	0.03 (0.03– 0.04)	0.05 (0.04 – 0.06)
Milk storage (hours)	0.03 (0.03 – 0.04)	-0.004 (-0.02 – 0.009)
Household size	0.08 (0.06 – 0.09)	-0.001 (-0.03 – 0.03)
Cash transfer program	-0.52 (-0.61 – -0.44)	-0.17 (-0.38 – 0.04)
Socio-economic Index		
- Quantile 1 (Highest)	0.02 (0.05 – 0.32)	0.05 (-0.10 – 0.21)
- Quantile 2	0.16 (-0.004 – 0.32)	-0.03 (-0.19 – 0.12)
- Quantile 3	0.21 (0.05 – 0.37)	0.05 (-0.10 – 0.20)
- Quantile 4	0.18 (0.02 – 0.33)	-0.01 (-0.16 – 0.14)
- Quantile 5 (Lowest)	Ref	Ref
Household head education		
- Formal schooling	-0.04 (-0.11 – 0.03)	0.09 (-0.20 -0.22)
- No formal schooling	Ref	
Gender of household head		
- Male	-0.002 (-0.05 – 0.04)	
- Female	Ref	
Household head main occupation		
- Livestock herding	-0.04 (-0.09 – 0.01)	-0.22 (-0.42 - -0.02)
- Non-livestock herding	Ref	

Higher frequency of milk consumption among children < 5 years old was associated with households receiving livestock feed (β=1.16, 95% CI [1.07, 1.26]), number of milk TLUs retained in the household (β=1.06, 95% CI [1.03, 1.09]), amount of household milk yield (β=1.04, 95% CI [1.03, 1.04]), milk storage in hours (β=1.01, 95% CI [1.0, 1.02]), household size and the health status of the child as shown in **Table 4.14** below.

Table 4.14: Factors associated with frequency of milk consumption among children <5 years

Parameter	Univariate (95% CI)	Multivariate (95% CI)
Feed received	1.10 (1.03 – 1.17)	1.16 (1.07 – 1.26)
Enhanced counselling	0.98 (0.89 – 1.07)	
Milk TLU	1.20 (1.19– 1.21)	1.06 (1.03 – 1.09)
Milk yield (litres)	1.04 (1.035– 1.04)	1.04 (1.03 – 1.04)
Milk storage (hours)	1.03 (1.02 – 1.03)	1.01 (1.00 – 1.02)
Household size	1.08 (1.06 – 1.09)	1.03 (1.01 – 1.06)
Cash transfer program	0.64 (0.58 – 0.70)	0.98 (0.82 – 1.18)
Socio-economic Index		
- Quantile 1 (Highest)	1.61 (0.84 – 3.11)	
- Quantile 2	1.67 (0.86 – 3.23)	
- Quantile 3	1.58 (0.82 – 3.05)	
- Quantile 4	1.48 (0.77 – 2.86)	
- Quantile 5 (Lowest)	Ref	
Education of the household head		
- Formal education	1.01 (0.87 – 1.17)	
- No formal education	Ref	
Gender of household head		
- Male	0.57 (0.45 – 0.72)	0.84 (0.64 – 1.12)
- Female	Ref	
Household head main occupation		
- Livestock herding	0.87 (0.79 – 0.95)	0.94 (0.82 – 1.07)
- Non-livestock herding	Ref	
Child health status (sick)	1.25 (1.18 – 1.33)	1.19 (1.09 – 1.30)

4.2.2.6 Factors associated with milk consumption (amount and frequency) among pregnant and lactating women.

Milk consumption among pregnant and lactating women was significantly associated with households receiving livestock feed (β=0.21, 95% CI [0.08, 0.33]), household milk yield (β=0.02, 95% CI [0.02, 0.03]), and household milk storage (β=0.02, 95% CI [0.004, 0.03]) as in **Table 4.15** below.

Table 4.15: Factors associated with milk consumption in litres among pregnant and lactating women

Parameter	Univariate (95% CI)	Multivariate (95% CI)
Feed received	0.15 (0.04 – 0.25)	0.21 (0.08 – 0.33)
Enhanced counselling	0.12 (-0.06 – 0.31)	0.14 (-0.07 – 0.33)
Milk TLU	0.08 (0.06– 0.10)	0.02 (-0.06 – 0.02)
Milk yield (litres)	0.02 (0.01– 0.02)	0.02 (0.02 – 0.03)
Milk storage (hours)	0.03 (0.03 – 0.04)	0.02 (0.004 – 0.03)
Household size	0.02 (0.01 – 0.04)	0.01 (-0.03 – 0.05)

Parameter	Univariate (95% CI)	Multivariate (95% CI)
Cash transfer program	-0.14 (-0.24– -0.03)	-0.13 (-0.40 – 0.15)
Socio-economic Index		
- Quantile 1 (Highest)	0.07 (0.02 – 0.11)	1.26 (1.03 – 1.55)
- Quantile2	0.12 (0.08 – 0.17)	1.24 (1.00 – 1.53)
- Quantile 3	0.06 (0.02 – 0.11)	1.23 (1.00 – 1.51)
- Quantile 4	0.08 (0.03 – 0.12)	1.18 (0.96 – 1.45)
- Quantile 5 (Lowest)	Ref	Ref
Household head education		
- Formal schooling	-0.01 (-0.02 – 0.01)	
- No formal schooling	Ref	
Gender of household head		
- Male	-0.02 (-0.08 – 0.02)	
- Female	Ref	
Household head Main occupation		
- Livestock herding	0.02 (0.01 – 0.03)	0.01 (-0.03 – 0.02)
- Non-livestock herding	Ref	

4.2.2.7. Effect of providing livestock feeds to milking animals during drought periods and nutrition counselling on undernutrition among children < 5 years

4.2.2.7.1 Measures of child nutrition status (stunting , wasting and underweight)

Nutrition status for children < 5 years of age as measured by stunting (low height-for-age z-scores), wasting (low weight-for-height), underweight (low weight–for–age) and MUAC for Age (Global Acute Malnutrition). The findings showed that 19% were stunted, 14% were severely stunted; 17% were wasted while 2% were severely wasted. While 37% of children were underweight and 2% were severely underweight and 11% were malnourished while 2 percent were severely malnourished.

4.2.2.7.1 Effect of provision of livestock feed to milking animals during drought periods and nutrition counselling on undernutrition in children < 5 years of age

Compared to the control group, livestock feeds intervention significantly reduced risk of acute malnutrition (GAM) by 11% (4%, 17%), stunting (height-for-age) by 8% (95% CI: 2%, 14%), wasting (weight-for-height) by 9% (95% CI: 3%, 15%) and underweight (weight-for-age) by 11% (95% CI: 7, 14%) among children <5years. Livestock feeds and nutrition counselling intervention significantly reduced the risk of global acute malnutrition by 26% (95% CI 5%, 43%), but no significant intervention effect on stunting, wasting and underweight as shown in **Table 4.16** below.

Table 4.16: Effect of provision of livestock feeds and nutrition counselling on undernutrition in children < 5 years of age

Intervention	Height-for-age (stunting)	Weight-for-height (wasting)	Weight-for-age (underweight)	Muac-for-age (GAM)
Control group	Reference	Reference	Reference	Reference
Provision of livestock feed	**0.92 (0.86 - 0.98)**	**0.91 (0.85 - 0.97)**	**0.89 (0.86 – 0.93)**	**0.89 (083 – 0.96)**
Provision of livestock feed and nutrition counselling	0.96 (0.80-1.15)	0.84 (0.68 – 1.05)	0.99 (0.83 – 1.18)	**0.74 (0.57 – 0.95)**

4.2.2.7.1 Factors associated with undernutrition in children < 5 years of age

Provision of livestock feed, number of milking TLUs in the household are significantly associated with reduced risk of undernutrition in children. Provision of enhanced nutrition counselling was only significantly associated with reduced risk of global acute malnutrition as shown in **Table 4.17** below.

Table 4.17: Factors associated with undernutrition in children < 5 years of age

	Height-for-age (stunting)		Weight-for-height (wasting)		Weight-for-age (underweight)		Muac-for-age (GAM)	
Parameter	Univariate OR (95%CI)	Multivariate OR (95% CI)	Univariate OR (95%CI)	Multivariate OR (95% CI)	Univariate OR (95%CI)	Multivariate OR (95% CI)	Univariate OR (95%CI)	Multivariate OR (95% CI)
Received feed	0.91 (0.86-0.98)	0.92 (0.86-0.98)	0.91 (0.86 -0.97)	0.91 (0.85-0.97)	0.83 (0.77 -0.88)	0.89 (0.86 –0.93)	0.91 (0.84-0.96)	0.89 (0.83 –0.96)
Nutrition counselling	1.01 (0.87-1.17)	0.96 (0.80-1.15)	1.06 (0.92-1.23)	0.84 (0.68 – 1.05)	0.99 (0.85 -1.15)	0.99 (0.83-1.18)	0.96 (0.87-0.99)	0.74 (0.57 -0.95)
Milking TLU's	0.96 (0.93-0.99)	0.93 (0.92-0.99)	0.94 (0.91 -0.97)	0.91 (0.86-0.97)	0.92 (0.90 -0.95)	0.93 (0.91 – 0.95)	0.97 (0.93 –1.00)	0.97 (0.91- 1.03)
Household size	0.95 (0.92-0.99)	0.96 (0.93-1.00)	1.04 (1.01-1.07)	1.02 (0.99-1.05)	1.03 (1.00 -1.07)		1.07 (1.03 -1.10)	1.01 (0.97 -1.04)
Socio-economic index (wealth quantiles)								
Quantile 1 (Highest)	0.81 (0.65-1.01)	0.87 (0.64-1.01)	1.16 (0.92-1.46)		0.95 (0.82 –1.10)		1.13 (0.93 –1.37)	
Quantile 2	0.76 (0.60-0.96)	0.92 (0.59-1.13)	1.22 (0.96-1.54)		0.95 (0.82– 1.11)		1.23 (0.99 -1.51)	
Quantile 3	0.75 (0.60-0.94)	0.85 (0.59-1.92)	1.10 (0.87-1.38)		0.98 (0.85 –1.13)		1.18 (0.97 –1.43)	
Quantile 4	0.73 (0.59-0.92)	0.88 (0.57-1.30)	1.18 (0.94-1.48)		0.96 (0.83 -1.12)		1.14 (0.94 –1.38)	
Quantile 5 (Lowest)	Reference	Reference	Reference		Reference		Reference	
Household head education								
Formal education	0.93 (0.69-1.25)		1.12 (0.87-1.44)		0.98 (0.91 –1.06)		0.76 (0.58 – 1.01)	
No formal education	Reference		Reference		Reference		Reference	

4.2.2.8. Effect of providing livestock feed to milking animals during drought periods and nutritional counselling on dietary outcomes among children < 5 years

Livestock feeds only intervention was significantly associated with increased MDD for children OR=1.8 (95% CI 1.6, 2.0) and women OR=1.55 (95% CI: 1.23, 1.89). Livestock feeds and nutrition counselling intervention was significantly associated with improved household dietary diversity score (HDDS) by 3% (95% CI 1%, 5%), increased minimum dietary diversity (MDD) for children OR=2.5 (95% CI: 2.3, 2.8) and increased minimum dietary diversity for women OR=4.22 (95% CI 3.29, 5.42) as shown in **Table 4.18** below.

Table 4.18: Effect of intervention on dietary diversity

Dietary indicator/Study arm	Household dietary diversity (HDD)	Minimum Dietary Diversity for children (MDD)	Minimum Meal frequency (MMF)	Minimum acceptable diet (MAD)	Minimum dietary diversity for women (MDD-W)
Control arm	Ref	Ref	Ref	Ref	Ref
Intervention arm 1	0.95 (0.93 – 1.02)	1.78 (1.60 – 1.98)	2.19 (1.56 – 3.07)	1.77 (1.53 – 2.04)	1.55 (1.23 – 1.89)
Intervention arm 2	1.03 (1.01 – 1.05)	2.54 (2.30 – 2.79)	1.61 (1.08 – 2.39)	3.10 (2.66 – 3.62)	4.22 (3.29 – 5.42)

4.3 Results for Objective III: Establishing the burden and effect of zoonoses (brucellosis & Q-fever), childhood illness syndromes (diarrhea, fever & acute respiratory infections) and their association with undernutrition in children below five years in Marsabit County, Kenya

Two articles have been published from this work as shown in the following citations[2, 3].

4.3.1 Socio-demographic characteristics of study participants (Human and animals)

A total of 1,734 households who had been enrolled in the study trial evaluating the effect of dry season livestock feeds provision and regular nutrition counselling on the risk of acute malnutrition were approached for enrollment, out of which 1,095 (63%) households agreed to participate in the brucellosis and Q-fever study. From these 1,095 households, a total of 1,299 participants were enrolled and provided samples, 1,074 (83%) of whom were women and 225 (17%) children. The mean age of enrolled women was 28.6 years (range: 17 – 46), while that of children was 23.4 months (range:5 – 42). Among women, 905 (84.3%) were lactating while 169 (15.7%) were not lactating. All households owned at least one livestock species (goats, sheep, camels and cattle) with ownership of goats at 96%, sheep (92%), camels (68%), cattle (43%), donkeys (60%) and chicken (13%). On average, the households had three camels, seven goats, six sheep and three cattle. In total, 2,387 animals were sampled

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[2] *Muema J, Mutono N, Wheelhouse N, Njuguna J, Jost C, Oyugi J, Bukania Z, Oboge H, Ogoti B, Makori A, Fernandez MDP, Omulo S, Thumbi SM. Endemicity of Coxiella burnetii infection among people and their livestock in pastoral communities in northern Kenya. Heliyon. 2022 Oct 21;8(10):e11133. doi: 10.1016/j.heliyon.2022.e11133. PMID: 36303929; PMCID: PMC9593183.*

[3] *Muema J, Oboge H, Mutono N, Makori A, Oyugi J, Bukania Z, Njuguna J, Jost C, Ogoti B, Omulo S, Thumbi SM. Sero - epidemiology of brucellosis in people and their livestock: A linked human - animal cross-sectional study in a pastoralist community in Kenya. Front Vet Sci. 2022 Nov 18;9:1031639. doi: 10.3389/fvets.2022.1031639. PMID: 36467641; PMCID: PMC9716101.*

including 1,876 (78%) goats, 322 (14%) sheep and 189 (8%) camels. No cattle were sampled as the few cattle kept by the communities were in dry season grazing areas.

4.3.2 Epidemiology, Burden, and Impact of brucellosis

4.3.2.1 Brucellosis seroprevalence in women and children

Of the 1,050 enrolled households, 133 had at least one participant who was seropositive for brucellosis, resulting in a household-level seroprevalence of 12.7% (95% CI: 10.7, 14.8). Individual human-level seroprevalence was 10.8% (9.1, 12.6), with a higher seroprevalence observed in women than in children (12.4 vs. 3.1%, p <0.001). No significant difference in seroprevalence between male and female children (4% vs 3%, p <0.682). Seroprevalence varied with socio-demographic characteristics as shown in **Table 4.19** below.

Table 4.19: Brucellosis seroprevalence in women and children by sociodemographic characteristics and results of univariable analysis.

	Women (N = 1,074)			Children (N = 225)		
Variable	% (n/N)	95% CI	p-value	% (n/N)	95% CI	p-value
Occupation						
Herding	12.9 (94/728)	10.6–15.6	0.658	-	-	
Employed	11.3 (39/346)	8.1–15.1		-	-	
Physiological status						
Lactating	10.5 (104/905)	4.9–18.9	0.088	-	-	
Non-lactating	17.2 (29/169)	11.8–23.7		-	-	
Education level*						
Formal education	10.5 (9/86)	4.9–18.9	0.573	0 (0/17)	-	0.442
No formal education	12.5 (124/988)	10.5–14.6		3.4 (7/208)	1.4–6.8	
Location (ward)						
Kargi	7.6 (16/209)	4.4–12.1	0.169	0 (0/8)	-	0.606
Korr	12.4 (53/426)	9.5–15.9		1.5 (1/66)	0.0–8.2	
Laisamis	14.2 (37/260)	10.2–19.1		2.8 (2/72)	0.3–9.7	
Logologo	15.3 (25/163)	10.2–21.8		5.1 (4/79)	1.4–12.5	
Loiyangalani	12.5 (2/16)	1.6 – 38.4		-	-	
Nutritional Status						
Malnourished	8.6 (11/128)	4.4–14.9	0.165	2.2 (1/45)	0.1–11.8	0.701
Healthy	12.9 (122/946)	10.8–15.2		3.3 (6/180)	1.2–7.1	

*For children, this refers to mother's education level.

4.3.2.2 Brucellosis seroprevalence in animals

Out of 1,244 herds sampled, 325 had at least one seropositive animal resulting in a herd seroprevalence of 26.1% (95% CI: 23.7, 28.7). The overall animal-level brucellosis seroprevalence was 19.2% (17.6, 20.8), with seroprevalence varying by animal type; 23.1% (21.2, 25.1) in goats, 6.8% (4.3, 10.2) in sheep and 1.1% (0.1, 3.8) in camels. Seroprevalence in animals varied by sociodemographic characteristics as shown in **Table 4.20** below.

Table 4.20: Brucellosis seroprevalence in animals by socio-demographic characteristics

Variable	Seroprevalence %(n/N)	95% CI	*p*-value
Location (Ward)			
Kargi	10 (41/395)	7.6 – 13.8	< 0.001
Korr	12 (113/931)	10.1 – 14.4	
Laisamis	24 (122/520)	19.8 – 27.4	
Logologo	41 (142/350)	35.4 – 45.9	
Loiyangalani	20 (39/191)	14.9 – 26.8	
Livestock type			
Goats	23 (433/1876)	21.2 – 25.1	< 0.001
Sheep	7 (22/322)	4.3 – 10.2	
Camels	1 (2/189)	0.1 – 3.8	
Reproductive disorders			
No	18 (301/1641)	16.5 – 20.3	0.139
Yes	21 (156/746)	18.1 – 24.0	
Household head occupation			
Herding	19 (337/1789)	17.1 – 20.7	0.508
Employed	20 (120/598)	16.9 – 23.5	
Household head education			
No formal education	19 (360/1882)	17.4 – 20.9	0.002
Formal education	29 (49/167)	22.6 – 36.9	
Grazing distance			
<5 km	29 (127/66)	16.3 – 22.4	0.059
5 - 10km	22 (162/746)	18.8 – 24.9	
>10km	17 (168/979)	14.9 – 19.7	

4.3.2.3 Factors associated with brucellosis seropositivity in women and children.

At household level, we observed significant associations at the household level between brucellosis exposure in people and their livestock (OR = 1.7, 95%CI: 1.2, 2.5, $p = 0.002$). None of the potential risk factors (age, sex, occupation, physiological status, geographical location, and nutrition status) included in the models were significantly associated with seropositivity among women or children ($p > 0.05$).

4.3.2.4 Factors associated with brucellosis seroprevalence in animals.

At the herd level, goat herds (OR = 3.86, 95%CI: 2.34, 6.73, p <0.001) and sheep flocks (OR = 3.02, 1.42, 5.91, p = 0.003) had higher odds of being brucellosis seropositive compared to camel herds. There was a significant association between seropositive herds and seropositive households (OR = 1.8, 1.23, 2.58, p = 0.002). Herds owned by household heads with formal education had higher odds of being brucellosis seropositive (OR = 2.45, 1.67, 3.61, p <0.001) compared to those owned by household heads with no formal education. There were significantly higher odds of brucellosis among animal herds from larger herds sizes compared to smaller ones (OR = 1.006, 95%CI 1.003, 1.009, p <0.001 as indicated in **Table 4.21** below

Table 4.21: Herd-level factors associated with brucellosis seropositivity

Variable	Odd Ratio (Confidence Interval)	*p*-value
Livestock type		
Goats	3.856 (2.344 - 6.728)	<0.001
Sheep	3.017 (1.416 - 5.914)	0.003
Camels	Ref	
Household seropositivity		
Positive	1.785 (1.228 - 2.576)	0.002
Negative	Ref	
Household head education		
Formal education	2.454 (1.670 - 3.606)	<0.001
No formal education	Ref	
Herd size	1.006 (1.003 - 1.009)	<0.001

At the individual animal level, goats (OR = 3.8, 95%CI 2.4, 6.7, p<0.001) and sheep (OR = 2.8, 95% CI 1.2, 5.7, p = 0.007) had significantly higher odds of being brucellosis seropositive compared to camels as shown in **Table 4.22** below.

Table 4.22: Animal-level factors associated with brucellosis seropositivity

Variable	OR (95% CI)	*p*-value
Livestock type		
Camels	Ref	
Goats	3.88 (2.37-6.75)	<0.001
Sheep	2.76 (1.17-5.65)	0.007
Household head education		
No formal education	Ref	
Formal education	1.38 (0.94-2.00)	0.091

4.3.3 Epidemiology, Burden, and Impact of Q fever

4.3.3.1 Q fever household level seroprevalence

A total of 144 of 1,095 households had at least one seropositive individual, resulting in household-level seroprevalence of 13.2% [95% CI: 11.2, 15.3].

4.3.3.2 Seroprevalence estimates of Q-fever in women and children.

The *C. burnetii* antibody seropositivity among women was 121/1,074, resulting to a seropositivity of 11.3% [9.4, 13.3] while that among children was 30/225, giving a seropositivity of 13.3% [9.2, 18.5]. Seroprevalence varied with socio-demographic characteristics as shown in **Table 4.23** below. Age was included as a continuous variable to determine its effect on the study outcome in both women and children. Age was not significantly associated with Q-fever seropositivity (p = 0.857). Age (older children) was only significantly associated with Q-fever seropositivity in children, OR = 1.1(1.0, 1.1), p = 0.049.

Table 4.23: Q-fever seroprevalence in women and children by sociodemographic characteristics and results of univariable analysis

	Women (N = 1,074)		Univariable analysis	Children (N = 225)		Univariable analysis
Variable	n/N (%)	95% CI	p-value	n/N (%)	95% CI	p-value
Occupation						
Livestock herding	91/728 (12.5)	10–15	0.86		-	-
Employment/business	29/318 (9.1)	6–12			-	-
Physiological status						
Lactating	112/905 (12.4)	10–15	0.026		-	-
Non-lactating	9/169 (5.3)	3–10			-	-
*Education level**						
Formal education	8/86 (9.3)	4–18	0.548	3/17 (17.6)	4–43	0.586
No formal education	113/988 (11.4)	10–13		27/208 (13.0)	9–18	
Location (ward)						
Kargi/SouthHorr	27/209 (12.9)	9–18	0.378	0/8 (0.0)	-	0.408
Korr/Ngurnit	52/426 (12.2)	9–16		10/66 (15.2)	8–26	
Laisamis	28/260 (10.8)	7–15		7/72 (9.7)	4–19	
Logologo	14/163 (8.6)	5–14		13/79 (16.5)	9–27	
Loiyangalani	0/16 (1.5)					
Nutritional Status						
Malnourished	14/128 (12.9)	6–18	0.900	6/45 (13.3)	5–27	1.000
Normal	107/946 (11.3)	9–14		24/180(13.3)	8–19	

*For children, this refers to mother's education level.

4.3.3.3 Q fever herd level seroprevalence

Of the 1,443 herds sampled, 1,208 herds had at least one seropositive animal, yielding a herd seroprevalence of 83.7% [81.7, 85.6].

4.3.3.4 Individual animal level seroprevalence estimates.

The overall seroprevalence in sampled animals was 69.5% [67.6, 71.3], with species seroprevalence of 74.7% [72.7, 76.7] among goats, 56.8% [51.2, 62.3] among sheep and 38.6% [31.6, 45.9] among camels. Seroprevalence in animals varied by sociodemographic characteristics as shown in **Table 4.24** below. Age was included as a continuous variable and was not associated with Q-fever seropositivity in animals (p = 0.9118).

Table 4.24: Q-fever seroprevalence in animals by socio-demographic characteristics and univariable analysis results

Overall seroprevalence 1658/2387 (69.5%)			Univariable analysis
Variable	Seroprevalence n/N(%)	95% CI	p-value
Geographical location (Ward)			
Kargi/Southhorr	280/395 (70.9%)	66.1 – 75.3	< 0.001
Korr/Ngurunit	586/931 (62.9%)	59.8 – 66.1	
Laisamis	396/520 (76.2%)	72.3 – 79.8	
Logologo	256/350 (73.1%)	68.2 – 77.7	
Loiyangalani	140/191 (73.3%)	66.4 – 79.4	
Species			
Goats	1402/1876 (74..7%)	72.7 – 76.7	< 0.001
Sheep	183/322 (56.8%)	51.2 – 62.3	
Camels	73/189 (38.6%)	31.7 – 45.9	
Reproductive disorders			
No	1145/1641 (69.8%)	67.5 – 71.9	0.620
Yes	513/746 (68.8%)	65.3 – 72.1	
Household head Occupation			
Livestock herding	1216/1789 (68.0%)	65.8 – 70.1	0.115
Employment/business	442/598(73.9%)	70.2 – 77.4	
Household head Education			
No formal education	1299/1882 (69.0%)	66.9 – 71.1	0.549
Formal education	119/167 (71.3%)	63.8 – 77.9	
Grazing distance			
<5 km	459/662 (69.3%)	65.7 – 72.8	0.182
5- 10km	536/746 (71.8%)	68.5 – 75.1	
>10km	663/979 (67.7%)	64.7 – 70.7	

4.3.3.5 Risk factors associated with Q-fever seropositivity in women and children.

Multivariable models showed significant associations between *C. burnetii* seropositivity and the physiological status of a woman (lactation), with the likelihood of exposure being 2.4 [1.3, 5.3] folds higher in lactating women than in non-lactating women (*p*=0.013). Among children, age was significantly associated with seropositivity, with the odds of seropositivity increasing by 1.1 [1.0, 1.1] for every unit increase in age as shown in **Table 4.25** below.

Table 4.25: Risk of being *C. burnetii* antibody seropositive in women and children

Women	Multivariate analysis		Children	Multivariate analysis	
Variable	OR(CI)	P value	variable	OR(CI)	P value
Household head occupation			Age	1.1 (1.002 – 1.1)	0.049
Livestock herding	1.4 (0.92- 2.23)	0.126	-	-	
Employment/business	Ref				
Physiological status			Sex		
Lactating	2.4 (1.28 – 5.28)	0.013	Male	0.4 (0.16 – 1.1)	0.078
Non-lactating	Ref		Female	Ref	

4.3.3.6 Risk factors associated with livestock seropositivity for Q-fever.

The likelihood of seropositivity to *C. burnetti* was 5 [3.8, 7.8] and 3 [1.8, 4.0] folds higher in goats and sheep, respectively, relative to seropositivity in camels. Statistically significant differences in *C. burnetii* antibody seroprevalence were observed among animals from different wards in the study area, with animals from Laisamis and Loiyangalani wards being respectively 1.4-fold more likely and 1.7-fold more likely to be seropositive compared to Kargi/South Horr as shown in **Table 4.26** below. Animals from households where the household head's main occupation was livestock herding had less odds of being seropositive OR = 0.56 (CI 0.4, 0.8), p=0.003 compared to those engaged in employment/business.

Table 4.26: Risk of being *C. burnetii* antibody seropositive in animals

	Multivariate analysis	
Variable	OR (95% CI)	P value
Animal-level factors		
Geographical location (Ward)		
Korr/Ngurunit	1.0 (0.7-1.4)	0.956
Laisamis	1.4 (1.0-1.9)	0.047
Logologo	1.1 (0.8-1.6)	0.590
Loiyangalani	1.7 (1.1-2.8)	0.017
Kargi/SouthHorr	Reference	
Species		
Goats	5.5 (3.9-7.8)	<0.001
Sheep	2.7 (1.8-4.0)	<0.001
Camels	Reference	
Herd- level factors		
Household head Occupation		
Livestock herding	0.6 (0.4-0.8)	0.003
Employment/business	Reference	
Household head formal education		
Yes	0.7 (0.5-1.1)	0.099
No	Reference	

4.3.3.6 Association between Q-fever seropositivity and nutrition status in women and children

When nutritional status was added in both the women and children individual-level models, there was no statistically significant association between Q-fever seropositivity and nutrition status in women, p=0.900 and children, p=1.000. Further, exposure to infectious zoonotic diseases (brucellosis and Q fever) was not significantly associated with risk of acute malnutrition in children and women, OR=1.82 (95% CI: 0.67, 5.21, p=>0.69).

4.3.3.7 Association between Q fever seropositivity in people and their livestock

We did not find a statistically significant association between Q-fever seropositivity in people and the livestock they kept when the association was tested at the household level (p=0.724).

4.3.3 Epidemiology, Burden, and Impact of child reported illness syndromes

4.3.3.1 Reported child illness syndromes among study participants

The study documented reported child illness syndromes of diarrhoea, fever, acute respiratory infection (ARI) and vomiting during the two weeks preceding household data collection visit. For the two weeks prior to the baseline survey visit, 104 (5.9%), 81 (4.6%), 168 (9.6%), and 22 (1.3%) of the children were reported to have had fever, diarrhea, ARI/cough and vomiting respectively as shown in **Table 4.27** below.

Table 4.27: Reported child illness syndromes at baseline

Health syndrome	Total N	Intervention Arm 1(%)	Intervention Arm 2(%)	Control (Arm 3) (%)
Children < 3yrs	1748	599	564	585
Fever	104(5.9%)	27(5%)	43(8%)	34(6%)
Diarrhoea	81(4.6%)	21(4%)	38((7%)	22(4)
ARI/Cough	168(9.6%)	38(6 %)	71(12%)	59(10%)
Vomiting	22(1.3%)	5(1%)	7(1%)	10(2%)

4.3.3.2 Effect of reported child illness syndromes on child nutritional status

Multivariable model results showed a significant association between reported syndromes of diarrhea, fever and acute respiratory infection, and acute malnutrition. Children with reported health illness (fever/diarrhea/ARI) were 1.64 times (95% CI 1.33, 2.03) more likely to be malnourished (global acute malnutrition) compared to children without the reported syndromes and 1.22 times (95% CI 1.01, 1.47) more likely to have low weight-for-height z-scores (wasting) compared to those who did not report the syndromes.

4.4 Results for Objective IV: Determination of the cost-effectiveness of providing livestock feeds to milking animals during drought periods and nutrition counselling in preventing undernutrition in children below five years in Marsabit County, Kenya

4.4.1 Activity-based costs

The total programme intervention costs over the 2-year period calculated from a provider perspective was $1,066,626. These costs included costs of providing livestock feeds to ~1200 households twice a year for ~2,400 TLUs and weekly nutrition counselling for ~600 households. Of these total intervention costs, 80% ($948,090) were for the livestock feed intervention while 20% ($118,536.3) was for the nutrition counselling intervention. The cost of feed distribution intervention only per beneficiary household was $790 while that of feed plus nutrition counselling was $987.6 for the 2-year project duration (**Table 4.28)**. The cost per beneficiary household for the feed-only intervention was $197.5 per critical dry period.

Table 4.28: Program cost Analysis per intervention

Intervention	Arm 1: Feeds only			Arm 2: Feeds plus Nutrition counselling		
	Amount (USD)	Percentage of total	Cost per household	Amount (USD)	Percentage of total	Cost per household
Feeds distribution component						
Livestock feed procurement	$252203	53.2	$420.3	$252203	42.6	$420.3
Feed transport cost	$108087	22.8	$180.1	$108087	18.2	$180.1
Feed inspection	$10883.5	2.3	$18.1	$10883.5	1.8	$18.1
Personnel - (Donor organization)	$7090	1.5	$11.8	$7090	1.2	$11.8
Beneficiary sensitization	$10472.2	2.2	$17.5	$10472.2	1.8	$17.5
Feed distribution	$32742.15	6.9	$54.6	$32742.15	5.5	$54.6
Personnel - (contracted NGO)	$31225.4	6.6	$52.0	$31225.4	5.3	$52.0
Logistics	$12222.2	2.6	$20.4	$12222.2	2.1	$20.4
Program operational costs	$ 9119.55	1.9	$15.2	$ 9119.55	1.5	$15.2
Nutrition counselling component	-	-		$118536.3	20.0	$197.6
TOTAL	**$474,045**	**100**	**$790**	**$ 592,581.3**	**100**	**$987.6**

4.4.2 Cost-effectiveness Analysis

4.4.2.1 Base case analysis

The cost per child in a household receiving feed-only intervention was $ 585.2 while the cost per child in a household receiving feeds plus nutrition counselling intervention was $ 803. ICERs were calculated as the additional costs incurred to avert an additional case of wasting or stunting relative to the control group. The cost per case of wasting averted in the feed-only intervention compared to the control group was $5,326.3 while the cost per case of stunting averted was $7,293. The incremental cost per case of wasting averted in the feeds plus nutrition counselling intervention relative to the control group was $3,086.4 and there was no statistically significant effect in stunting in the feeds plus nutrition counselling intervention as shown in **Table 4.29** below.

Table 4.29: Base case cost-effectiveness results

Results	Arm 1: Feeds only	Arm 2: feeds plus nutrition counselling
Total cost[1] (USD)	$ 474,045	$ 592,581.3
No. of children in the programme[2]	810	738
Incremental cost per child receiving intervention (USD)[3]	$ 585.2	$ 803
Decrease in prevalence of wasting[4]	11%	26%
Cases of wasting averted	89	192
Decrease in prevalence of stunting[4]	8%	NS
Cases of stunting averted	65	
ICER—$/case of wasting averted	$5,326.3	$3,086.4
ICER—$/case of stunting averted	$7,293	

[1]Analysis of costs includes all costs from the provider perspective.
[2]Number of children included in programme per intervention arm and whose baseline data was collected.
[3]Costs are incremental relative to the control group.
[4]Difference in difference estimates relative to control group for outcomes with significant results.
NS, not significant

4.4.2.2 Cost-effectiveness threshold

Incremental cost-effectiveness ratios (ICERs) were calculated as the additional costs incurred to avert an additional case of wasting or stunting relative to the control group. The cost per case of wasting averted in the feed-only intervention was $5,326.3 while the cost per case of stunting averted was $7,293. The cost per case of wasting averted by the feeds plus nutrition counselling intervention was $3,086.4. Interventions costing less than 1 GDP per capita and less than 3 GDP per capita are considered “very cost-effective” and “cost-effective” respectively using WHO criteria on cost-effectiveness thresholds of health interventions. Interventions costing less than 3 GDP per capita for Kenya ($6,021, Kenya’s GDP per capita for 2021 was $2,007) were considered cost-effective. Both livestock feed only, and livestock feed plus nutritional counselling were considered cost-effective in preventing acute malnutrition (wasting) at a cost of $5,326 and $3,086 per case of wasting averted with a cost-effective ratio of 2.6 and 1.5 respectively. The cost per case of stunting averted by the feed only intervention was $7,293, with a cost-effectiveness ratio of 3.6 which was above the cost-effectiveness threshold.

CHAPTER FIVE: DISCUSSION

5.1 Study Objective I: Quantitative assessment of impact of livestock interventions on maternal and child nutritional outcomes in sub-Saharan Africa

This review synthesised existing evidence on the effect of nutrition-sensitive livestock-oriented programs/interventions on diet and nutrition outcomes in children below five years and pregnant and lactating women in Africa setting. The results showed that despite the drawbacks associated with livestock keeping as a risk factor for disease and mortality in children (Kaur et al., 2017), nutrition-sensitive livestock interventions have a significant positive effect on diet-related outcomes of consumption of nutrient-dense animal source foods and on attaining minimum dietary diversity, while the impact on undernutrition anthropometric indicators (stunting, wasting and underweight) and micronutrient status is limited.

Livestock Impact evaluation studies and child nutrition

The evidence on the impact of livestock programs/interventions on nutrition has improved in recent years since the reviews reported by Leroy, 2007 (Leroy & Frongillo, 2007) and Delia Grace, 2018 (Grace et al., 2018). In 2018, (Ruel et al., 2018) synthesised empirical evidence on linkage between nutrition-sensitive agriculture programs and nutrition outcomes. However, that review differs from this review because the former focussed on general agriculture interventions including homestead food production systems, home vegetable gardens, biofortified crops, livestock, and irrigation projects, in low- and middle–income countries and their effect on nutrition in the general population. This current review focused mainly on livestock-oriented interventions and their effect on nutrition in children < 5 years and/ or pregnant and lactating women specifically in Africa.

Based on this evidence synthesis, a sizeable percentage of articles showed that livestock interventions improved access to and consumption of nutrient dense animal source foods (Caswell et al., 2021; Dumas, Lewis, et al., 2018; Flax et al., 2021; Hoddinott et al., 2015; Kabunga et al., 2017; MacDonald et al., 2010; McKune et al., 2020; Otiang & Yoder, 2022; Rawlins et al., 2014; Stewart et al., 2019), attaining minimum dietary diversity (Flax et al., 2021; Lenjiso et al., 2016; Lutter et al., 2021; Marquis et al., 2018; Rawlins et al., 2014) and haemoglobin concentration and prevalence of anaemia (Lambrecht et al., 2021; Le Port et al., 2017; MacDonald et al., 2010; Muleta, Hailu, Stoecker, et al., 2021). Additionally, some livestock interventions improved children's stunting or height-for-age (HAZ) z-scores (Argaw et al., 2018; Bierut et al., 2021; Dumas, Lewis, et al., 2018; Headey & Hirvonen, 2016; Hoddinott et al., 2015; Kabunga et al., 2017; Kidoido & Korir, 2015; Lenjiso et al., 2016; Long et al., 2012; MacDonald et al., 2010; Marquis et al., 2018; McKune et al., 2020; Mosites et al., 2016; Mosites et al., 2015; Otiang & Yoder, 2022; Passarelli et al., 2020; Rawlins et al., 2014; Stewart et al., 2019), wasting or weight-for-height (WHZ) z-scores (Kabunga et al., 2017; Kidoido & Korir, 2015; Lenjiso et al., 2016; MacDonald et al., 2010; McKune et al., 2020; Otiang & Yoder, 2022; Rawlins et al., 2014; Stewart et al., 2019), and underweight or weight-for-age (WAZ) z-scores (Aiga et al., 2009; Kidoido & Korir, 2015; Marquis et al., 2018; Passarelli et al., 2020) which are indicators of chronic and acute nutritional status in children. This positive effect is because livestock and livestock products are a source of essential, nutrient dense and highly bio-available ASFs and are a source of household income through sales of livestock and livestock products which translates to improved nutritional status among women and children in underserved and vulnerable populations.

Overall, effects were reported on child diets including consumption of animal source foods; meeting minimum dietary diversity; and for specifically, milk consumption, linear growth and better HAZ z-scores. However, effect on stunting, wasting and underweight varies with some studies reporting effects on WAZ and WHZ z-score but with not on HAZ and vice-versa depending on the type of the intervention. For example, a livestock transfer program in Rwanda; distribution of small animals through revolving funds in Malawi and establishment of small-scale egg production centres in Zambia documented positive effects on consumption of animal source foods (Dumas, Lewis, et al., 2018; MacDonald et al., 2010; Rawlins et al., 2014). Overall, this review reported successes on increasing production diversity and consumption of animal source foods. The documented effect of interventions evaluated was mainly the improved access to and consumption of nutrient dense animal source foods and improved dietary diversity. However, the effect reported on nutritional status measured by height -for- age z-scores (stunting), weight-for-height z-scores (wasting), and weight-for-age z-scores (underweight) was either weak or not present at all.

Similarly, evidence on impact on micronutrient status was also uncommon with only one study reporting effect on Hb concentrations in children (Le Port et al., 2017). Marquis et al (2018) assessed the impact of a livestock intervention involving donation of improved chicken for egg production, provision of inputs and husbandry training on diet diversity in Ghana, it was found that children in the intervention group met minimum dietary diversity and had higher HAZ, and WAZ z-scores (Marquis et al., 2018). An animal health intervention in rural Kenya increased consumption of ASFs and improved child growth. This intervention involved vaccination of chicken against Newcastle disease and parasite control while the control group received only parasite control. Intervention increased both HAZ and WHZ z-scores in the intervention group relative to control group (Otiang & Yoder, 2022)

Impact of livestock intervention on Child HB concentration/ anaemia

Similarly, a few studies showed that livestock interventions improve child HB concentrations thus reducing anaemia in children. In rural Senegal, a cluster randomized controlled trial (Le Port et al., 2017) tested the effect of using a dairy value chain to distribute micronutrient-fortified yogurt to improve haemoglobin levels (Hb) and reduce iron deficiency anaemia among children 24 – 59 months-old and showed improved Hb concentrations and reduced prevalence of anaemia. In eastern Ethiopia, consumption of camel milk by pastoralist communities was associated with lower prevalence of anaemia when compared to cow milk consumption (Muleta et al., 2021). Additionally, a small animal revolving funds intervention programme in Malawi yielded a decrease in prevalence of anaemia in pregnant women and pre-school children (MacDonald et al., 2010). Notably, this very program was implemented as an integrated package that included iron supplementation and malaria control hence it was difficult to attribute the effect to a specific component of the program.

Impact of livestock ownership on consumption of Animal Source Foods

Generally, livestock ownership is associated with increased consumption of animal source foods (milk, meat, and eggs). Milk consumption was positively associated with child linear growth particularly in households that own milking animals (De Beer, 2012). Majority of the livestock-oriented observational studies reviewed showed an association between livestock ownership, consumption of animal source foods, household, or individual dietary diversity and in some cases child nutritional status. However, these associations were context specific, and several effect modifiers on the association between livestock ownership and consumption of ASFs and child nutritional outcomes were identified. These include market access, socioeconomic status, income, number of livestock owned, livestock diseases and food security status. Market access was the main effect modifier on the effect of livestock ownership and consumption of animal source foods and nutritional outcomes of children.

This suggests that milk market development and access to milk markets can be an alternative to household livestock ownership (Hoddinott et al., 2015). To support this, a study conducted in Nepal reported that food markets regulate dietary intake and households with better access to markets are less vulnerable to seasonal variations in dietary intake and nutrition status (Mulmi et al., 2016).

The studies on dairy cow ownership showed that dairy production is associated with increased milk consumption and better child nutritional outcomes in Ethiopia, Uganda, Tanzania, and Kenya. In Ethiopia specifically, cow ownership was also associated with lower prevalence of childhood stunting, and increased linear growth (Hoddinott et al., 2015). However, this association was context specific and dependent on market access. No association observed between cow ownership and stunting in households with good access to local markets. In Uganda, cow ownership was associated with increased milk consumption and reduced stunting (HAZ) but not with underweight (WAZ) and wasting (WHZ). Even then, the reduced stunting was only seen in households with large farms (Kabunga et al., 2017). In Tanzania, dairy production predicted reduced levels of stunting, wasting and underweight although this association was only observed among poorer households (Kidoido & Korir, 2015). In Kenya, child nutrition outcomes among children from dairy farmers and dairy customers were compared to those from rural households not practising dairy farming. It was found that milk consumption was a good predictor of better nutrition outcomes for all levels of stunting, wasting and underweight for dairy farmers and dairy customers with the same household income compared to households not practising dairy farming (Hoorweg et al., 2000). A pathway analysis of the relationship between ownership of improved dairy and child nutritional outcomes in Uganda showed that milk consumption was associated with improved HAZ z-scores (Kabunga et al., 2017).

Impact of diet interventions on child nutrition status

Diet interventions involving consumption of ASFs showed improved nutritional outcomes. Long and others evaluated a 5-months comparison feeding intervention of animal source foods program on toddler growth in rural Kenya. The program involved provision of plain porridge (no ASF), meat porridge and milk porridge (Long et al., 2012). It was found that linear growth was significantly greater for the milk group than the meat group and plain energy porridge group although small sample size and short follow-up period limited the clarity of the results. In addition, Argaw and others evaluated a fish oil supplementation intervention on linear growth, morbidity, and systemic inflammation among children 6 – 24 months old in Ethiopia. Surprisingly, no significant effect of fish oil supplementation on linear growth was found (Argaw et al., 2018). Further, when Lutter and others assessed the impact of a 6 – months egg complementary feeding intervention in Malawi on energy intake and dietary diversity among children 6 – 9 months, there was improvement in usual energy intake and dietary diversity in the intervention group compared to the control group (Lutter et al., 2021). Bierut and others examined the effect of a daily supplementation of bovine colostrum/egg in Malawi compared to isoenergetic corn/soy flour on linear growth faltering among children 9 – 12 months of age. The intervention reduced growth faltering among children in intervention group compared to those in control group (Bierut et al., 2021). When Caswell and others assessed the impact of an egg intervention on nutrient adequacy among young Malawian children it was found that the intervention resulted in increased intakes of protein and several micronutrients.

Not all studies reported a positive or beneficial relationship between livestock interventions and nutritional outcomes in women and children. Several studies reported no significant differences between intervention and control groups. A dairy goats donation program in

Ethiopia, did not find any differences in consumption of animal source foods and the authors attributed this to the evaluation being conducted too early to detect any accrued improvements (Kassa et al., 2003). Similarly, no effect on child HAZ z-scores was demonstrated in the livestock transfer project in Rwanda (Rawlins et al., 2014). In Malawi, Prado and others and Steward and others examined the effect of an egg intervention on child development score and child linear growth respectively among children participating in a Project. The project involved provision of 1 egg per day to children aged 6 – 15 months of age coupled with hygiene and handwashing during food preparation messages to mothers for both intervention and control groups. No significant difference was realised between intervention and control group on child development score (Prado et al., 2020). Similarly, no significant intervention effect on height-for -age, weight-for-age and weight-for-height z-scores were observed (Stewart et al., 2019).

Remaining gaps and priority for research

Generally, the design and methods of studies on the effect of nutrition-sensitive livestock interventions have improved. This is attributed to the adoption of experimental and quasi experimental designs, coupled with clearer objectives and better control study arms. However, the greatest limitations that hinder the generalizability of findings from these studies remain as small sample sizes and shorter periods of intervention implementation. Most of the programs reviewed were implemented based on donor funding cycles which were limited to 1 – 2 years on average. No scale-up strategies/plans were documented hence the short-term implementation duration may have masked the true effect sizes for these interventions. Long-term livestock-oriented nutrition-sensitive programs with scale-up strategies could be more impactful in influencing nutrition outcomes, especially stunting which is a long-term measure. This is in addition to majority of the programs being integrated and complex which makes it difficult to assess the effect of individual program components on nutrition outcomes. The small sample sizes and short periods of program implementation might explain the observed lack of interventions effect on height – for – age (HAZ) z-scores in some of the studies as stunting is a long-term measure. The quality of the livestock-oriented observational studies reviewed was varied. Much as this is the case, there is a general improvement in quality with recent studies using better statistical methods, and well-defined age groups of study participants as they assessed nutritional status indicators. However, these observational studies used cross-sectional design making it impossible to infer causality. Additionally, some studies used nationally representative datasets such as DHS which could have large variations in some observed characteristics.

Important to note is the increase in the number of experimental studies on effects livestock interventions on child nutrition outcomes, especially the randomised controlled trials. Of the 12 randomised controlled trials (RCTs) reviewed, 7 were on provision of animal source foods in diets (Argaw et al., 2018; Bierut et al., 2021; Caswell et al., 2021; Long et al., 2012; Lutter et al., 2021; Prado et al., 2020; Stewart et al., 2019); 3 involved poultry interventions coupled with a training program (Marquis et al., 2018; McKune et al., 2020; Passarelli et al., 2020); 1 was on SBCC on consumption of animal source foods (Flax et al., 2021); and 1 was on vaccination of chicken against Newcastle disease (Otiang et al., 2021). It is likely that all these studies presented of good-quality evidence since they were randomised controlled trials with counterfactual analysis. These interventions were either implemented alone or incorporated a nutrition and health behaviour change communication (SBCC) strategies. Coupled with this, the analysis methods used were either baseline and endline comparisons or regression to determine treatment effect for intervention–control comparisons.

Livestock interventions, women empowerment, and child nutrition status

Women empowerment in decision making and engagement in livestock programs is a key pathway from livestock to improved child nutrition (Moore et al., 2022, 2023). Women have been shown to play a significant role on household nutrition (Ibnouf, 2009; Kurz & Johnson-Welch, 2001; Onyango et al., 1994). Thus, livestock oriented nutrition-sensitive programs should target animals or animal products which women have access to and control over so as to ensure maximum benefits on women and child nutrition (Maranga, et al., 2018).

Livestock, Infection/morbidity, and child nutrition status

Although infection/ morbidity was not considered as an outcome in the present review, livestock interventions particularly livestock keeping may be a significant risk factor for increased risk to disease and thus, negatively influencing nutritional outcomes in women and children (Headey & Hirvonen, 2016; Klous et al., 2016; Marshak et al., 2017). As such, much as livestock ownership has a positive association on consumption of nutrient dense animal source foods and better nutritional outcomes, it also predicts negative health consequences due to increased exposure to animal waste. In Ethiopia, Headey and Hirvonen in 2016 found a positive association between poultry ownership and child height-for-age z scores. However, the practice of corralling poultry in household dwellings overnight was negatively associated with child height-for-age z scores. This is possibly due to increased children's exposure to chicken faeces leading to increased risk of infection (Headey & Hirvonen, 2016).

In rural Kenya, a one-year cohort study that followed up children below five years found no association between livestock ownership and child growth. The authors attributed this to a potentially high disease burden among the children (Mosites et al., 2016). However, this study could not determine whether the disease burden was due to actual transmission of diseases between livestock and humans or the impact of livestock diseases on household economy. Departing from this, in Ghana, it was observed that children from households owning livestock were less likely to have anaemia compared to those from non-livestock owning households. Additionally, livestock ownership was not associated with child morbidity (Lambrecht et al., 2021).

The effect of livestock ownership on child morbidity is varied with some studies hypothesizing that livestock ownership may indirectly be associated with negative effects particularly morbidity due to exposure to animal faeces (Headey & Hirvonen, 2016). This means that hygiene might be an important mediating factor linking livestock ownership to child growth. Future reviews in this topic should incorporate infection status and morbidity for both women and children especially in African setting. Consequently, since livestock are hypothesised to expose children to animal faeces especially chicken and animal diseases, there is need to integrate such program with sanitation, and hygiene (WASH) plans. In the same vein, studies on fecal pathogen pathways should be studied when assessing nutrition-based interventions. Furthermore, there is increasing evidence on the negative impacts of livestock on child gut health and child nutrition (Chen et al., 2021). Exposure to enteric pathogens leads to chronic infection of intestines and inflammation of the gut leading to dietary deficits. To ensure comprehensive assessment of effect of livestock on nutrition and health outcomes, there is urgent need to include poor gut health as an immediate determinant of child undernutrition, hence effectively expanding the UNICEF framework to include inadequate dietary intake, disease and poor gut health as immediate causes of malnutrition (Chen et al., 2021).

Role of markets and seasonality in child nutrition outcomes

The pathways from livestock interventions to improved nutrition outcomes could be mediated by several factors including household incomes, access to markets and seasonality. Livestock productivity may be prone to seasonal variations and child nutrition outcomes may also vary depending on seasonal trends and climatic shocks. Nutrition-sensitive livestock intervention that prevents seasonal variation in child nutrition outcomes could be beneficial in improving child nutrition outcomes. However, evidence on livestock programmes addressing the seasonality of malnutrition is limited. Well-designed long-term livestock intervention studies should be designed to explore the effect of livestock interventions on nutrition during emergencies or climatic shocks such as drought.

In Ethiopia, higher levels of milk production, household income, dietary diversity and child nutritional status were observed in milk market participating households compared to non-participating households (Lenjiso et al., 2016). However, despite the significant differences in household milk production between milk market participating households and non-participant households, no significant difference was observed in consumption of ASFs generally and milk consumption specifically. Therefore, the better dietary diversity and nutritional status in children in participating households could potentially be attributed to increased household income.

Social behaviour change communication (SBCC) and child nutrition outcomes.

Incorporating a training component or a social behaviour change communication (SBCC) component in the nutrition-sensitive livestock programming could be beneficial in improving nutritional outcomes. In Rwanda, Flax et al (2021) investigated the effect of a social behaviour change communication intervention promoting consumption of ASFs on maternal ASFs knowledge, child milk consumption and dietary diversity among beneficiaries of a livestock transfer program (Flax et al., 2021). The intervention was associated with increased maternal knowledge on ASFs and child milk consumption. However, there were no significant differences between the intervention and control group on diet diversity. Similarly, the SBCC intervention did not influence household milk retention or decision to sale milk depicting that nutrition education alone is not enough to change nutrition outcomes in households with poor food security. Similarly, no difference in anthropometric indices (HAZ and WAZ z-scores) between the intervention groups were observed in Malawi when Passarelli et al (2020) assessed the impact of a poultry intervention with or without an additional nutrition BCC component on child nutrition status (Passarelli et al., 2020). Further, in Burkina Faso, McKune and others in 2020) evaluated the effect of livestock intervention (chicken gifting) and a culturally tailored behaviour change package on child egg consumption and nutrition status. The intervention involved two components, full intervention (gifting chicken + nutrition BCC) and exclusive Nutrition BCC). Both interventions significantly increased egg consumption compared to control group while full intervention significantly decreased wasting and underweight (McKune et al., 2020).

Social behaviour change communication interventions had impact on increased consumption of ASFs. However, this consumption was influenced by production and food security situation. For effective and impactful SBCC interventions, they could be tailored with an objective to increase production diversity. Furthermore, these interventions should aim to influence decision making around retention of animal source products for home consumption. Finally, SBCC interventions should target influencing how proceeds from sale of animal source products could be used for household nutrition.

Cost-effectiveness of livestock interventions in preventing acute malnutrition

Increasingly, organizations and governments are interested in evidence data on not only the effectiveness of nutrition-sensitive agricultural interventions in improving nutrition outcomes but also on their cost-effectiveness (Puett, 2019). Economic evaluation studies of agriculture nutrition and health projects are gaining prominence with the Strengthening Economic Evaluation for Multi-sectoral strategies for Nutrition (SEEMs-Nutrition) project (Levin et al., 2019) and guidelines developed by the Action Against Hunger (ACF) (Puett, 2019). However, most of the economic evaluations have focused on general agricultural interventions or cash transfer-based interventions (Fenn et al., 2017; Trenouth et al., 2018). Data on the cost-effectiveness of livestock-oriented nutrition-sensitive interventions on nutrition outcomes is scarce. Future research should focus on designing economic evaluation studies to determine how cost-effective are livestock interventions in preventing undernutrition.

Although promising, livestock programming for improved nutritional outcomes still needs more evidence to be able to confirm causal inference (Ruel et al., 2018). For example, of the 29 articles included in the evidence synthesis, 12 were randomized controlled trials reporting on varied livestock interventions/programs and nutrition outcomes. The increase in the number of randomized trials on nutrition-sensitive livestock programming is encouraging and will help elucidate empirical evidence on the influence of livestock interventions/programs on nutritional outcomes. However, livestock interventions/ programs are by nature integrated, complex and involving multiple outcomes which needs to be considered when designing such trials. A recent paper by Leroy and others provided guidance on how to strengthen causal inference from randomised controlled trials of complex interventions to ensure such trials are conducted adhering to highest scientific standards (Leroy et al., 2022). Such guidelines will be critical for future nutrition-sensitive livestock programming in providing the much-needed empirical evidence on their effectiveness in improving nutritional outcomes.

Overall, this review found considerable evidence underscoring the beneficial effects of nutrition-sensitive livestock interventions on nutritional outcomes of women and children. This was mainly through increased consumption of ASFs, improved dietary diversity and in some instances child nutritional status (stunting, wasting and underweight). A substantial heterogeneity in reporting metrics across studies was detected, which limited the number of studies and outcomes which could be included in computation of pooled effect sizes. Overall, despite the growing number of studies in this subject, the quality of the evidence is still low particularly in the African setting.

5.2 Study Objective II: Determination of the effect of providing livestock feeds to milking animals during drought periods and nutrition counselling on milk yield, milk consumption and undernutrition in women and children below five years in Marsabit County, Kenya

The study determined the effectiveness and cost-effectiveness of nutrition-sensitive livestock intervention (providing livestock feeds and nutrition counselling) in preventing undernutrition in children below five years during dry seasons in Kenya's drylands using a cluster randomised control community trial. The intervention sustained household milk yield during the dry season, increased number of tropical livestock units of milking animals the households were able to maintain at the household when the rest of the herds migrated in search of pasture and water, increased milk production and amount per TLU sustained, increased milk consumption among children < 5 years, improved child dietary outcomes and child nutritional status outcomes (stunting, wasting and underweight). Compared to the control group, intervention households produced on average 1.6 litres of milk per day per household during dry season representing a 129% increase in milk production. The increase of 0.9 litres per day is a significant achievement particularly during a dry season when most of the animals would have stopped lactation. The results are consistent with another study conducted in southern Ethiopia which also demonstrated an increase in milk production among intervention households who received dry-season livestock feed support (Sandler et al., 2015). However, it is difficult to compare the effect sizes in the two studies as their design, context and analysis methods were different.

The study demonstrated an increase in milk consumption among children in intervention households where children in the intervention arm receiving livestock feed only consumed on average 200 ml of milk per day more compared to the control group, while children in the intervention arm who received livestock feeds plus nutrition counselling consumed on average 240 ml of milk per day more relative to the control group. This result is consistent with other studies which documented increased dairy consumption in children in households receiving nutrition-sensitive livestock interventions (Hoddinot et al., 2015; Kabunga et al., 2017; Rawlins et al., 2014). A cross-sectional survey conducted in Rwanda assessed the impact of Heifer International's dairy cows transfer program in Rwanda on milk consumption among program beneficiaries compared to non-project beneficiaries (Rawlins et al., 2014). The study used econometric regression analysis and matching techniques to test associations and concluded that the dairy cow donation intervention was positively associated with increased milk consumption for cow beneficiaries. However, the study was limited by a small sample size and the cross-sectional design which could not allow the authors to infer causal relationships. Another study in Ethiopia tested the association between cow ownership and milk consumption in children < 5 years by comparing milk consumption in children in households owning cows and those without cows. The authors concluded that cow ownership is an important driver of dairy product consumption such as milk (Ruel et al., 2018b). However, this study had limitations in that cow ownership is non-random and the study design was non-experimental hence could only report associations and not cause-effect relationships. A study in Uganda analysed the Uganda 2009/2010 national panel survey (UNPS) data using propensity score matching to assess the association between the adoption of improved dairy cows and milk consumption and found an association between the adoption of improved dairy cows with child milk consumption (Kabunga et al., 2017). However, the study had some limitations which hindered generalization of the findings since household matching used cross-sectional data and hence can't differentiate when households adopted the improved cows. Furthermore, the use of a nationally representative dataset could have large variations in observed characteristics.

This study was designed to detect the effect of providing livestock feed intervention and targeted nutrition counselling on reducing the risk of undernutrition (stunting, wasting and underweight) in children <5 years, particularly during the dry season. A significant intervention effect on all three indicators of undernutrition where there was a decrease of up to 11% in the risk of wasting and being underweight and an 8% decrease in the risk of stunting for households that received livestock feed intervention during the dry season was demonstrated. Additionally, households that received both livestock feed and nutrition counselling intervention demonstrated up to 26% reduction in risk of acute malnutrition but had no significant effect on stunting. The pathway by which our intervention affected nutritional status indicators is likely to be multidimensional. Our current analysis supports improved diet diversity through the consumption of nutrient dense animal source foods as one path. This could have happened due to (i) increased and/ or sustained household milk yield during the dry period and the ability to retain more milking animals around the household due to the feed availability, (ii) increased income for purchasing market foods possibly from the sale of milk, and (iii) increased child-feeding knowledge from the nutrition counselling intervention. The weekly meetings with community health volunteers were expected to increase the mother's knowledge in caregiving behaviours.

Other experimental nutrition-sensitive livestock interventions have documented effects on undernutrition indicators previously although significant heterogeneity in reporting metrics and outcomes measured exists. Long et al (2012) evaluated a 5-month comparison feeding intervention of animal source foods program on toddler growth in rural Kenya. The program involved the provision of plain porridge (no animal source food), meat porridge, and milk porridge (Long et al., 2012). The study found that linear growth was significantly greater for the milk group than the meat group and plain energy porridge group although the small sample size and short follow-up period limited the clarity of the results.

Marquis et al (2018) assessed the impact of a livestock intervention involving the donation of improved chicken for egg production, provision of inputs and husbandry training on diet diversity, consumption of eggs and nutritional status (HAZ, WAZ, and WHZ) in Ghana. Compared to the control group, children in the intervention group met minimum dietary diversity and had higher HAZ, and WAZ z-scores (Marquis et al., 2018).

Prado et al (2020) and Steward et al (2019) examined the effect of an egg intervention on child development score and child linear growth respectively among young Malawian children participating in the Mazira project. The project involved the provision of 1 egg per day to children aged 6 – 15 months of age coupled with hygiene and handwashing during food preparation messages to mothers for both intervention and control groups. No significant difference between the intervention and control groups on child development score (Prado et al., 2020). Similarly, no significant intervention effect on height-for-age, weight-for-age and weight-for-height z-scores were observed (Stewart et al., 2019).

McKune and others in 2020 evaluated the effect of livestock intervention (chicken gifting) and a culturally tailored behaviour change package on child egg consumption and nutrition status in Burkina Faso. The intervention involved two components, full intervention (gifting chicken + nutrition BCC) and partial intervention (only Nutrition BCC). Both full and partial interventions significantly increased egg consumption compared to the control group while full intervention significantly decreased wasting and underweight (McKune et al., 2020). An animal health intervention in rural Kenya increased the consumption of ASFs and improved child growth. The intervention involved vaccination of chicken against Newcastle disease and parasite control while the control group received only parasite control (Otiang et al., 2021). The intervention increased both HAZ and WHZ z-scores in the intervention group relative to the control group.

Nutrition-sensitive livestock interventions incorporating nutrition and health behaviour change communication have been shown to improve child dietary outcomes and, in some cases, nutritional status outcomes. Nutrition education alone can improve child nutrition if access to and availability of food is not a limiting factor. Flax et al (2021) tested the impact of a social behaviour change communication intervention promoting the consumption of ASFs on maternal ASFs knowledge, child milk consumption and dietary diversity among Girinka livestock transfer program beneficiaries in Rwanda (Flax et al., 2021). The intervention was associated with increased maternal knowledge of ASFs, and child milk consumption but there were no significant differences between the intervention and control groups on diet diversity which the authors attributed to low milk production and high levels of food insecurity and poverty. Similarly, the SBCC intervention did not influence household milk retention or the decision to sell milk depicting that nutrition education alone is not enough to change nutrition outcomes in households with poor food security.

Most of the nutrition-sensitive livestock interventions have the greatest impact on dietary outcomes. This study demonstrated the impact on dietary diversity where households in the intervention group had improved household dietary diversity scores, and children in the intervention group were 2.5 times more likely to attain minimum dietary diversity for children and the mothers were 4 times more likely to attain minimum dietary diversity for women relative to those from the control group. Other previous studies have also demonstrated the impact on dietary diversity outcomes (Flax et al., 2021; Lenjiso et al., 2016; Lutter et al., 2021; Marquis et al., 2018; Rawlins et al., 2014). A study in Rwanda assessed the impact of dairy cow and meat goat donation programs on dietary diversity and found increased individual dietary diversity for dairy cow beneficiary households. Receiving a dairy cow was associated with an average increase of 1.17 food groups consumed (Rawlins et al., 2014). In Ethiopia, a comparison of dietary diversity among children in milk market participating households compared to non-participant households depicted that milk market participant households have significantly higher levels of dietary diversity of young children. Milk market participant households had a mean dietary diversity score of 5.3 while non-participants have a score of 4.3 (Lenjiso et al., 2016). In Ghana, the provision of chicken and husbandly training was associated with children in the intervention group meeting minimum diet diversity (AOR 1.65, 95% CI 1.02 - 2.69) compared to children in the control group (Marquis et al., 2018).

The strengths of the study included the implementation of a cluster randomised controlled trial design, the selection of the clusters sufficiently separated to prevent treatment contamination and the blinding of the research assistants to prevent them from knowing the allocation of treatment interventions to the clusters to minimise bias.

In summary, this study demonstrated that integrated nutrition-sensitive livestock interventions that increase access to high quality nutrient dense animal source foods and women's nutrition and health knowledge can improve dietary diversity, height-for age z scores, weight for height z scores and weight for age z scores.

5.3 Study Objective III: Establishing the burden and effect of zoonoses (brucellosis & Q-fever), childhood illness syndromes (diarrhea, fever & acute respiratory infections) and their association with undernutrition in children below five years in Marsabit County, Kenya

5.3.1. Epidemiology, burden, and impact of brucellosis on child nutrition status

This "One Health" sero-epidemiologic study of brucellosis among people and their livestock from a predominantly pastoral community in Kenya indicated a high prevalence of brucellosis in people and domestic ruminants from the same households. By simultaneously studying both people and their livestock, we examine the associations between exposure status in animals and people and find a significant association between animal and human brucellosis seropositivity at the household level. Further, we explored factors associated with increased risk of brucella species exposure in both human and domestic ruminant populations and highlighted the implications of our findings to disease burden, spread, and control strategies.

A systematic review of brucellosis in Kenya estimates that the national human brucellosis seroprevalence is 3%, compared to 10.3% among pastoralist communities (Njeru, Wareth, et al., 2016), supporting the estimate of 11% in our study community. Nevertheless, our estimate is lower than those reported in other pastoralist communities, which range between 14% and 36% (Kairu-Wanyoike et al., 2019). The high seroprevalence observed in pastoralist communities is attributed to the increased frequency of human contact with infected livestock and consumption of unpasteurized dairy products . Infected animals shed bacteria in milk and parturition materials, which increases the probability of human infection during human-animal interactions (Munyua et al., 2021). This may also explain why women in our study, the majority of whom were herders, had higher seropositivity than children. Further, assuming that brucellosis is endemic in this setting, older persons in general are likely to have more exposure over time compared to children.

The higher seroprevalence in animals compared to humans in our study (19% vs. 11%) suggests a higher likelihood of exposure among animals than humans. In nomadic production systems, large herds interact in communal grazing lands and watering points, increasing the likelihood of disease transmission (McDermott & Arimi, 2002). Nevertheless, these results contrast those of an earlier study in Kenya which reported seroprevalence levels of 3.5% in animals and 35.8% in humans (Kairu-Wanyoike et al., 2019). The observed differences may be attributable to differences in our study populations. We sampled children <5 years and reproductive-age women in a community that practices a pure pastoral production system, while the earlier study sampled the general population in a community that practices irrigated agricultural production.

The seroprevalence of brucellosis among animals varied by species. There were four- and three-fold higher odds of brucellosis seropositivity in goats and sheep, respectively, compared to camels. Similar results have been reported in two pastoral settings in Kenya which found a higher likelihood of exposure among small ruminants compared to other species (Osoro et al., 2015). This could be because small ruminants mainly graze near homesteads where abortions are more likely to occur, increasing their risk of exposure. Alternatively, these differences may be due to varying susceptibility to *Brucella* spp. among different animal species. Further research is required to determine the drivers of species differences in *Brucella spp*. infection in this setting.

Seropositivity at the herd level increased with increasing herd size. Similar relationships have been reported in previous studies (Ali et al., 2017; Kairu-Wanyoike et al., 2019; Muma et al., 2007; Terefe et al., 2017) and could be explained by the higher probability of mixing between infected and susceptible animals in large herds (Racloz et al., 2013). Additionally, the pastoral production system increases the probability of animal contact between and within herds due to communal grazing systems, and the concentration of animals at common watering points (Racloz et al., 2013).

The study found higher odds of brucellosis seropositivity among livestock from households with formally educated than non-formally educated household heads, contrary to findings by Njenga *et al*., (Njenga et al., 2020). Formally educated household heads are more likely to own larger herds due to their higher economic status which may have contributed to the observed higher brucellosis prevalence.

The study found a significant association between human and animal seropositivity at the household level, with the odds of human seropositivity being 1.8 times higher in households with a seropositive animal compared to those without. These results indicate that seropositivity in humans depends on human–animal contact (Kubuafor et al., 2000; McDermott & Arimi, 2002) and that animals are reservoirs and sources of brucellosis for humans (Kairu-Wanyoike et al., 2019; Osoro et al., 2015). Unlike our study, studies conducted in Togo and Mongolia found no associations between human and animal brucellosis seropositivity (A. S. Dean et al., 2013; Zolzaya et al., 2014). This may be attributed to the village-level sampling employed in the two studies. Further, the study in Mongolia did not require human and animal sampling from the same households.

This study finds no correlation between brucellosis seropositivity in humans and malnutrition. Nevertheless, since we tested for exposure to *Brucella* spp., we could not distinguish past exposure and active brucellosis infections. Therefore, we cannot rule out the influence of brucellosis infection on human nutritional status either directly or indirectly.

This study provides evidence that brucellosis is endemic in pastoralist settings and there is a significant association between animal and human brucellosis seropositivity at the household level. These data can contribute to formulating targeted control interventions that focus on the risk factors that are unique to such communities. Public health sensitization and sustained human and animal brucellosis screening are required. To better assess the true burden of brucellosis, its transmission dynamics and socio-economic impact, further studies are warranted. Coupling linked human-animal study approaches with the use of molecular diagnostic techniques to speciate circulating *Brucella* spp. may provide detailed information to guide brucellosis control and prevention interventions.

5.3.2. Epidemiology, burden, and impact of Q fever on child nutrition status

The study reports a high prevalence of *C. burnetii* in domestic ruminants with more than two-thirds of goats and sheep, and more than a third of camels previously exposed. We also report a high prevalence of *C. burnetti* in people with exposure levels in children (13.3%) similar to those observed in adults (11.3%) suggesting a high infection pressure in the study region of northern Kenya. By studying both people and their livestock, we explore the associations between exposure status in animals and in people and do not find clear results suggesting a direct association at household level. Further, we explored factors associated with increased risk of *C. burnetii* exposure in both human and domestic ruminant populations and examined the implications of our findings to disease burden, spread, and control strategies.

There were no statistically significant differences in *Coxiella burnetii* exposure levels among children <5 years and women of reproductive age. This could possibly be due to high *Coxiella burnetii* infection levels in this setting making the probability of exposure between children and adults almost similar as children are exposed to *Coxiella burnetii* early in life (Kobbe et al., 2008). The exposure to *C.burnetii* in children has been reported elsewhere (Kobbe et al., 2008). Our results differ from previous studies which showed greater risk in older people and attributed it to the cumulative risk of exposure in older people compared to children (Njeru et al., 2016). However, children's naïve immune response could be a predisposing factor. Furthermore, our results suggest that Q-fever is not just an occupational hazard among adults but also affects children. Lactating women had higher odds of exposure compared to non-lactating women. *C. burnetii* has been isolated from breast milk previously (Boden et al., 2012; Kumar et al., 1981; Prasad et al., 1986). However, the pathogenic role of *C. burnetii* in lactating women is still uncertain. Further research on the role of physiological status including pregnancy and lactation in Q-fever transmission dynamics is plausible.

Very high seroprevalence was recorded in animals compared to humans where for every 100 animals sampled, at least 69 of them had been previously exposed. Goats had the highest seroprevalence with three-quarters of the sampled goats having been exposed to Q-fever compared to 57% of sheep and 37% of camels. This could be associated probably with environmental exposure with goats being browsers and closer to the ground compared to camels hence a higher risk of exposure through a contaminated environment. Future studies in this setting should consider environmental sampling. At the herd level, for every ten herds sampled at least eight had an animal positive for Q-fever antibodies. The results indicate the disease is endemic in animal and human populations in this setting. A study by Larson and others found *C. burnetii* seroprevalence estimates of 20% in cattle, 18% in goats and 13% in sheep in Laikipia county (Larson et al., 2019). Another study conducted in two arid and semi-arid (ASAL) counties of Isiolo and Samburu found a *C. burnetii* seroprevalence of 21% in camels (Muturi et al., 2021). A recent systematic review conducted in Kenya recorded evidence of *C. burnetii* infections ranging from 7% – 20% in sheep, 20% - 46% in goats and 20% - 46% in camels in Kenya (Njeru et al., 2016). This study recorded higher seroprevalence estimates in animals compared to previously conducted studies in the country. However, our study focused on lactating animals proving milk to households that were all female and older animals. Previous studies have shown higher seroprevalence estimates in female animals as well as older animals (Benaissa et al., 2017; Hussein et al., 2015; Muema et al., 2017). All our sampled animals were female and female animals are more likely to be in closer proximity to birth products the primary route of infection as well as being older compared to the general population.

Significant differences in apparent exposure levels to *C. burnetii* were observed among the animals included in this study. Our multivariable analysis revealed that seroprevalence varies by species, geographical location (ward) and the main occupation of the household head for the combined goats, sheep and camels data. Seropositivity across the three sampled species was heterogenous with goats being 5.4 folds and sheep 2.6 folds likely to be seropositive compared to camels. The results indicate goats are an important species in the transmission dynamics of *C. burnetii* in this region. Other studies have found similar trends in Kenya and by extension the African continent where high exposure levels have been found in goats compared to sheep (Abushahba et al., 2017; Folitse et al., 2020; Klaasen et al., 2014; Muema et al., 2017). However other studies have also recorded higher seroprevalence estimates in sheep compared to goats (Johnson et al., 2019; Ruiz-Fons et al., 2010) hence further research is required to understand the inherent differences in *C. burnetii* transmission dynamics among small ruminants.

Several studies have documented age as a determinant of *C. burnetii* exposure in animals, where increasing age is associated with increased odds of being *C. burnetii* antibody seropositive (Browne et al., 2017; Dhaka et al., 2020; Filioussis et al., 2017; Klemmer et al., 2018; Lafi et al., 2020). However, in our study, age was not statistically associated with *C. burnetii* antibody seropositivity. This could be partly due to the choice of our study animal population which were mainly lactating animals whose age structure may not be very different hence the disease epidemiology is more homogenous as compared to the general animal population.

In the last few years, studies looking at the epidemiology of *C. burnetii* in camels in Kenya have shown high exposure levels to the pathogen in northern Kenya and provided evidence camels play a significant role in the epidemiology and transmission of *C. burnetii* to humans and other domestic animals (Browne et al., 2017; Larson et al., 2019; Muturi et al., 2021). Consequently, in the design of surveillance, prevention and control measures for this pathogen should consider the growing camel population in this setting.

Significant differences in *C. burnetii* antibody seropositivity were observed in animals reared in different geographical locations (wards). Animals from Laisamis and Loiyangalani wards had a 1.4- and 1.7-folds higher likelihood of being *C. burnetii* seropositive respectively compared to animals from Kargi/SouthHorr ward. Since animals from the region are all reared in the same system of nomadic pastoralism, other factors could have contributed to the observed heterogeneity in *C. burnetii* exposure levels. Although our study did not collect and incorporate environmental covariates as putative risk factors for *C. burnetii* seropositivity in animals, environmental factors such as vegetation density, precipitation, wind speed and soil characteristics could play a role in explaining the observed differences in *C. burnetii* seroprevalence in animals across the different wards (Clark & Soares Magalhães, 2018; Van Leuken et al., 2016). Previous studies have explored the role of environmental factors in *C. burnetii* dispersal as documented during the outbreak in Netherlands (Roest et al., 2011; Van Der Hoek et al., 2011; Van Leuken et al., 2016), however spatial epidemiological studies on the role of environmental factors in *C. burnetii* dispersal are rare in the region, which limits our understanding of the role of environmental factors in Q-fever transmission dynamics in this setting.

The study was conducted in an area with high rates of undernutrition (Wayua, 2017). The relationship between infectious diseases and malnutrition has been shown to be bidirectional in which infections weaken the body's ability to fight diseases and cause malnutrition (Ambrus & Ambrus, 2004; Farhadi & Ovchinnikov, 2018). However, data on the effect of zoonoses such as Q-fever on human nutrition outcomes are extremely rare in this setting (Thumbi et al., 2015). The study findings found no association between Q-fever seropositivity in humans and malnutrition. However, the study only looked at exposure to *C. burnetii* and could not distinguish past exposure and active infection of Q-fever, hence cannot rule out the influence of Q-fever infection on human nutritional status.

Increased risk of adverse pregnancy outcomes such as abortions and other reproductive disorders have been reported among women infected with *Coxiella burnetii* in previous studies (Nielsen et al., 2014). In this setting where high levels of *C. burnetii* exposure in women were reported, further investigation on the possible effect on *C. burnetii* infection on reproduction in women should be explored.

This study reported the exposure to Q-fever in humans and livestock among the pastoral community in Marsabit, Northern Kenya. Our results indicated that Q-fever is endemic in this setting, although the disease is neglected and not part of the diseases considered in surveillance and routine diagnosis at health facilities and veterinary diagnostic laboratories. Further studies designed in a One Health approach and utilizing molecular diagnostic tests to identify active *C. burnetii* infection are required to identify factors modulating *C. burnetii* burden and transmission dynamics and its effects on health and nutrition in humans in this setting. Such evidence will be beneficial in setting the country's disease control and prevention strategies.

5.3.3. Epidemiology, Burden, and Impact of reported child illness syndromes on acute malnutrition

Childhood health and nutrition is a critical global public health issue. Diarrhea, fever and acute respiratory infection constitute major causes of morbidity and mortality in children before their fifth birthday (Rahman & Hossain, 2022). Enteric and respiratory infections are believed to lead to acute weight loss, which can lead to acute and/ or chronic undernutrition. Children with diarrhoea who have acute malnutrition are at higher risk of mortality compared to their healthy counterparts (Tickell et al., 2020).

The study demonstrated a significant association between reported syndromes diarrhoea, fever and acute respiratory infections with acute malnutrition where children who experienced these syndromes in the two weeks preceding a data collection visit had a 1.64 times higher risk of being malnourished. The complex relationship between childhood infections and malnutrition has been described in previous studies. For instance, diarrhoea is associated with impaired weight gain due to reduced nutrient intake and malabsorption and malnutrition can lead to increased susceptibility to or severity of diarrhoea (Guerrant et al., 1992; Mata, 1992). Interventions that interrupt the transmission of infection may also have an impact on nutritional status. Such interventions such as access to improved sanitation and hygiene may improve child nutritional status by reducing exposure to enteric and respiratory pathogens (Bountogo et al., 2021).

A bi-directional relationship between malnutrition and infections has been established. Malnourished children are at increased risk of infection while acute, chronic or recurrent infections contribute to malnutrition. Malnourished children suffer increased frequency of infectious disease, children with malnutrition are at significantly higher risk of more severe disease and suffer significantly more acute and long-term morbidity and mortality when infected (Katona & Katona-Apte, 2008). The complex mechanism through which malnutrition and disease operates is mainly through the roles of the environment, burden of exposure to pathogens because of crowding or poor water and sanitation, gut microbiota, chronic intestinal inflammation, mucosal barrier loss and immune function. Colonization of gut, respiratory and other mucosal surfaces, is associated with infections. Malnutrition causes change in the normal pattern of colonizing organisms and alters the normal barrier functions (Walson & Berkley, 2018).

5.3.4. Costs and Cost-effectiveness of nutrition-sensitive livestock interventions in preventing undernutrition

We conducted an economic evaluation on the cost-effectiveness of a cluster randomised controlled trial providing livestock feed and nutrition counselling during dry season in preventing undernutrition in children < 5 years in a pastoralist community in Kenya. The livestock feeding intervention decreased the risk of wasting and stunting by 11% and 8% respectively and averted 89 cases of wasting and 65 cases of stunting while the livestock feeding, and nutrition counselling intervention decreased the risk of wasting by 26% and averted 192 cases of wasting. Both interventions were considered cost-effective in preventing wasting but not stunting.

The cost to avert a case of wasting in the feed-only intervention was $5,326.3 while the cost to avert a case of wasting was $ 3086.4 in the feed plus nutrition counselling intervention. The cost to avert a case of stunting was $ 7,293 in the feed-only intervention, but it was not statistically significant in the feed plus nutrition counselling intervention. Although there is a scarcity of similar cost-effectiveness studies to compare these results with, there is published evidence on effectiveness in preventing wasting for other interventions such as cash transfer programs (Trenouth et al., 2018).

Although evidence on the cost-effectiveness of nutrition-sensitive interventions is on demand by organizations and governments, the evidence data on the effectiveness of nutrition-sensitive agricultural interventions in improving nutrition outcomes is limited (Puett, 2019). Economic evaluation studies of agriculture nutrition and health projects are gaining prominence with the Strengthening Economic Evaluation for Multi-sectoral strategies for Nutrition (SEEMs-Nutrition) project (Levin et al., 2019) and guidelines developed by the Action Against Hunger (ACF) (Puett, 2019). However, most of the economic evaluations have focused on general agriculture interventions or cash transfer-based interventions (Fenn et al., 2017; Trenouth et al., 2018). These results provides the first step in improving livestock programming for improved nutrition status in children particularly among pastoral communities.

5.4 Limitations of the study

The main limitation of the study is the use of three intervention arms instead of four which hindered the understanding of the net impact of nutrition counselling intervention on undernutrition. This was due to financial constraints. Secondly, biological samples were analysed using serology only and determined the burden of brucellosis and Q-fever based on IgG antibodies which could not differentiate past exposure and active infection. Although serology is useful in screening for exposure to pathogens it may not determine the presence of a clinical infection which could have affected the analysis demonstrating an association between brucellosis and Q-fever with child nutrition outcomes. Furthermore, the study was not able to determine the outcome of micronutrient deficiencies otherwise known as hidden hunger which was a missed opportunity in the study although dietary diversity was a proxy to give direction on possible deficiencies.

On the other hand, although the communities were trained not to share feed with non-project beneficiaries, they still shared due to strong kinship ties which might have underestimated the treatment effect in the study. This finding should be interpreted in this context.

Specific limitations for each objective are provided. The systematic review and meta-analysis are subject to some limitations that ought to be considered when interpreting the study findings. One limitation is that it synthesised evidence from heterogenous study designs and outcome variables that potentially affects some of the study conclusions. The second weakness of the review is that it synthesised evidence based on the direction of the association and focused on the positive effects of livestock interventions and did not consider infection status and morbidity outcomes, and therefore the review did not provide a holistic approach on the effect of livestock interventions on health and nutrition. The other potential limitation is that there were very small (4) number of studies that were included in the meta-analysis and from which pooled effect sizes were calculated, which might have reduced the precision of our estimates. This was because of heterogeneity in reporting metrics of the studies included in the review. Furthermore, the review left out other important outcomes such as women empowerment and seasonality of malnutrition in our review, which could have provided a clear picture on the pathways from livestock interventions to improved nutritional status.

Despite the above-mentioned limitations, the review has several strengths that makes the study findings useful and contributes to the body of evidence in this field. The computation of pooled effect sizes on the impacts of livestock interventions on nutritional outcomes is the first step in providing the much-needed evidence on the impact of nutrition-sensitive livestock interventions/ programs on nutrition outcomes for vulnerable communities. Secondly, the focus of our study in the less studied Africa continent provides evidence for governments and development partners for decision making. Further, focusing on livestock interventions provides an excellent opportunity to elucidate evidence on the net contribution of livestock to human nutrition outcomes and could provide evidence for a policy shift in nutrition-sensitive programming particularly for livestock dependent communities.

For the brucellosis study, the study population comprised lactating animals, children < 5 years, and women of reproductive age. While these populations provided data on exposure levels for this population, they may not be representative of the general population. The lack of sampling cattle, which is also a key species kept in this setting limited the generalizability of our results. The cross-sectional nature of our study limited our assessment of temporal variations in brucellosis seropositivity. We used an indirect IgG ELISA to test the presence of antibodies against *Brucella* spp. and could not distinguish between past exposure and active infections. Further, failure to also consider using an IgM ELISA kit in addition to the IgG may have led to failure to detect some positive cases that had the acute phase of the disease, and hence our reported seroprevalence may not be the true prevalence of the disease due to potential misclassification bias. However, a key strength of this study is the use of the One Health concept by simultaneously assessing brucellosis exposure in people and their livestock. In this case, we find evidence of a household-level association between levels of exposure to brucellosis in livestock and people

for the Q fever study, the use of an indirect IgG ELISA to test the presence of antibodies against *C. burnetti* could not distinguish between historical exposure and active infections. Additionally, the tests used had less than 100% sensitivity and specificity which could pose a risk of misclassification. The study population was mainly female animals providing milk to households and children under five years and women of reproductive age. Although this population could provide valuable information on disease transmission and exposure levels for this population segment, the estimates may not be representative of the general population as not all ages and gender are included in the study. Our study did not include environmental factors as covariates when investigating factors associated with Q-fever antibody seropositivity, which may have accounted for some of the observed variations across different geographical study regions. Our study sampled only females and children for the humans which does not provide a complete randomized profile of human populations in the survey area. Although this was informed by the need to link the disease burden data with maternal and child nutritional data, future works should aim at sampling all age groups and gender in this setting. However, a key strength of our study is the use of the One Health concept by simultaneously assessing Q-fever in people and their livestock. In this case, we do not find evidence of a household level association between levels of exposure to *C. burnetii* in livestock and people. However, this finding is biologically plausible given that the main mode of transmission for *C. burnetii* is the inhalation of aerosols from a contaminated environment, hence human exposure could occur even outside the household level given the disease's endemicity in the region.

The economic evaluation study was subject to some limitations. First, the cost-effectiveness analysis methodology is limited in that the full effect of nutrition-sensitive livestock interventions could have been underestimated since cost-effectiveness ratios are calculated using a single effectiveness result at a time and no provision/index for programs with a potentially wide range of outcomes. In addition, livestock interventions are likely to appear less cost-effective in achieving nutrition objectives compared to nutrition-specific interventions due to the diverse causal pathways between nutrition-sensitive interventions and nutrition outcomes.

Finally, the study utilized activity-based costing from a provider perspective. This led to failure to account for beneficiary costs incurred to receive the intervention such as transportation fares to distribution and time spent during distributions which could have been factored in had we used a societal perspective. However, these costs were minimal as the feeds were delivered to the village level. Furthermore, the focus of the study was on providing evidence to governments and development organizations on what it will cost to implement such intervention evidence which is vital for planning especially when delivering implementations in the humanitarian context.

Despite the highlighted limitations, the study provided very crucial cost data on the cost-effectiveness of nutrition-sensitive interventions in preventing undernutrition from a cluster randomized controlled trial. Data on the cost-effectiveness of livestock-oriented nutrition-sensitive interventions on nutrition outcomes is scarce. Efforts should be put into ensuring that all nutrition-sensitive livestock interventions implemented also embed economic evaluation studies to assess the cost-effectiveness of these interventions in preventing undernutrition.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the findings, it can be concluded that:

i. From the systematic review and the meta-analysis evidence synthesis conducted, evidence on the impact of livestock interventions on nutrition outcomes is still limited despite the increase in the number of livestock interventions and programs designed with an objective of improving child nutrition increasing. This may be attributed to the heterogeneity realized in reporting metrics; implementation context; and design challenges.

ii. The nutrition sensitive livestock intervention – providing livestock feeds to milking animals during critical dry periods and regular nutrition counselling was effective in reducing the risk of acute malnutrition in children < 5 years and improved dietary outcomes during dry season. The intervention prevented the usually observed seasonal variations in levels of acute malnutrition during dry periods and/ or drought.

iii. There is a high burden of exposure to brucellosis and Q fever both in people and their domestic animals. Although the association between exposure to brucellosis or Q fever with child nutritional status was not found, its possibility cannot be ruled out since only serological tests were done with no ability to differentiate between prior exposure and active infection.

iv. There is an association between undernutrition and reported child illness syndromes of fever, diarrhea, as well as acute respiratory infections.

v. The provision of livestock feeds and nutrition counselling during dry periods is a cost-effective strategy in preventing acute malnutrition in children <5 years of age in pastoralist communities in northern Kenya during dry season or drought emergencies.

6.2 Recommendations

i. Although there is growing evidence on the role of nutrition-sensitive livestock interventions in improving child diets and nutrition status, the results of the evidence synthesis demonstrated gaps in design, sample size calculations and implementation timeframe. Furthermore, majority of the programs are integrated making it difficult to disentangle the net effect of the livestock intervention on nutrition outcomes. Researchers in the livestock, nutrition and health space should endeavour to carry out better designed randomised controlled trials are required to better determine the effectiveness of livestock interventions on nutrition outcomes of stunting, wasting and underweight. Such studies should be designed from onset with these nutrition objectives and should be powered to determine treatment effects on stunting, wasting and underweight.

ii. The provision of targeted livestock feeding during the dry season focusing on milking animals in pastoralist communities that experience frequent climatic shocks should be adopted by governments (national and sub-national) and development organizations as an integrated nutrition-sensitive livestock intervention for preventing acute malnutrition in Kenya's drylands.

iii. There is a need to develop guidelines on the timing of the intervention, the type, and quantity of livestock feed to be provided and the optimal number of tropical livestock units to be maintained in the household to sufficiently provide milk to the household during the dry season. This task could be spearheaded by the Ministry of Agriculture, Livestock and Fisheries and bring together all other relevant stakeholders.

iv. Community engagements and awareness creation on the importance of targeted livestock feeding during the dry season as a resilience-building activity and nutrition-sensitive intervention should be initiated by relevant government departments both in the ministry of agriculture and livestock development, and ministry of health as well as development partners using this study's findings as the evidence. This will allow the communities to adopt and replicate the study findings in their own context for sustainability.

v. Deliberate attempts are needed to ensure the livestock feed is available in the target communities for communities to purchase for their animals. This could be achieved by government or development partners working with the private sector to ensure commercial livestock feed are available or working with the communities to produce and preserve locally available livestock feeds for use during the dry season.

vi. There is a need to conduct awareness creation on zoonotic diseases such as brucellosis and Q-fever targeted on control and prevention interventions that focus on the risk factors that are unique to such communities. Public health sensitization and sustained human and animal surveillance is required.

vii. Community education targeted at improved hygiene and sanitation is required to reduce childhood infections such as diarrhea and acute respiratory infections (ARI) are required to ensure child health and nutrition are improved. This could include WASH programs by government and development partners.

viii. Further research using linked human-animal study approaches with the use of molecular diagnostic techniques is required to understand the true burden of brucellosis and Q-fever, their transmission dynamics in this setting, and ascertain if the two diseases have any effect on the high levels of acute malnutrition reported in these settings. Such data could provide detailed information to guide disease control and prevention interventions.

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APPENDICES

Appendix I: Consent form (English version)

Title of study: PREVENTING ACUTE MALNUTRITION IN WOMEN AND CHILDREN AMONG PASTORAL COMMUNITIES THROUGH LIVESTOCK INTERVENTIONS IN NORTHERN KENYA.

Principal investigator/ institutional affiliation: DR. JOSPHAT MUEMA. University of Nairobi , institute of Tropical and Infectious Diseases (UNITID), College of Health Sciences, P.O BOX 19676-00202 Nairobi Tel (+254) 020 4915060; Email: josphat.muema@gmail.com

Introduction:
Hi, my name is Josphat Mulei Muema. I am a PhD student at the University of Nairobi. Are you the head of household? (If not ask to speak to the head of the household).

We are carrying out a research on livestock and human nutrition by targeting children aged 5 years and below, pregnant and lactating women. This is because animal products such as milk, meat and blood form an important source of food for children 5 years and below.

Would like to hear more about the study?

Purpose of study:

The study is being conducted to gain an understanding on whether providing feed to your animals during dry periods reduces the episodes of malnutrition among children under the age of 5 years and pregnant and lactating women. The outcome of the study will help both the County government of Marsabit and the National government to have an effective Drought Risk Management programme as they work towards ensuring the citizens of Kenya are economically and socially productive. We have chosen your community because you rely on livestock as a main source of food and household incomes. When there is drought, there is decreased availability of forage, which is needed for animals to produce milk. Milk is the main component for the diet of your children under five years of age. So, when forage conditions get worse, so do the levels of acute malnutrition. We estimate that 1800 households from the community will take part in the study.

What will happen today?

If you take part in the study, we will ask you a few questions today. This will take about 30 minutes. You can choose not to answer any questions. The questions will be about your willingness and eligibility of your household and household members to participate in the study. If we find that you are eligible to take part and are willing to participate in the study, we will enroll you in the study. Once the study begins, it will continue for 18 months. If we find that you are not eligible or are unwilling to participate, we will exclude you from participating in the study.

What will happen during the study?

The study will be conducted in Laisamis sub-county. Villages within a select number of wards will participate in the study. Each selected village will be assigned one of three study arms, and all qualifying households in that village will receive the same treatment. One arm will be receiving livestock feed enough to feed 2-3 milking animals during the dry period. Second arm will receive livestock feed and nutritional education and counselling. The third arm will be a control, and will not receive the two interventions from the study but will receive deworming medicines for their animals. These dewormers will also be given to households in arms 1 and 2 of the study. All study households will be visited by animal health assistants in the study, and if animals are sick they will receive veterinary advice. We will visit your house every six weeks and every three months. These visits will take about 30-60 minutes. During the visits, we will:

- Collect the height, weight and middle upper arm circumference of child, lactating women and pregnant women
- Ask you about the food intake of the child, lactating women and pregnant women in your household during the several days before our visit
- Ask about milk production data
- Ask about the health status of household members
- Ask about your livestock and their health status
- Ask about the hygiene practices
- At the time of starting the study and at the end of the study, we will request to collect 10ml of blood samples from 2-3 of your milking animals.
- For mothers and children enrolled in the study, blood samples will be collected at enrolment time and at the end of the study. No more than 5ml of blood will be collected from children and mothers.

What will happen to the samples collected?

The samples will be sent to the University of Nairobi institute of tropical and infectious diseases (UNITID) laboratories. Blood samples from the livestock will be tested for infections that can infect humans. Samples from people will be tested for diseases that can be passed from animals to humans such as brucellosis and Q fever. The samples will be stored at these laboratories until the data analysis is complete and the study report is written.

Benefits of being in the study

- If in the intervention arm one, you will receive livestock feeds enough to feed 2 -3 milking livestock, and if in intervention arm 2, you will receive similar feed as arm 1 for your livestock and nutritional education and counselling. All households will receive veterinary advice during household visits and dewormers for their livestock.
- You will be helping us have a better understanding on ways of reducing malnutrition among children under 5 years who live in pastoral communities.

Risks

There are minimal risks involved with this study.

- The interviews and sample collection procedures will take time and may inconvenience you. Well-trained personnel will conduct these in order to minimize any such risk
- Giving any milk, and blood samples does not pose any risk to the participant

Privacy

Information about your household and your child will be kept private to the extent allowed by law. Your child's name and location of your household will be recorded so that the study workers can find you every round during the study. The name and contact information of a neighbor may also be recorded, or for someone that can help us locate you in case you are away from home when we stop by. Only the study team and the ethics committee can see your information. All the information will be kept in secured computer files. No one will be able to identity you or any member of your household who has participated in the study. All personal information that can identify you will be destroyed and not used in any publication.

Voluntary

Your participation in this research is completely voluntary. You may choose not to be part of the study. There will not be any penalty if you choose not to participate. You may choose not to answer specific questions or to stop participating at any time.

Who to contact

If you have questions or concerns about this study you can call Josphat Muema on 0721778740. If you have concerns regarding your personal rights as a research participant in the study or would like to report a concern or complaint about this study, please contact **Kenyatta National Hospital / University of Nairobi Ethics Review Committee(KNH-UoN ERC)** Tel. **2726300 Ext 44102 Nairobi – Kenya or E-mail: uonknherc@uonbi.ac.ke.**

Signature of participant *(if the participant is literate)*

The risks and benefits of this study have been explained to me. I have had a chance to ask questions. All my questions were answered. I can choose to be in this study. I can drop out of the study at any time. I will receive a copy of this.

I agree to participate.

Date (DD/MM/YY): ______________________

Name of parent (print): __________________

Signature of parent: ____________________ OR Thumbprint: __________________

Name of child ________________________

Name of lactating woman ______________

Name of pregnant woman _____________

SIGNATURE OF WITNESS: (*if participant is illiterate*)

I have heard the explanation of this study. The procedures, risks, and possible benefits were explained to me. I do not work with the principal investigator or with any other person who works under or with the investigator. I confirm that the participant has voluntarily consented to participate in this study.

Date (DD/MM/YY): _____________________________

Name (print): _______________________________

Signature: _______________________________ OR Thumbprint: _________________

Statement of Person Obtaining Informed Consent

I have carefully explained to the parent of the child being asked to take part in the study what will happen to their child.

I certify that when this person signs this form, to the best of my knowledge, he or she understands the purpose, procedures, potential benefits, and potential risks of his or her child's participation.

I also certify that he or she:

- ☐ Speaks the language used to explain this research
- ☐ Reads well enough to understand this form or, if not, this person has heard and understood when the form was read to him or her
- ☐ Does not have any problems that could make it hard to understand what it means for his or her child to take part in this research.

__________________________________ ________________________

Signature of Person Obtaining Consent Date

__________________________________ ________________________

Printed Name of Person Obtaining Consent

Appendix II: Household level data collection questionnaire

1.0 Household level Data Questionnaire

(This is a follow up questionnaire, which captures household level details including household demographics, and socio-economic status. This should be administered at recruitment (month 0) and after every 3 months.

1.1 Interviewer ID code _________________
1.2 Ward: _________
1.3 Sublocation: _________
1.4 Village Name: _________

2.0 Household details

2.1 Interview Date _____
2.2 Household ID code ___/___/___
2.3 GPS Coordinates ____________
2.4 Visit Number ________

3.0 Household eligibility

3.1 Is the Household Eligible? ________

(1. Yes 2. No) ***(if Yes, skip to 4.0. If no, go to 3.2 after which the questionnaire will end)***

3.2 If NO, Reason for ineligibility ________

(1. No Adult Occupier > 16 years 2. Withdrawal 3. Other Reason)

If "Other Reason", Specify _____________

4.0 Respondent details

(Preferably the household head, if not available – spouse or most senior household member

4.1 Name of the respondent _____________ (First name, last name)
4.2 Gender of the respondent _____________

(1. Male 2. Female)

4.3 Respondent's Date of Birth ___(select date) (***The respondent should be more than 16 years)***
4.4.Respondents age ____________
4.5 Is the respondent the household head? ____________
Yes 2. No) (***If Yes, go to 4.7. If No, go to 4.6)***
4.6 If No, what is the relationship of the respondent to the household head?_____ (***choose one)***
Spouse 2. Son/daughter 3. Brother/sister 4. Uncle/aunt 5. Nephew/niece 6. Grandchild 7. Other)
If "Other", Specify________________
4.7 What is the respondent's highest level of education?____________ **(*choose one)***

(1. No formal education 2. Primary school 3. Secondary school 4. College-graduate 5. Madrassa 6.Other)

If "Other", Specify _______________

4.8 What is the respondent's marital status?___________ ***(choose one)***

(1. Single 2. Married monogamous 3. Married polygamous 4. Divorced/Separated 5. Widow(er)).

4.9 What is the respondent's primary occupation?____________ ***(choose one)***

(1. Livestock herding 2. Own farm labor 3. Employed (salaried) 4. Waged labor (casual)) 5. Petty trade 6. Merchant/trader 7. Firewood/charcoal 8. Fishing 9. Income earned by children 10.Other)
If "Other", Specify _________________

4.10 What is the respondent's secondary occupation?__________ ***(choose one)***

(1. Livestock herding 2. Own farm labor 3. Employed (salaried) 4. Waged labor (casual) 5. Petty trade 6. Merchant/trader 7. Firewood/charcoal 8. Fishing 9. Income earned by children 10.Other)
If "Other", Specify _________________

4.11 Does the respondent own a Mobile Phone?

(1. Yes 2. No) ***(If Yes, go to 4.11.1. If No, go to 5.0)***

4.11.1 If Yes, what is the mobile phone number ____________(numeric)

5.0 Household demographics

5.1 How many people currently live in this household? ___________ (numeric)

5.2 How many of them are males? ________ (numeric)

5.3 How many of them are females? ________ (numeric)

Age categorization

5.4 Select the age category and number of household members in each category

Age Category	Number of Males	Number of Females
□ 0 – 3 years	______________	________________
□ 4 – 5 years	______________	________________
□ 5 – 18 years	______________	________________
□ Above 18 years	______________	________________

5.4.1 Do any of household children attend school?

(1. Yes 2. No) ***(If Yes, continue to 5.4.1.1. If No, skip to 5.4.2)***

5.4.1.1 If Yes, how many males attend school ___________

5.4.1.2 How many females attend school __________

5.4.1.3 In the last one month of school, has any of them missed school?

(1. Yes 2. No)

5.4.2.1 If Yes, how many days have they missed school in total?

Males _______________ (numeric)

Females _____________ (numeric)

5.4.1.4 What was the main reason for missing school?

Males___________________ ***(choose one)***

(1. Sickness 2.Weather (rain, floods, storms) 3.Family labor responsibilities 4. Working outside home 5. Teacher absenteeism 6. Too poor to buy school items 7. Household doesn't see value of schooling 8. No food in the schools 9. Migrated/moved from school area 9. Insecurity 10. No school near by 11. Married 12. Others)

If "Other", Specify_____________

Female _________________ ***(choose one)***

(1. Sickness 2.Weather (rain, floods, storms) 3.Family labor responsibilities 4. Working outside home 5. Teacher absenteeism 6. Too poor to buy school items 7. Household doesn't see value of schooling 8. No food in the schools 9. Migrated/moved from school area 9. Insecurity 10. No school near by 11. Married 12. Pregnancy 13. Others)

If "Other", Specify_____________

5.1.4.5 How much money in total has the household spent on education in the last three months? Kshs. _________(numeric)

5.4.2 For the ones above 18 years, please fill in the table below for each person (will have entry for 10 people)

Age	Occupation	Highest level of Education
____________________	______________________	_____________________
____________________	______________________	_____________________

6.0 Household socio-economic status

6.1 Does the households currently own any of the following assets:

Asset	Yes/No	No. of items in usable condition
□Radio		
□Phone		
□Fridge		
□TV		
□Bicycle		
□Animal drawn cart		
□Car		
□Motorbike		

6.2 Does the household have electricity ______?

(1. Yes 2. No)

(Enumerator to observe from the homestead for the following)

6.3 Observe the main material of the floor of the dwelling and record observation _ (***choose one)***

(1. Natural floor (earth, sand, dung) 2. Rudimentary floor (wood planks, palm/bamboo) 3. Finished floor (cement, polished wood, ceramic tiles) 4. Other, specify______)

6.4 Observe the main material of the exterior roof of the dwelling and record observation **(choose one)**

(1. Locally available materials (e.g. old clothes, old boxes) 2. Rudimentary roofing (polythene, cardboards, blankets) 3. Improved roofing (sisal, iron sheets, hide (skin)) 4. Other, specify_______)

6.5 Observe the main material of the exterior walls of the dwelling and record observation ***(choose one)***

(1. Locally available materials (old clothes, old boxes, mud/cow dung) 2. Rudimentary walls (polythene, cardboards, blankets) 3. Finished walls (sisal, iron sheets, tiles, hide (skin)) 4. Other, specify______)

6.6 What is the household main current source of income? _______________ ***(choose one)***

(1. Sale of livestock 2. Sale of livestock products 3. Sale of crops 4. Petty trading (e.g. sale of firewood), casual labor 5. Employment (salaried income) 6. Sale of personal assets 7. Remittance 8. Other, specify ___________)

6.7 In the last one month, has the household received money from the following cash transfer programs? __________

Program	Yes/No	Amount received
Hunger Safety Net		
Orphaned and Vulnerable children		
Older persons		
People with disabilities		
Nutrition Improvement through cash and health education		

6.8 In the last one month, have the household received any relief assistance? ________
(1. Yes 2. No)

7.0 Livestock ownership and herd dynamics

7.1 How many animals of each species do you own currently have? ________________ (*Fill in the number in the table below)*

7.2 In the last one month

- Have there been births among your animals ______(1. Yes 2. No)
- Have there been deaths among your animals _____(1. Yes 2. No)
- Have you received any gifts in form of animals _____(1. Yes 2. No)
- Have you given out any of your animals _____(1. Yes 2. No)
- Have you purchased any animals into your herd _____(1. Yes 2. No)
- Have you sold any animals from your herd _____(1. Yes 2. No)

(If "Yes" to any of the above, fill the number of animals in the appropriate sections in the table below. If No, skip to 8.0)

Species No. currently No. Births No. Deaths No. Gifts in No. Gifts Out No. Purchased No. Sold

- Calves (< 12 months)
- Adult bulls (<1 year)
- Adult cows (< 1 year)
- Sheep (<6 months)
- Male sheep (> 6 months)
- Female sheep (> 6 months)
- Goats (< 6 months)
- Male goats (> 6 months)
- Female goats (> 6 months)
- Camels (< 12 months)
- Male camels (> 12 months)
- Female camels (>12 months)
- Chicken
- Others

If "Others", Specify

7.2.1 If Yes, to purchases

Species	Total purchase costs (Kshs)
Cattle	______________
Sheep	______________
Goats	______________
Camels	______________

☐ Chicken ______________
☐ Other, specify

7.2.2 If Yes, to sales

Species	Total Sales (Kshs)
☐ Cattle	______________
☐ Sheep	______________
☐ Goats	______________
☐ Camels	______________
☐ Chicken	______________
☐ Other, specify	

8.0 Milking herd and milking hygiene

8.1 In the last 7 days, how many of your animals have produced milk either for own household consumption or for sale?

Species	Number of animals	Total amount of milk (litres)
☐ Cattle	______________	________________
☐ Sheep	______________	________________
☐ Goats	______________	________________
☐ Camels	______________	________________

8.2 In the last 7 days, have you sold any of the milk produced by animals in your herd?
(1. Yes 2. No) ***(If Yes, continue to 8.2.1. If no, skip to 8.3)***

8.2.1 If "Yes"

Species	Total amount of milk sold (litres)	Total income from sale (Ksh)
☐ Cattle	____________	________________
☐ Sheep	_____________	________________
☐ Goats	__________	________________
☐ Camels	______________	________________

8.2.2 In what form is the milk mainly sold?___________

☐ Fresh milk
☐ Boiled milk
☐ Sour milk
☐ Processed forms (cheese, ghee)
☐ Other

If "Other", specify__________

8.3 In the last one month, have you moved any of your milking herd away from the homestead in search of pastures/water?
(1. Yes 2. No) ***(If Yes, go to 8.3.1. If no, skip to 8.4)***

8.3.1 If Yes, which milking herd species have you moved?

☐ Cattle
☐ Sheep
☐ Goats
☐ Camels

8.3.2 If Yes, are you receiving any milk from these animals?
(1.Yes 2. No) ***(If Yes, go to 8.3.3. If no, skip to 8.4)***

8.3.3 If Yes, how many times in the last month have you received milk? ________________
8.3.4 What amount of milk have you received? ___________(litres)
8.4 If some of the milking herd has been moved away from the homestead, have you left any of the milking animals near the homestead?

(1.Yes 2. No) ***(If Yes, go to 8.4.1. If no, skip to 8.5)***

8.4.1 If "Yes"

- Which animal species and number of animals?
- How many milking animals?
- Total amount of milk produced per day (liters/day)

Species	Number at homestead	Number being milked	Total amount of milk (liters/day)
□ Cattle	_____________	_______________	_______________
□ Sheep	______________	_______________	_______________
□ Goats	______________	_______________	_______________
□ Camels	_______________	_______________	_______________

8.5 What do you use to collect the milk when you are milking? ________________

(1. Plastic container 2. Metallic/ aluminum container 3. Gourd 4.Other, specify ____)

8.6 Describe the practices conducted before milking? _____ (enumerator ticks all that apply)

□ Wash hands without soap
□ Wash hands with soap
□ Wash the teats without soap
□ Wash the teats with soap
□ Wash the container being milked to without soap
□ Wash the container being milked to with soap
□ Nothing
□ Other
If "Other", specify ___________

8.7 Do you store milk produced from your herd? _______________

(1. Yes 2. No) ***(If Yes, continue to 8.7.1. If no, skip to 9.0)***

8.7.1 If yes, for how long (on average) do you store the milk? (in hours) _______________ (numeric)

8.7.2 In what form is the milk mainly stored?

□ Fresh milk
□ Boiled milk
□ Sour milk
□ Processed forms (cheese, ghee)
□ Other
If "Other", specify__________

8.7.3 Do you store your milk in the collection container or a separate container? __ ***(choose one)***

(1. Collection container 2. Separate container 3. Both)

8.7.4 What do you use to store your milk? ______________ (***choose one)***

(1. Plastic jerry can 2. Aluminum/stainless steel jerry can 3. Traditional gourd/container 4. Other)If "Other", specify _______________

8.7.5 How do you prepare the container used for storage? ____________________ ***(choose one)***

(1. No preparation 2. Wash with water 3. Wash with water and soap 4. Wash with sand 5. Smoke the container 6. Other) If Other, specify ______________

9.0 Herd health

9.1 In the last one month, have any animals in your herd been sick? ______

(1. Yes 2. No) ***(If Yes, go to 9.1.1. If No, skip to 9.3)***

9.1.1 If yes,

Species	Number of animals were sick	Do you know the disease the animals suffered from? (Yes/No)
☐ Cattle	_______________	__________________
☐ Sheep	_______________	__________________
☐ Goats	_______________	__________________
☐ Camels	_______________	__________________
☐ Chicken	_______________	__________________
☐ Other, specify	_______________	__________________

9.2 What were the symptoms observed in the animals? (tick all that apply) ___________

Symptoms	Species of animal
☐ Decreased appetite/ inappetite	_______________
☐ Abortion/still birth	_____________
☐ Loss of body condition	_______________
☐ Coughing/ nasal discharge/ difficulty breathing	_______________
☐ Diarrhea	_______________
☐ Lameness/recumbency/inability to move	_______________
☐ Circling/head pressing/aggression/incoordination	_______________
☐ Hair loss/ itching/lump	_______________
☐ Bloody urine/ abnormal vaginal/ preputial discharge/ scrotal swelling	________
☐ Other symptoms	_________ Specify:_________

9.3 Are the animals available (for body scoring)?_________________

(1. Yes 2. No) ***(If Yes, go to 9.3.1. If No, skip to 10.0)***

9.3.1 Body Scoring Index (use the FAO reference-pictorial evaluation tool for livestock condition scoring)

Livestock species	Body Score (1-5)
☐ Cattle	_______________
☐ Goats	_______________
☐ Sheep	_______________
☐ Camels	_______________
☐ Other (specify)	_______________

10.0 Veterinary interventions, herd management and feeding

10.1 In the last one month, have your animals received any treatment/veterinary intervention?

(1. Yes 2. No) (***If Yes, go to line 10.1.1. If No, skip to 10.4)***

10.1.1 If Yes, specify the animals (tick all that apply)

Species	Deworming	Vaccination	Antibiotics	Tick Control	Trypanocides	Other
☐ Cattle						
☐ Goats						
☐ Sheep						

☐ Camels
If "Other" specify __________

10.1.2 If vaccinations, which vaccinations were given to the animals in the last one month?__

☐Lumpy skin disease
☐ Foot and mouth disease
☐ Contagious caprine pneuro pneumonia
☐ East Coast Fever
☐ Sheep and goat pox
☐ Other, specify _________
☐ Black quarter and anthrax
☐ Rift Valley Fever
☐ Brucellosis
☐ PPR
☐ Don't Know

10.1.3 If ectoparasite control, what ectoparasite control method did you use? ___________

- ☐ Acaricide dip
- ☐ Spray
- ☐ Hand picking
- ☐ Pour on
- ☐ Don't Know
- ☐ Other, specify ____________

10.2 Who provided the treatment/intervention for the animal(s)? ___________

- ☐ Animal health service provider
- ☐ Self
- ☐ Neighbor/other herder
- ☐ Community animal health worker

10.3 What was the approximate total cost of treatment/interventions (in Ksh) ___(numeric)

10.4 How far off are your animals currently grazing? ___________ ***(choose one)***

(1. Below 1 km 2. 1 to 5 km 3. 5 to 10 km 4. More than 10 km 5. Migration (fora)- without returning to the household)

10.5 Which water point do your animals currently go to drink water? ______ (***choose one)***

11.0 Livestock feeding

11.1 In the last 1 month, has the household acquired any feed supplements? ___________

(1. Yes 2. No) ***(If Yes, go to 11.1.1. If No, skip to 12.0)***

11.2 If Yes, please fill the table below (*the option for 'provided by project' will not appear during the baseline)*

	Type of feed			
Source of feed	Hay	Range Cubes	UMNB	Amount of feed
☐Bought	_________	_________	_________	_________
☐Provided by project	_________	_________	_________	_________
☐Provided by neighbor/family	_________	_________	_________	_________
☐Other	________	_________	_________	_________

If "other", specify ____

11.3 For the feeds provided by the project, what happened to the feeds? (*This question will not appear during the baseline)*

- ☐ Fed only animals selected for the study
- ☐ Fed all animals in my homestead
- ☐ Shared the feed with another homestead
- ☐ Sold the feed
- ☐ Other, specify ______________

11.4 For the feeds provided by the project, when was the feed received? ______ (select date) *(This question will not appear during the baseline)*

11.5 How long did the feed last ______(in days) *(This question will not appear during the baseline)*

11.6 If answered "Yes" to bought feeds, how much did the household spend in buying the feeds Kshs ______ (numeric)

11.7 For the feeds bought, what happened to the feeds? ___________ (tick all that apply)

- Fed own animals
- Gave some to the neighbor
- Sold

11.8 For the feeds provided by neighbor/family, what happened to the feeds? __________ (tick all that apply)

(1. Fed own animals 2. Gave some to the neighbor 3. Sold)

12.0 Sanitation, sources of water for domestic consumption, cooking fuel and time allocation

12.1 Currently, what is the main source of drinking water? _________

12.2 In the last one week, how many household members went to collect water? _________

12.3 How many times did the household member(s) go to collect water during the week? ___

12.4 Which household members went to collect drinking water? ____________

(1. Adult female 15+ 2. Adult male 15+ 3. Female child <15 years 4. Male child <15 years 5. Water at the homestead 6. Other, specify _____)

12.5 Do you store drinking water at the household? ______________

(1. Yes 2. No) ***(If Yes, go to 12.5.1. If No, skip 12.6)***

12.5.1 If Yes, how is the water stored? ______________ ***(choose one)***

(1. Open container/ jerry can 2. Closed containers/ jerry can 3. Other, specify______)

12.6 Do you do anything to your water prior to drinking? __________

(1. Yes 2. No) (***If Yes, go to 12.6.1. If No, skip to 12.7)***

12.6.1 If Yes, what? __________

- Boiling
- Add bleaching/chlorine/water guard
- Strain through coagulant e.g alum
- Strain through a cloth/sieve
- Use water filter (composite/sand/ceramic)
- Solar disinfection
- Let it settle
- Don't know
- Other, specify__________

12.7 How much water did the household use yesterday? (excluding water for animals) _______________(in litres)

12.8 What is the primary source of cooking fuel/energy?_____________ ***(choose one)***

(1. Electricity 2. Natural Gas 3. Kerosene 4. Firewood 5. Charcoal 6. Animal dung 7. Other)

If "Other", Specify __________

12.9 What kind of toilet facility do members of the household/homestead usually use? *(enumerator to verify)*

(1. Flush or pour flush toilet 2. Pit latrine 3. Composting toilet 4. Bucket toilet 5. No facility (bush/field) 6. Other, specify ______)

12.10 Do you share this toilet facility with other households?

(1. Yes 2. No)

<u>13.0 Household expenditures and feeding patterns</u>

<u>Animal source foods</u>

13.1 For the last 3 days, has the household consumed milk?

(1. Yes 2. No) ***(If Yes, go 13.1.1. If No, skip to 13.2)***

13.1.1 If Yes, please fill the table below:

Species	Produced home(ltrs)	Purchased(ltrs)	From fora/gifts(ltrs)	Purchased cost (ksh)
☐ Cattle	_________	______	_________	________
☐ Sheep	_________	_________	______________	____
☐ Goats	_________	________	______________	_____
☐ Camels	______________	________	______________	______
☐ Other, specify	_________	_______	_______	_____

13.2 For the last 3 days, has the household consumed any meat?

(1. Yes 2. No) ***(If Yes, go to 13.2.1. If No, skip to 13.3)***

13.2.1 If Yes,

Species	Amount at home (kg)	Amount purchased(kg)	Amount as gifts(kg)	Expenditure (Kshs)
☐ Cattle	_______	_____	__________	_______
☐ Sheep	_______	_______	_________	______
☐ Goats	__________	_______	___________	________
☐ Camels	___________	_______	________	_______
☐ Chicken	____________	_______	_________	________
☐ Other, Specify	__________	_______	__________	_______

13.3 For the last 3 days, has the household consumed any eggs?

(Yes 2. No) (***If Yes, go to 13.3.1. If No, skip to 13.4)***

13.3.1 If Yes,

<u>Species</u>	<u>Number from home</u>	<u>Purchased</u>	<u>Gifts</u>	<u>Total expenditure (Kshs)</u>
☐ Chicken	__________	_______	____	______
☐ Other, Specify	_________	__________	____	_______

<u>Non-animal source food expenditures</u>

13.4 For the last 3 days, has the household consumed any of the following foods?

(1. Yes 2. No) (***If Yes, go to 13.4.1. If No, skip to 13.5)***

<u>Food classes</u>	<u>Amount produced at home (kg)</u>	<u>Amount purchased(kg)</u>	<u>Amount as gifts(kg)</u>	<u>Total expenditure (Kshs)</u>
☐ Legumes/pulses, nuts and seeds (Peas/Beans/Lentils/Other pulses consumed)	_______	________	______	_____
☐Grain, Grain products and other	______	_________	_____	______

starchy foods(Maize/millet/cassava/bananas/ potatoes)				
□ Vegetables (Leafy greens /onions/tomatoes)	________	__________	______	_____
□ Fruits	______	__________	____	______
□ Cooking oil	______	_________	___	______
□ Other, Specify	______	_________	______	_____

13.5 Feeding patterns

13.5.1 Who influences what is eaten in the household? __________ ***(tick all that apply)***

□ Father/husband
□ Mother/wife
□ Son
□ Daughter
□ Uncle
□ Aunt
□ Grandmother
□ Mother-in-law
□ Daughter-in-law
□ Niece
□ Nephew
□ Other, specify___________

13.5.2 Who routinely prepares what the household eats? __________ ***(tick all that apply)***

□ Father/husband
□ Mother/wife
□ Son
□ Daughter
□ Uncle
□ Aunt
□ Grandmother
□ Mother-in-law
□ Daughter-in-law
□ Niece
□ Nephew
□ Other, specify_______

13.5.3 What influences the entire family feeding patterns? __________ ***(tick all that apply)***

□ A drawn timetable
□ Dietary diversity/balanced diet
□ Availability of a particular food in the household
□ Cost
□ Availability of a particular food in the market
□ Season
□ Sickness of a family member.
□ Other, specify _____
□ Random decision

14.0 Human health characteristics and health expenditures

14.1 Has any household member been sick (could not work or attend school) in the last one month ____________
(1. Yes 2. No 3. Don't Know)

14.2 Has any household member visited a health clinic or hospital in the last one month _______ (Yes/No) ***(If Yes, go to 14.3. If No, skip to 14.4)***

14.3 How many visits to a health clinic or hospital were made by household members in the last 1 month ______ (total for household)

14.3.1 Which health facility did they visit? _________

14.4 Has the household spent any money on health care (hospital visits, buying drugs etc) in the last 1 month _________

(1. Yes 2. No) ***(If Yes, go to 14.4.1. If No, end the questionnaire)***

14.4.1 If "Yes", what is the estimate of the total money spent Kshs_______ (numeric)

Appendix III: Individual level data collection questionnaire

Study Participant Individual Level data questionnaire

<u>1.0 Individual questionnaire</u>

(This questionnaire captures individual level details for the mother-child pair, and should be administered during recruitment and the regular 6-week visits)

1.1 Interviewer ID code _________________

1.2 Ward: _________

1.3 Sub location: _________

1.4 Village Name: _________

<u>2.0 Household details</u>

2.1 Interview Date _____

2.2 Household ID code ___/___/___

2.3 GPS Coordinates ____________

2.4 Visit Number ________ (numeric)

<u>3.0 Individual details</u>

3.1 Respondents under the study being interviewed ___________ ***(tick all that apply)***

- ☐Mother
- ☐Pregnant person
- ☐Child (To be answered by mother or caregiver)

If mother/pregnant person is selected, questions for pregnant person/mother go to 3.2

If Child go to 4.0

<u>3.2 Mother/Pregnant person</u>

3.2.1 Individual ID ____________

3.2.2 Name of the respondent (First Name) ____________ (Last Name) ________________

3.2.3 Date of birth ____________ ***(the respondent should be 16 years and above)***

3.2.4 Have you ever attended school ___________ (1. Yes 2. No) ***If Yes go to 3.2.4.1, if No go to 3.2.5***

3.2.4.1 If yes, what is the respondent's highest level of education completed? ____________ ***(choose one)***

1. Pre-primary 2. Primary School 3. Secondary school 4. College graduate 5. Madrassa 6. Other)

If "Other", Specify ____________

3.2.5 What is the marital status of the respondent? ________***(choose one)***

(1. Single 2. Married monogamous 3. Married polygamous 4. Divorced 5. Separated 6. Widow(er))

3.2.6 What is the primary occupation of the respondent? ________***(choose one)***

(1. Pastoralist (livestock only) 2. Own farm labor 3. Employed (salaried) 4. Waged labor (casual)) 5. Petty trade/hawking 6. Merchant/trader 7. Firewood/charcoal 8. Fishing 9. Income earned by children 10. House wife 11. Other)

If "Other", Specify _________________

3.2.7 What is the secondary occupation of the respondent? ________________***(choose one)***

(1. Pastoralist (livestock only) 2. Own farm labor 3. Employed (salaried) 4. Waged labor (casual)) 5. Petty trade/hawking 6. Merchant/trader 7. Firewood/charcoal 8. Fishing 9. Income earned by children 10.House wife 11.Other)
If "Other", Specify _________________

3.2.8 What is the physiological status of the respondent? _________***(choose one)***
(1. Pregnant 2. Lactating 3. Not pregnant and not lactating 4. Pregnant and lactating)

(If pregnant or pregnant and lactating is selected, continue to 3.2.8.1. If option 2 or 3 is selected, go to 3.3)
3.2.8.1 If pregnant, age of pregnancy in months ______________**(check mother child booklet)**

3.3 Hand washing
3.3.1 Within the last 24 hours, have you washed your hands? ___________***(choose one)***

(1. Yes 2. No) ***(If Yes, go 3.3.1.1, If no, go to 3.4)***
3.3.1.1 If Yes, at what instances did you wash your hands? _______***(tick all that apply)***

☐After visiting the toilet
☐Before cooking
☐Before eating
☐After going to the toilet
☐Other, specify ______

3.3.1.2 If Yes, what did you use to wash your hands? ____________ ***(tick all that apply)***

☐only water
☐soap and water
☐Traditional herbs
☐ Other, specify ______

3.4 Nutritional education and counseling

In the last one month, have you received any nutritional counseling/education? _______
(1. Yes 2. No) ***(If Yes, go to line 3.4.1, If No, skip to 3.5)***
3.4.1 If yes, who gave you the nutritional counseling? __________________
(1. Community Health Volunteer 2. Health Worker 3. Mother to mother support group 4. Other, specify____________)
3.4.2 How many times did you receive nutritional counseling? ____________ (numeric)

3.4.3 What topics did you discuss during nutritional counseling/education? _________________ ***(tick all that apply)***

☐Maternal nutrition	☐Antenatal care (pregnant women)
☐Breastfeeding	☐Iron folic acid supplementation
☐Complementary feeding	☐Growth monitoring
☐Feeding children older than 2 years	☐Immunization
☐Food/milk processing (preparation, preservation)	☐Vitamin A supplementation
☐Milk handling and sanitation	☐Hygiene
☐Feeding a sick child	☐Others, specify______________

3.5 Food intake

3.5.6 In the last 24 hours, have you consumed any of the following foods? __ (***tick all that apply)***

#	Food type	Consumption(Yes/No)	Frequency (for animal source foods)	Amount (litres for milk)
1.	Fresh raw milk			
2.	Boiled milk			
3.	Pasteurized milk			
4.	Tea			
5.	Fermented milk			
6.	Milk powder			
7.	Other milk products			
8.	Eggs			
9.	Fish (fresh, dried or shell fish)			
10.	Flesh meats and offals (beef, mutton, poultry)			
11	Organ meat (Iron rich)liver, kidney, heart or other organ meats or blood based foods			
12	Cereals and cereal products(maize, sorghurm, spaghetti, pasta, anjera, bread)			
13	Vitamin A rich vegetables and tubers: Pumpkins, carrots, orange sweet potatoes			
14	White tubers and roots: white potatoes, white yams, cassava or foods made from roots			
15	DARK GREEN LEAFY VEGETABLES (dark green leafy vegetables, including wild forms locally available vitamin A rich leaves such as amaranth, cassava leaves, kale, spinach)			
16	OTHER VEGETABLES (other vegetables (e.g. tomato, onion, eggplant etc.)			
17	VITAMIN A RICH FRUITS (ripe mango, cantaloupe, apricot (fresh or dried), ripe papaya, dried peach, and 100% fruit juice made from these + other locally available vitamin A rich fruits			
18	OTHER FRUITS (other fruits, including wild fruits and 100% fruit juice made from these)			
19	PULSES AND LEGUMES (dried beans, dried peas, lentils			
20	NUTS AND SEEDS (Any tree nut, groundnut/peanut or certain seeds, or nut/seed “butters”) or pastes			
21	OILS AND FATS (oil, fats or butter			

	added to food or used for cooking)			
22	SWEETS (sugar, honey, chocolate, candies, cookies/biscuits, cakes, sweet pastries, ice cream			
23	SPICES AND CONDIMENTS, BEVERAGES (spices (black pepper, salt), condiments (soy sauce), coffee, tea, alcoholic beverages			

(If milk was consumed, go to 3.5.6.1 , if Not, skip to 3.5.7)

3.5.6.1 What was the source of milk consumed? ___________ ***(tick all that apply)***

☐Own livestock
☐Bought
☐Given by neighbour/relative
☐Food aid
☐Traded/bartered
☐Other
☐if other, specify ___________________

3.5.6.2 If from own livestock from which animal was the milk

☐Camel
☐Goat
☐Sheep
☐Cattle

3.5.6.3 For any milk consumed (fresh, boiled, fermented) in the last 24hrs

#	Food type	Consumption(Yes/No	Frequency	Amount(litres)
1.	Fresh raw milk			
2.	Boiled milk			
3.	Pasteurized milk			
4.	Tea			
5.	Fermented milk			
6.	Milk powder			
7.	Any other specify			

3.5.7 In the last 2 weeks, have you suffered any health problem? ______________________

(1.** Yes 2. No) (**If Yes, go to 3.5.7.1, If not, go to 3.5.8)

3.5.7.1 Which of the following problems did you have? _________________ ***(tick all that apply)***

☐Fever
☐Watery diarrhea
☐Bloody diarrhea
☐ARI/Cough
☐Other
☐if other, specify ___________________

3.5.8 The number of children below 5 years recruited in the study? ________________ (numeric)

<u>4.0 Questions for child 5 years and below</u>

(To be answered by the mother, or the child caretaker)

4.1.1 Individual ID _________________
4.1.2 Name of the child: _________________(First, last)
4.1.3 Date of birth _________________(select date)
4.1.4 How was the child (Name) age verified? __________________ (tick all that apply)
□Health card
□Birth certificate
□Baptism calendar
□Seasonal calendar
□Other
□if other, specify ___________________
4.1.5 weight of child at birth _____________ (get from clinic book. If missing record 99)

4.1.6 Is the child (NAME) a Male or Female? ___________________ (1. Female 2. Male)
4.2 Is the child (Name) still breastfeeding? _____________________
(1. Yes 2. No) ***(If yes, go to 4.2.1. If No, go to 4.3)***
4.2.1 If yes, was the child breastfed yesterday during the day or at night?________________
(1.Yes 2. No) ***(If Yes, go to 4.2.2, If No, skip to 4.2.3)***
4.2.2 If yes, yesterday was the child (NAME) breastfed whenever he/she wanted or on a fixed schedule?_________________
(1. Whenever child wanted 2. Fixed schedule)
4.2.3 Have you introduced (NAME) to other foods (liquids or semisolids) in addition to breastmilk? ______________
(1. Yes 2. No) ***(If Yes, go to 4.2.4, if No, go to 4.3)***
4.2.4 If yes at what age was the child (NAME) introduced to other foods (liquids or semi solids) in addition to breastmilk?
4.3 What is the child currently feeding on? ______________ ***(choose one)***
(1. Non-exclusive breastfeeding with liquids only 2. Non-exclusive breastfeeding with solids only)
(If non-exclusive breastfeeding with liquids only, go to 4.3.1. If non-exclusive breastfeeding with solids only, skip to 4.3.2)
4.3.1 If the child is breastfeeding while taking liquids only, in the last 24 hours, has the child consumed any of the following? ***(tick all that apply)***

<u>Food item</u>
□Plain water
□Infant formula
□Fresh animal milk
□Powdered milk
□Juice/juice drinks
□Clear broth
□Yoghurt
□Thick porridge
□Other liquids
□if other, specify ___________________

4.3.2 If the child is not breastfeeding or breastfeeding while consuming solid foods, in the last 24 hours, has the child consumed any of the following foods? ______________________
(tick all that apply)

Please describe to me everything that the child ate. Fill in the table then tick all the foods stated below. Probe until the respondent says "nothing else"

#	Food type	Consumption(Yes/No)	Frequency (for animal source foods)	Amount (litres for milk)
1.	Fresh raw milk			
2.	Boiled milk			
3.	Pasteurized milk			
4.	Tea			
5.	Fermented milk			
6.	Milk powder			
7.	Other milk products			
8.	Eggs			
9.	Fish (fresh, dried or shell fish)			
10.	Flesh meats and offals (beef, mutton, poultry)			
11	Organ meat (Iron rich)liver, kidney, heart or other organ meats or blood based foods			
12	Cereals and cereal products(maize, sorghurm, spaghetti, pasta, anjera, bread)			
13	Vitamin A rich vegetables and tubers: Pumpkins, carrots, orange sweet potatoes			
14	White tubers and roots: white potatoes, white yams, cassava or foods made from roots			
15	DARK GREEN LEAFY VEGETABLES (dark green leafy vegetables, including wild forms locally available vitamin A rich leaves such as amaranth, cassava leaves, kale, spinach)			
16	OTHER VEGETABLES (other vegetables (e.g. tomato, onion, eggplant etc.)			
17	VITAMIN A RICH FRUITS (ripe mango, cantaloupe, apricot (fresh or dried), ripe papaya, dried peach, and 100% fruit juice made from these + other locally available vitamin A rich fruits			
18	OTHER FRUITS (other fruits, including wild fruits and 100% fruit juice made from these)			
19	PULSES AND LEGUMES (dried beans, dried peas, lentils			
20	NUTS AND SEEDS (Any tree nut, groundnut/peanut or certain seeds, or nut/seed "butters") or pastes			
21	OILS AND FATS (oil, fats or butter added to food or used for cooking)			
22	SWEETS (sugar, honey, chocolate, candies, cookies/biscuits, cakes, sweet			

	pastries, ice cream			
23	SPICES AND CONDIMENTS, BEVERAGES (spices (black pepper, salt), condiments (soy sauce), coffee, tea, alcoholic beverages			

(If milk was consumed, go to 4.3.2.1, if not, skip to 4.4)

4.3.2.1 What was the source of milk consumed by the child? _________________ ***(tick all that apply)***

□Own livestock
□Bought
□Given by neighbour/relative
□Food aid
□Traded/bartered
□Other
□if other, specify ___________________

4.3.2.2 If the milk is from own animals, from which animal was the milk __(***tick all that apply)***

□Camel
□Goat
□Sheep
□Cattle

4.4 Has the child recently received or is currently under any treatment for malnutrition? ____
(1. Yes 2. No) ***(If Yes, go to 4.4.1. If No, skip to 4.5)***

4.4.1 If Yes, what was the outcome? __________________ ***(choose one)***
(1. Recovered/Recovering 2. Defaulted)

4.4.2 If Yes, how much did the treatment cost? _________________

4.5 In the last 2 weeks, has your child been sick? _________________
(1. Yes 2. No) ***(If Yes, go to 4.5.1. If No, skip to 4.6)***

4.5.1 If "Yes", what type of illness did your child have? (***choose all that apply)***

□ Fever
□ Watery diarrhea
□ Bloody diarrhea
□ ARI/Cough
□ Other, specify _________

4.5.2 Did you seek advice or treatment? __________________
(1. Yes 2. No) ***(If Yes, go to 4.5.3. If no, go to 4.6)***

4.5.3 If Yes, where did you seek treatment? __________________ ***(tick all that apply)***
(1.Traditional healer 2. Community health worker 3. Private clinic/pharmacy/hospital 4. Shop/kiosk 5. Public clinic/ hospital
6. Mobile clinic 7. Relative/ friend 8. Local herbs 9. NGO 10. Faith based hospital 11. Other, specify __________)

4.6 If the child is 6 months and above, in the last 6 months, has the child taken any vitamin A supplements?
(1.Yes 2.No)

4.7 If child is 1 year and above, in the last 6 months, has the child taken any de-wormers?
(1.Yes 2.No)

4.8 Has the child been vaccinated? ________________

(1. Yes 2. No 3. Don't know) ***(If yes, go to 4.8.1. If no or don't know, go to 5)***

4.8.1 If yes, which vaccines ***(tick all that apply)***

#	Vaccine	Has the child received the following vaccines(1=yes, 2=No 3=Don't know)	Evidence(1=card, 2=recall)
1	BCG vaccine(check for scar)		
2	Polio vaccine – 1st dose(6weeks)		
3	Polio vaccine – 2nd dose(10 weeks)		
4	Polio vaccine – 3rd dose(14 weeks)		
5	IPV(inactivated Polio vaccine)		
6	Diphtheria/pertussis/Tetanus/HepatitisB/Haemophilus influenza type B 3rd dose(14 weeks)		
7	Diphtheria/pertussis/Tetanus/HepatitisB/Haemophilus influenza type B 3rd dose(14 weeks)		
8	Diphtheria/pertussis/Tetanus/HepatitisB/Haemophilus influenza type B 3rd dose(14 weeks)		
9	Pneumococcal vaccine – 1st dose (6 weeks)		
10	Pneumococcal vaccine – 2nd dose (10 weeks)		
11	Pneumococcal vaccine – 3rd dose (14 weeks)		
12	Rotavirus vaccine (Rotarix) – 1st dose (6 weeks)		
13	Rotavirus vaccine(Rotarix) – 2nd dose (10 weeks)		
14	Rotavirus vaccine(Rotarix) – 3rd dose (14 weeks)		
15	Measles vaccine (9 months)		
16	Measles vaccine (18 months)		
17	Yellow fever vaccine (9 months)		
18	Other specify		

5.0 ANTHROPOMETRIC MEASURES

5.1 Mother/pregnant woman measures

5.1.1 Weight of mother in kgs: ________________(*two decimal places*)

5.1.2 Mid-upper arm circumference of the mother in cms: ________________(*two decimal places*)

5.2 Child measures

5.2.1 Height of the child in cms: ___________________ (*two decimal places*)

5.2.2 Weight of the child in kgs: _______________________ (*two decimal places*)

5.2.3 Mid-upper arm circumference of child in cms: _________________ (*two decimal places*)

Appendix IV: Human sample tracking form

HUMAN SAMPLE TRACKING SHEET

Location: ___________________________ **Household ID:** ________________**Date:** _______________

Study Participant (Mother, Child): ___________________**Staff:** _______________________

#	Sample ID (Barcode)	Study participan	Sample type	Study visit	Sex	Age	Physiological status
1	Place barcode here						
2	Place barcode here						
3	Place barcode here						

Sample type
Serum - SR
Whole blood-WB
Blood Clot - BC

Study visit type
1 – Baseline
2 – Six months' visit
3 – Twelve months'visit

Sex
Male - M
Female-F

Physiological status:
P - Pregnant
L – Lactating
NP/NL – Not pregnant & Not Lactating
PL – Pregnant & Lactating

Appendix V: Animal sample tracking form

ANIMAL SAMPLE TRACKING SHEET

Location: _________________ Household ID: ________ Date: _______

Species (Bovine, Goat, Sheep, Camel): _____________ Staff: ______________

#	Sample ID (Barcode)	Species	Sample type	Study visit	Breed	Sex	Age	Physiological status	History
1	Place barcode here								
2	Place barcode here								
3	Place barcode here								

Sample type
Serum - SR
Whole blood - WB
Blood Clot - BC
Milk - MK

Study visit type
1 – Baseline
2 – Six months' visit
3 – Twelve months' visit

Sex
Male - M
Female - F

Breed
A - indigenous
B – Exotic
C - Crossbreed

Physiological status:
L - lactating
NL – Non-lactating

Age(cattle): A= 2-3 yrs., B= 3-4yrs, C = 4-5yrs D = >5yrs (**sheep/goats):** A= <1yr, B=1-2yrss,

C= 2-3yrs D=3-4yrs E=>4yrs **(Camels):** A= <4yrs B =4-6yrs C= >6yrs

History: 1 = Abortions 2 = still births 3 = weak young 4 = Metritis 5 = Retained placenta

6 = Swollen joints

Appendix VI: Ethical approvals for the study

UNIVERSITY OF NAIROBI
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P O BOX 20723 Code 00202
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Telegrams: MEDSUP, Nairobi

Ref. No.KNH/ERC/R/14

24th January, 2023

Josphat Mulei Muema
Reg. No. W80/53736/2018
PhD Candidate
Institute of Tropical and Infectious Diseases (UNITID)
Faculty of Health Sciences
University of Nairobi

Dear Josphat,

Re: Approval of Annual Renewal – Impact of livestock-based interventions and nutritional education on under-nutrition and health in children below five years of age among pastoral communities in Northern Kenya (P850/10/2019)

Refer to your communication dated 16th January, 2023.

This is to acknowledge receipt of the study progress report and hereby grant annual extension of approval for ethical research protocol P850/10/2019 for data analysis.

The approval dates are 20th February 2023 – 19th February 2024.

This approval is subject to compliance with the following requirements:

a) Only approved documents (informed consents, study instruments, advertising materials etc) will be used.
b) All changes (amendments, deviations, violations etc.) are submitted for review and approval by KNH- UoN ERC before implementation.
c) Death and life threatening problems and severe adverse events (SAEs) or unexpected adverse events whether related or unrelated to the study must be reported to the KNH- UoN ERC within 72 hours of notification.
d) Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to KNH- UoN ERC within 72 hours.
e) Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. (*Attach a comprehensive progress report to support the renewal*).
f) Clearance for export of biological specimens must be obtained from KNH- UoN-Ethics & Research Committee for each batch of shipment.
g) Submission of an executive *summary* report within 90 days upon completion of the study.

Protect to Discover

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Yours sincerely,

DR. BEATRICE K.M. AMUGUNE
SECRETARY, KNH- UoN ERC

cc. The Dean, Faculty of Health Sciences, UoN
The Senior Director, Clinical Services, KNH
The Chair, KNH-UoN ERC

Appendix VI: Administrative approvals for the study

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 813794

Date of Issue: 01/March/2023

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Appendix VII: Dissertation submission permission document

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Our Ref: W80/53736/2018

April 17, 2023

Josphat Mulei Muema
Department of Medical Microbiology
Faculty of Health Sciences

Dear Josphat,

NOTICE OF INTENT TO SUBMIT YOUR Ph.D THESIS

We wish to acknowledge receipt of your notice of intent to submit your PhD thesis dated April 17, 2023 entitled; ***"Preventing Acute Malnutrition in Women and Children Among Pastoral Communities Through Livestock Interventions in Northern Kenya".*** We also wish to acknowledge receipt of the abstract of the thesis. Please submit a soft copy of the thesis to the **Chairman, Department of Medical Microbiology.**

In addition you should run and submit an anti – plagiarism test on your thesis whose tolerance levels should be 15% and below.

Please note that you will be expected to show proof of acceptance for publication of two (2) papers in referred journals as a requirement for full Ph.D students before graduation.

We look forward to receiving a soft copy of your thesis within three (3) months from the date of this letter.

Thank you.

ASSOCIATE DEAN POSTGRADUATE STUDENTS AND RESEARCH, FACULTY OF HEALTH SCIENCES UNIVERSITY OF NAIROBI

PROF. EVELYN WAGAIYU
ASSOCIATE DEAN
POSTGRADUATE STUDENTS & RESEARCH

CC. **Chairman, Department of Medical Microbiology**
..../EC

ISO 9001:2015 CERTIFIED Quality Management System Excellence in University Education and Training

Appendix VIII: Abstracts of the four (04) papers published from the study

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Research article

Endemicity of *Coxiella burnetii* infection among people and their livestock in pastoral communities in northern Kenya

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Keywords:
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Coxiella burnetii
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Livestock
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Kenya

ABSTRACT

Background: *Coxiella burnetii* can be transmitted to humans primarily through inhaling contaminated droplets released from infected animals or consumption of contaminated dairy products. Despite its zoonotic nature and the close association pastoralist communities have with their livestock, studies reporting simultaneous assessment of *C. burnetii* exposure and risk-factors among people and their livestock are scarce.

Objective: This study therefore estimated the seroprevalence of Q-fever and associated risk factors of exposure in people and their livestock.

Materials and methods: We conducted a cross-sectional study in pastoralist communities in Marsabit County in northern Kenya. A total of 1,074 women and 225 children were enrolled and provided blood samples for Q-fever testing. Additionally, 1,876 goats, 322 sheep and 189 camels from the same households were sampled. A structured questionnaire was administered to collect individual- and household/herd-level data. Indirect IgG ELISA kits were used to test the samples.

Results: Household-level seropositivity was 13.2% [95% CI: 11.2–15.3]; differences in seropositivity levels among women and children were statistically insignificant ($p = 0.8531$). Lactating women had higher odds of exposure, odds ratio (OR) = 2.4 [1.3–5.3], while the odds of exposure among children increased with age OR = 1.1 [1.0–1.1]. Herd-level seroprevalence was 83.7% [81.7–85.6]. Seropositivity among goats was 74.7% [72.7–76.7], while that among sheep and camels was 56.8% [51.2–62.3] and 38.6% [31.6–45.9], respectively. Goats and sheep had a higher risk of exposure OR = 5.4 [3.7–7.3] and 2.6 [1.8–3.4], respectively relative to camels. There was no statistically significant association between Q-fever seropositivity and nutrition status in women, $p = 0.900$ and children, $p = 1.000$. We found no significant association between exposure in people and their livestock at household level ($p = 0.724$) despite high animal exposure levels, suggesting that Q-fever exposure in humans may be occurring at a scale larger than households.

Conclusion: The one health approach used in this study revealed that Q-fever is endemic in this setting. Longitudinal studies of Q-fever burden and risk factors simultaneously assessed in human and animal populations as well as the socioeconomic impacts of the disease and further explore the role of environmental factors in Q-fever epidemiology are required. Such evidence may form the basis for designing Q-fever prevention and control strategies.

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Sero – epidemiology of brucellosis in people and their livestock: A linked human – animal cross-sectional study in a pastoralist community in Kenya

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Background: Brucellosis is associated with massive livestock production losses and human morbidity worldwide. Efforts to control brucellosis among pastoralist communities are limited by scarce data on the prevalence and risk factors for exposure despite the high human-animal interactions in these communities. This study simultaneously assessed the seroprevalence of brucellosis and associated factors of exposure among pastoralists and their livestock in same households.

Methods: We conducted a cross-sectional study in pastoralist communities in Marsabit County – Kenya. A total of 1,074 women and 225 children participated and provided blood samples. Blood was also drawn from 1,876 goats, 322 sheep and 189 camels. Blood samples were collected to be screened for the presence of anti-Brucella IgG antibodies using indirect IgG Enzyme-Linked Immunosorbent Assay (ELISA) kits. Further, Individual, household and herd-level epidemiological information were captured using a structured questionnaire. Group differences were compared using the Pearson's Chi-square test, and p-values <0.05 considered statistically significant. Generalized mixed-effects multivariable logistic human and animal models using administrative ward as the random effect was used to determine variables correlated to the outcome.

Results: Household-level seropositivity was 12.7% (95% CI: 10.7–14.8). The individual human seroprevalence was 10.8% (9.1–12.6) with higher seroprevalence among women than children (12.4 vs. 3.1%, $p < 0.001$). Herd-level seroprevalence was 26.1% (23.7–28.7) and 19.2% (17.6–20.8) among individual animals. Goats had the highest seroprevalence 23.1% (21.2 – 25.1), followed by sheep 6.8% (4.3–10.2) and camels 1.1% (0.1–3.8). Goats and sheep had a higher risk of exposure OR = 3.8 (95% CI 2.4–6.7, $p < 0.001$) and 2.8 (1.2–5.6, $p < 0.007$), respectively relative to camels. Human and animal seroprevalence were significantly associated (OR = 1.8, [95%CI: 1.23–2.58], $p = 0.002$). Herd seroprevalence varied by household head education (OR= 2.45, [1.67–3.61, $p < 0.001$]) and herd size (1.01, [1.00–1.01], $p < 0.001$).

Conclusions: The current study showed evidence that brucellosis is endemic in this pastoralist setting and there is a significant association between animal and human brucellosis seropositivity at household level representing a potential occupational risk. Public health sensitization and sustained human and animal brucellosis screening are required.

KEYWORDS

brucellosis, sero-epidemiology, pastoralists, livestock, Kenya

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STUDY PROTOCOL

REVISED Impact of livestock interventions on maternal and child nutrition outcomes in Africa: A systematic review and meta-analysis protocol [version 2; peer review: 2 approved]

Josphat Muema[1,2], Julius Oyugi[1], Zipporah Bukania[3], Mutono Nyamai[2,4], Christine Jost[5], Tewoldeberhan Daniel[6], Joseph Njuguna[7], Samuel Mwangi Thumbi[1,2,8,9]

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Abstract
The challenge of undernutrition (stunting and wasting) still remains a major health concern in children below 5 years of age in Africa, with the continent accounting for more than one third of all stunted children and more than one quarter of all wasted children globally. Despite the growing evidence on the role of agriculture interventions in improving nutrition, empirical evidence on the impact of livestock intervention on nutrition in Africa is scant.
This review is aimed at determining whether livestock interventions are effective in reducing undernutrition in children below five years of age and in pregnant and lactating women in Africa. The review will be conducted according to PRISMA guidelines. Major electronic databases will be searched and complemented with grey and non-indexed literature from google and google scholar, and expert consultation for additional articles and reports. PICO criteria will be used while employing search strategies including MeSH, Boolean search operators and truncation/wildcard symbol to narrow or broaden the search. Articles on effect of livestock interventions on maternal and child nutrition conducted in Africa that meet the set inclusion criteria will be included in the review after critical appraisal by two independent reviewers. A standardized form will be used to extract data from included studies. The extracted data will be summarized and synthesized both qualitatively and quantitatively and

Open Peer Review

Reviewer Status ✓ ✓

	Invited Reviewers 1	2
version 2 (revision) 01 Oct 2021	✓ report	✓ report
version 1 08 Jan 2021	? report	? report

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Any reports and responses or comments on the article can be found at the end of the article.

key outcomes presented. Evidence generated from the systematic review and meta-analysis will be important for guiding nutrition sensitive livestock interventions and policies on nutrition programming, specifically on how to leverage on livestock interventions to reduce the burden of undernutrition.

Keywords
Livestock interventions, Malnutrition, Under-five children, Systematic review, Africa

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Author roles: Muema J: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Writing – Original Draft Preparation, Writing – Review & Editing; **Oyugi J**: Methodology, Supervision, Validation, Writing – Review & Editing; **Bukania Z**: Methodology, Supervision, Validation, Writing – Review & Editing; **Nyamai M**: Data Curation, Formal Analysis, Investigation, Methodology, Validation; **Jost C**: Methodology, Validation, Writing – Review & Editing; **Daniel T**: Methodology, Validation, Writing – Review & Editing; **Njuguna J**: Methodology, Validation, Writing – Review & Editing; **Thumbi SM**: Conceptualization, Methodology, Supervision, Validation, Visualization, Writing – Review & Editing

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The impact of livestock interventions on nutritional outcomes of children younger than 5 years old and women in Africa: a systematic review and meta-analysis

Josphat Muema[1,2,3]*, Nyamai Mutono[2,3,4], Stevens Kisaka[1,4], Brian Ogoti[1,4], Julius Oyugi[1], Zipporah Bukania[5], Tewoldeberhan Daniel[6], Joseph Njuguna[7], Irene Kimani[7], Anita Makori[2,4], Sylvia Omulo[1,2,3,8], Erin Boyd[9], Abdal Monium Osman[10], Luc Gwenaelle[10], Christine Jost[9,11] and SM Thumbi[1,3,4,8,12,13]

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Background: Nutrition-sensitive livestock interventions have the potential to improve the nutrition of communities that are dependent on livestock for their livelihoods by increasing the availability and access to animal-source foods. These interventions can also boost household income, improving purchasing power for other foods, as well as enhance determinants of health. However, there is a lack of synthesized empirical evidence of the impact and effect of livestock interventions on diets and human nutritional status in Africa.

Objective: To review evidence of the effectiveness of nutrition-sensitive livestock interventions in improving diets and nutritional status in children younger than 5 years old and in pregnant and lactating women.

Methods: Following PRISMA guidelines, we conducted a systematic review and meta-analysis of published studies reporting on the effect of livestock interventions on maternal and child nutrition in Africa. Data were extracted, synthesized, and summarized qualitatively. Key outcomes were presented in summary tables alongside a narrative summary. Estimation of pooled effects was undertaken for experimental studies with nutritional outcomes of consumption of animal-source foods (ASFs) and minimum dietary diversity (MDD). Fixed effects regression models and pooled effect sizes were computed and reported as odds ratios (ORs) together with their 95% confidence intervals (CI).

Results: After the screening, 29 research papers were included in the review, and of these, only 4 were included in the meta-analysis. We found that nutrition-sensitive livestock interventions have a significant positive impact on the consumption of ASFs for children < 5 years (OR = 5.39; 95% CI: 4.43–6.56) and on the likelihood of meeting minimum dietary diversity (OR = 1.89; 95% CI: 1.51–2.37). Additionally, the impact of livestock interventions on stunting, wasting, and being underweight varied depending on the type of intervention and duration of the program/intervention implementation. Therefore, because of this heterogeneity in reporting metrics, the pooled estimates could not be computed.

Conclusion: Nutrition-sensitive livestock interventions showed a positive effect in increasing the consumption of ASFs, leading to improved dietary diversity. However, the quality of the evidence is low, and therefore, more randomized controlled studies with consistent and similar reporting metrics are needed to increase the evidence base on how nutrition-sensitive livestock interventions affect child growth outcomes.

KEYWORDS

children, women, livestock intervention, undernutrition, nutrition outcome, Africa