ASSOCIATION OF DIETARY DIVERSITY AND MICROBIAL SAFETY OF FOOD ON NUTRITIONAL STATUS OF CHILDREN AGED 6-59 MONTHS IN SEDENTARISED PASTORAL HOUSEHOLDS, MARSABIT COUNTY, KENYA

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A Thesis Submitted to the Graduate School in Partial Fulfillment of the Requirements for the Doctor of Philosophy Degree in Food Science of Egerton University

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DECLARATION AND RECOMMENDATION

Declaration

I hereby declare that this thesis is my original work and has not been presented in this university or any other for the award of a degree.

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Recommendation

This thesis has been submitted with our approval as University supervisors

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DEDICATION

Dedicated to my parents: Late Bishop Joram Adongo Odundo and Jenifer Adongo, wife Alice Otieno, Daughter; Cynthia Adhiambo and sons; Jorry Collins and Ian Luke and Niece Rosemary. My late uncle, Jared Owalo Odundo (late) and Jonathan Obel Onyango. Without your support, this would not have worked out.

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ABSTRACT

The transition from nomadic to sedentary pastoralism has introduced dietary changes among previously nomadic communities. However, limited information exists on how these practices affect the nutritional status of children aged 6–59 months, particularly regarding complementary food safety. This study assessed the impact of dietary diversity and microbial safety of foods on the nutritional status of children in Marsabit County, Kenya. A cross-sectional survey across six wards targeted children aged 6–59 months. Using multistage sampling, 394 children participated with caregiver consent. Data collection involved pre-tested questionnaires and anthropometric measures. For food safety, samples of food (127), water (27), and hand swabs (48) were collected from 127 households. Fumonisin and aflatoxins were analyzed using immuno-affinity columns (AccuScan Gold®), while AFM1, AFM2 in milk, and AFB1, AFG1, AFB2, and AFG2 in cereals were assessed using HPLC-FD. Microbial analysis included total viable, coliform, yeast, and mold counts, with *Escherichia coli* and *Salmonella* spp. identified via AOAC methods. Descriptive statistics and tests, such as chi-square and ANOVA, summarized population data, while linear and logistic regressions explored undernutrition predictors ($p < 0.05$). Results showed stunting, underweight, and wasting prevalence at 38.1%, 23.0%, and 18.5%, respectively, with 97% of children consuming mainly grains, roots, and tubers. About 51.5% did not meet the minimum dietary diversity score. Consuming legumes and eggs reduced stunting odds (OR=0.50, p=0.010), while dairy intake reduced underweight risk (AOR=2.09, p=0.015). Median fumonisin (300 μg/kg) and aflatoxins levels exceeded EU standards, with median AFB_1, AFM_1, and AFM_2 also above regulatory limits. Mean microbial loads (± SE) for total viable counts, coliforms, yeast, and molds surpassed KEBs and EU values. *Salmonella* spp. prevalence was highest in Bubisa (57%), with E. coli detected in all tested foods. High viable counts increased underweight risk (AOR=4.304, p=0.004), while molds and *E. coli* correlated strongly with stunting (AOR=1.314, p<0.001; AOR=1.88, p=0.008). The study reveals high stunting and underweight rates linked to cereal-based diets and inadequate food hygiene. Raising caregiver awareness of food handling in sedentary pastoral settings is essential. Further research on mycotoxins should include biomarker assessments and identifying specific *E. coli* and *Salmonella* strains linked to stunting and underweight.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

AEZ	Agricultural Ecological Zones
AFB	Aflatoxin B
AFG	Aflatoxin G
ASAL	Arid and Semi-arid lands
CDD	Child Dietary Diversity
CIDP	County Integrated Development Plan
CLSI	Clinical and Laboratory Standards Institute
DNA	Deoxyribonucleic Acid
DDS	Dietary Diversity Score
EAEC	Enteroaggregative *Escherichia coli*
EBF	Exclusive Breast Feeding
EHEC	Enterohemorrhagic *Escherichia coli*
EPEC	Enteropathogenic *Escherichia coli*
ETEC	Enterotoxigenic *Escherichia coli*
FAO	Food and Agriculture Organization of the United Nations
GoK	Government of Kenya
HAZ	Height for Age Z-score
HPLC	High Performance Liquid Chromatography
IARC	International Agency for Research on Cancer
ICF	Inner City Fund
KES	Kenya Shilling
KNBS	Kenya National Bureau of Statistics
MOH	Ministry of Health
NACOSTI	National Council of Science, Technology and Innovation
PCA	Plate count agar
PDA	Potato Dextrose Agar
Spp	Species
TCC	Total coliforms Counts
TVC	Total Viable Counts
UNICEF	United Nations Children Fund
USAID	United States Agency for International Development
WHO	World Health Organization of the United Nations

WHZ	Weight for Height Z-score
WAZ	Weight for Age Z-score

CHAPTER ONE
INTRODUCTION

1.1 Background of Study

Complementary feeding is the process of introducing family foods to an infant's diet as they transition from exclusive breastfeeding. This phase usually takes place between the ages of 6 and 23 months, when breast milk alone no longer satisfies the child's nutritional requirements (WHO, 2021). Suboptimal complementary feeding practices contributes to malnutrition which impacts negatively on under-five child's cognitive development, health and linear growth (Akombi *et al.*, 2017; Kassa *et al.*, 2016). Use APA 7th edition for in-text citations as previously advised

Globally, malnutrition remains a significant public health issue, affecting millions of children under five years old. According to the World Health Organization, UNICEF, and the World Bank (2021), 22% of children worldwide are stunted, and 6.8% are wasted due to inadequate nutrition. Eastern Mediterranean, Southeast Asia and the Sub-Saharan Africa continue to bear the brunt of this crisis, with these regions accounting for 50% of child deaths related to malnutrition (de Onis & Branca, 2016; UNICEF, 2019).

Malnutrition, particularly undernutrition, remains a significant public health concern in Kenya. Data from the two most recent Kenya Demographic and Health Surveys (KDHS) show that stunting and underweight prevalence rates declined from 26% and 11% in 2015 (KNBS & ICF, 2015) to 18% and 10% in 2023 (KNBS & ICF, 2023). However, certain pastoral areas within the Arid and Semi-Arid Lands (ASAL) continue to exhibit high rates of stunting, with West Pokot at 43.9%, Turkana at 30.3%, Mandera (26.8%) and Marsabit at 23.8% (KNBS & ICF, 2023).

The pastoral production system is changing from extensive free range production system to current sedenteral and semi-pastoralism. The traditional extensive mobile grazing methods are being replaced by modern peri-urban and sedenteralised systems. Peri-urban production systems are emerging with a trend of 22.9% in urban pastoral areas, where livestock are kept on-farms near towns to take advantage of urban markets for milk and meat (CIDP-Marsabit 2023). This shift towards a sedentary system, with limited foraging options, calls for supplementation and this poses new challenges to both animal and human nutrition and health. While pastoralists have always consumed animal source foods like meat and milk and occasionally supplemented with blood and wild fruits and vegetables (Oniang'o *et al.*, 2003),

the changing lifestyle has introduced changes in dietary intakes where more households rely more on purchased food items largely comprising of cereals and pulses (Prall & Scelza, 2023). Shrinking grazing land and population pressure among sedenteral pastoralists around emerging urban centres has resulted into diminished natural fodder and pasture. Because of this, pastoralists are adopting new production practices where livestock is supplemented with preserved feeds and concentrates (Lengarite *et al.,* 2014). The supplements originate from commercial stores or agrovets supplied by agents including government agencies, non-governmental organizations and individuals during the drought.

A study by Makau *et al.* (2016) showed milk from dairy animals supplemented with commercial feeds and on-farm crop residue formulations in peri-urban systems has high levels of mycotoxins (fumonisin and aflatoxin) as compared to the milk from rural dairy animals. Under pastoral production system, livestock are under free range grazing system which can be compared to rural feeding system, hence assumed the mycotoxins are less (Noor, 2013). Emerging sedentary pastoralists in Kenya's ASAL regions have transitioned from a diet rich in animal-source foods like milk and blood to a more cereal- and pulse-based diet, often supplemented by famine relief. This dietary shift has negatively impacted dietary diversity, particularly among children. According to KNBS (2023), the minimum dietary diversity for children in remote regions is lower than in urban areas (32.8% vs. 50.8%), and even lower in specific regions like Marsabit (5%) and Isiolo (13%) for children aged 9-23 months (Young *et al.,* 2024). While all age groups consume similar food types, the preparation and handling of complementary foods for children aged 6-59 months differ significantly from that of adults in terms of processing level.

These commercially purchased foods including cereals and pulses have been shown to contribute to malnutrition due to their contamination through handling and processing practices (Achaglinkame *et al.,* 2017). Handing of cereals, pulses and milk processing for consumption calls for understanding of the risk of safety and quality through contamination by pathogenic and or toxigenic and spoilage microorganisms. Spoilage comes by the degradation of nutrient components in the food/feed by spoilage microbes such as *Pseudomonas* spp, lactic acid bacteria (LABs) and molds (Batt, 2016). Once in food, the spoilage microorganisms produce metabolites (amines, esters, acids, alcohols) that impart undesirable sensory properties to cooked food hence affect food quality (Húngaro *et al.,*

2014). Pathogenic microbes such as enteric bacteria and molds for example. *Aspergillus* spp produce toxins that can cause disease to human.

Once in the liver, aflatoxin forms epoxides (AF-8, 9-epoxide) that bind to protein or DNA. The bound AF-8, 9-epoxides and DNA molecule can interfere with protein synthesis and impair growth in children (Bbosa *et al.*, 2013). Aflatoxin can also alter intestinal integrity and cause nutrient deficiencies and immune suppression due to inflammation and nutrient malabsorption and growth faltering in under five children (Gong *et al.*, 2016; Turner, 2013) . Exposure to aflatoxin also leads to chronic hepatitis which predisposes an individual to hepatocellular carcinoma (Kew, 2013).

Pastoralists hardly have knowledge in handling commercial feeds and foods. With emergence of sedenteral lifestyle in a pastoral environment, livestock feeding and dietary intakes have since changed. The handling and processing practices of the commercial feeds/foods pose a risk of safety and quality of the products for the under-five children. This change is likely to contribute to high malnutrition and diarrhoea rates in settlement. This study aimed to assess the impact of dietary diversity, microbial safety, on the nutritional status of children aged 6-59 months transitioning from nomadic to sedentary pastoralism in Marsabit, northern Kenya.

1.2 Statement of the Problem

The shift from nomadism to sedenteral lifestyle in a pastoral environment has changed livestock feeding and dietary intake of pastoralists. There is increased use of commercial livestock feeds by many suppliers, whose quality and safety cannot be guaranteed. Complementary diets have also shifted from animal source foods (ASF) to cereal and pulses-based foods. Due to handling and processing practices of these complementary foods by pastoralists, there is a risk of contamination that may lead to low quality and unsafe products. This predisposes the under-five to malnutrition and microbial foodborne diseases. Currently, limited data exists on status of human exposure to foodborne contaminants and subsequent effect on nutritional status among children aged 6-59 months in ASALs. There is need therefore, to evaluate the quality and safety of complementary foods provided to children aged 6-59 months in transitional pastoral households in northern Kenya. The purpose of this study was to determine the impact of dietary diversity, microbial safety on nutritional status of children in settled pastoral household in Marsabit County.

1.3 Objectives

1.3.1 Overall Objective

To contribute to food and nutrition security of the transitional pastoral communities by assessing the quality and safety of foods consumed by children under the age of 6-59 months in Marsabit County.

1.3.2 Specific Objectives

i. To assess nutritional status of children aged 6-59 months in transitional pastoral households in Marsabit County.

ii. To determine the dietary diversity and nutrient intakes of children aged 6-59 months in transitional pastoral households in Marsabit County.

iii. Determine levels of Aflatoxin and Fumonisin in complementary foods for children aged 6-59 months in transitional pastoral households.in Marsabit County.

iv. Determine the levels of *Salmonella* spp, and *Escherichia coli* in complementary foods for children aged 6-59 months in transitional pastoral households.in Marsabit County.

1.4 Research Hypotheses

i. There is no significant differences in the current nutritional status of children aged 6-59 months in transitional pastoral households in Marsabit County?

ii. There is no significant in the current dietary diversity of children aged 6-59 months in transitional pastoral households in Marsabit County?

iii. There is no significant difference in levels of Aflatoxin (AF), Fumonisin (FUM) in feed supplements and foods consumed by children aged 6-59 months in transitional pastoral households in Marsabit County

iv. There is no significant difference in the presence and levels of *Salmonella* spp, and *Escherichia coli* in foods consumed by children aged 6-59 months in transitional pastoral households in Marsabit County.

1.5 Justification

Information generated from this study will support interventions aimed addressing global policy on sustainable development goals of ensuring good health and wellbeing of children, clean water and sanitation and responsible consumption (UN, 2015). The study was also built on the Kenya vision 2030 and the bottom up transformation agenda (BETA) which focus on

scaling up High Impact Nutrition Interventions (HINI) and social pillars on water and sanitation and reduction of under-five mortality rates in the ASALs. The study also provides baseline information for implementation of food safety policies on safety guidelines on livestock feeds and food in Kenya at county levels. The Kenya Bureau of Standards (KEBS) has insufficient infrastructure to monitor quality of feed and food in the expansive ASAL area. The county governments are yet to establish regulatory institutions to reinforce policy issues pertaining to feed and food quality and safety practices in ASAL. Information generated from this study can provide benchmarks for developing strategies for improving food safety and complementary feeding practices among pastoral caregivers.

1.6 Scope of the Study

The study was conducted among children aged 6-59 months who were breastfeeding and receiving complimentary foods. The research focused on settled and semi-settled population in Marsabit County. The research assessed dietary diversity levels in terms of quality (diversity) and contamination of foods commonly consumed by the children. The research also assessed the safety status of feeds supplemented to home based lactating herds and attempted to quantify levels of contaminants in livestock products especially milk. The research also shows association between the parameters of dietary diversity, safety and nutritional status of children.

1.7 Limitations of the Study

The study was cross sectional in design hence missed out on effect of seasonality in dietary changes among pastoralists. Dietary intakes especially the Dietary Diversity score (DDS) questionnaire was qualitative in nature hence may not directly quantify the nutrients intake levels. Due to time and resource allocation in this study, evaluation of foodborne pathogens was limited to *E. coli* and *Salmonella* Spp. Only foods from staple food sources consumed by target population was evaluated for microbial safety.

1.10 Operational Definition of Terms

Anthropometry: Measurement of children's weight and height to obtain information about nutritional status.

Caregiver: A caregiver in this study refers to any individual who is responsible for the care and well-being of a child, typically someone who manages or directly influences the child's feeding, nutrition, health, and development. This individual can be a parent, guardian, or

another family member, but may also include non-family members such as a nanny or foster parent. In this study, over 90% of respondents were mothers.

Complementary food: Any food or beverage other than breast milk, including water which are consumed by pastoralist child aged 6-23 months while he or she remains breastfeeding or ceased breastfeeding**.**

Dietary diversity: Refers to the variety of different food groups consumed by pastoralist children aged 6-59 months.

Household: A group of people who live in the same dwelling and eat meals together.

Malnutrition: A nutritional disorder or condition resulting from faulty or inadequate nutrition among children.

Nutritional status: Measurement of the extent to which children physiological needs for nutrient is met through adequate nutrient intake and the body's ability to digest, absorb and use these nutrients.

Transitional households: Households that are either **s**ettled or semi-settled as a results of asset shock occasioned by frequent droughts and climate change.

Pastoralists: Refers to households who primarily rely on the raising and herding of livestock, such as cattle, sheep, goats, camels, or other animals, as their main source of livelihood.

Sedenterisation: refers to the process in which traditionally nomadic or semi-nomadic pastoral communities settle in one place and adopt a more permanent, fixed lifestyle. This transition often involves reducing or completely abandoning their nomadic movements in search of grazing lands and water for their livestock. Instead, they may adopt practices such as mixed farming (combining livestock rearing with crop cultivation), engage in settled agriculture, or rely on government-provided services like permanent water sources and infrastructure.

Dietary Diversity score: is a measure used to assess the variety of different food groups consumed over a specific period, usually a 24-hour recall. It reflects the range of food groups in an individual's diet, indicating nutritional adequacy (FAO, 2021). A higher DDS often correlates with improved nutrient intake and better overall health outcomes. It is commonly applied in nutrition research to evaluate the quality of diets, especially in relation to micronutrient adequacy.

Dietary Diversity: Dietary diversity here refers to the variety of different foods or food groups consumed by children aged 6-59 months in settled pastoral households 24 hours preceding the survey period.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This section gives a critical look at the existing research activities on infant and young child feeding practices, globally and in pastoral areas specifically. It focuses on children nutritional status in Kenya. It also looks at the dietary diversity and discusses the current status of food safety in terms of aflatoxin, fumonisin and selected foodborne pathogens. The chapter concludes with a conceptual framework within which the research work was conducted.

2.2 Infant and Young Child feeding Practices

Optimal breastfeeding practices include three key elements: (1) initiating breastfeeding within the first hour of birth to provide colostrum, a highly nutritious first milk; (2) exclusive breastfeeding for the first six months without any additional foods or liquids except necessary supplements; and (3) continued breastfeeding beyond one year based on the mother's and child's preferences (WHO, 2010; WHO/UNICEF, 2021). Although widely recommended (Black *et al.*, 2013), the timing, frequency, and duration of breastfeeding can vary significantly across different cultures and socioeconomic contexts.

In the first six months of life, breast milk supplies infants with all essential nutrients and energy (Figure 2.1). However, by six months, breast milk alone meets only about half of the child's energy needs, and by the second year, only about one-third (PAHO/WHO, 2001). Thus, introducing at the right moment, safe, nutrient-dense and diverse complementary foods is crucial to support the child's nutritional requirements as they grow (WHO/UNICEF, 2021; Williams *et al.*, 2016). Beyond nutrition, breastfeeding contributes to cognitive and sensory development and offers antibodies that protects the child from chronic and infectious diseases (Pang *et al.*, 2020).

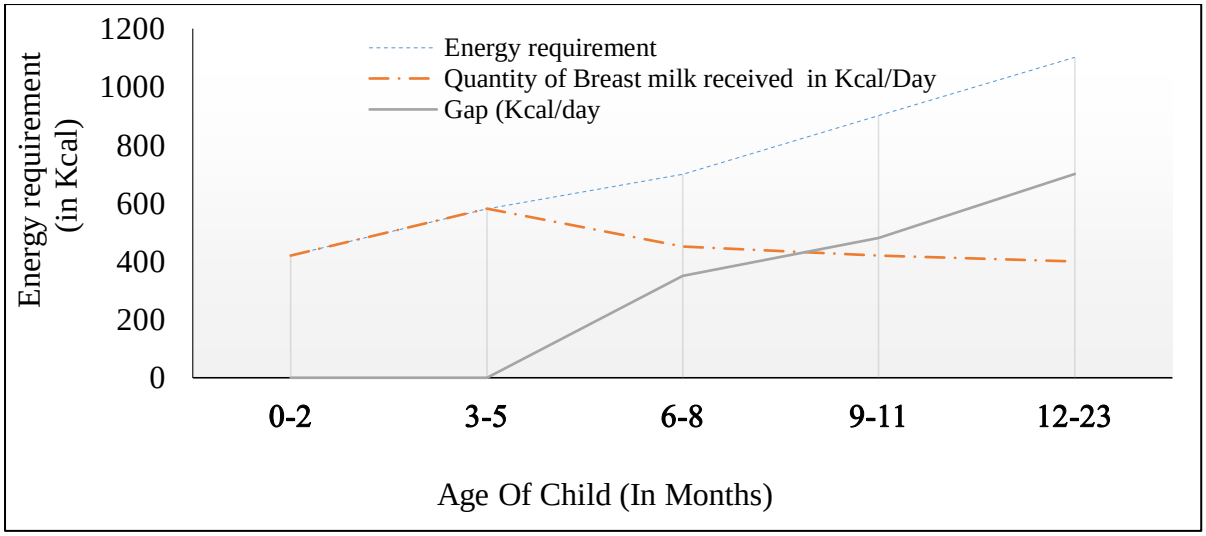


Figure 2.1: *Energy Requirement and supply form breast milk for infant and young child*

Source: PAHO/WHO (2001)

At the 6th month after birth the energy supply from breast milk does not meet the increased energy levels of an infant hence the need for timely introduction of complementary feeding. Worldwide, prevalence of exclusive breastfeeding stands at 47% and is highest (59%) in Southern Asia (UNICEF, 2016). It is much lower in Latin America and the Caribbean (33%), eastern Asia (28%), western Africa (25%), and western Asia (21%) (UNICEF, 2016). Additionally, 69% of women introduce semi-solid and solid foods during breast feeding (UNICEF, 2016). These figures are low compared to breast feeding practices in East Africa and especially in Kenya. More women (61%) in East Africa initiate early breast feeding compared to 53.48% who practice exclusive breast feeding (Issaka *et al.*, 2017).

According to KNBS & ICF (2023), 61% of children aged 0-6 months in Kenya are exclusively breastfed. Additionally, among children under 6 months, 61% receive only breast milk, with this rate dropping to 42% among those aged 4-5 months. Furthermore, 75% of children under 6 months are primarily breastfed. Similarly, breast feeding, and consumption of complementary foods begins at age 2-3 months (13%) and peaks at 98% between ages 9-12 months and drops to about 51% at 23 months. Among pastoral communities in Kenya, over 75% of mothers practice exclusive breastfeeding compared to over 95 % who initiate early breastfeeding (Galgallo, 2017; Opiyo, 2018).Similarly, higher percentage of pastoral women (86%) continue with breastfeeding beyond 1 year after birth. However, early introduction of complementary food has also been observed in Kenya at age 2-5 months with

about 84% of children of age 12-17 months are breast fed and consume complementary foods at the same time (KNBS, 2015; KNBS, 2023).

Although exclusive breast feeding (EBF) is considered safe and associated with reduced diarrheal episodes in children (Kirk *et al.*, 2017; Ogbo *et al.*, 2016), risks abound from mothers who consume contaminated foods especially from toxigenic molds and yeast in animal products and poorly handled cereal based food products (Kang'ethe *et al.*, 2017; WHO, 2015b) especially in pastoral areas where milk remains a significant component of diet. Also, early introduction of complementary feeding at a time recommended for EBF underscores need to for safe and nutrient dense complementary foods in order to insure the health of the growing child. Currently data is lacking on the safety status of both breast milk and complementary foods given to sedenteral children in pastoral areas of Kenya. Complementary feeding entails timely introduction of solid and semi-solid foods at age 6 months, with gradual increases in the amount of food given and frequency of feeding as the child gets older (Abeshu*et et al.*, 2016).

Table 2.1 gives summary of nine core indicators and two optional indicators for assessing optimal complementary feeding practice in a population Children aged 6-23 months should receive four or more of seven different food groups within a 24-hour period, to be able to attain a minimum dietary diversity (WHO, 2021).

Table 2.1: Indicators for assessing optimal complementary feeding practice in a population

Breast Feeding indicators	**Complementary feeding indicators**
1. Ever breastfed	7. Introduction to solid foods
2. Early initiation of breastfeeding	8. Minimum dietary diversity 6-23 months
3. Exclusively breastfed for the first two days after birth	9. Minimum meal frequency 6-23 months
	10. The minimum recommended milk
4. Exclusive breastfeeding under six months	feeding frequency for non-breastfed children aged 6-23 months
5. Mixed milk feeding under six months	11. Minimum acceptable diet 6-23 months
	12. Egg and/or flesh food consumption 6–23
6. Continued breastfeeding 12-13 months	months
	13. Sweet beverage consumption 6-23 months
	14. Unhealthy food consumption 6-23 months
	15. Zero vegetable or fruit consumption 6–23 months
	Other Indicators
	16. Bottle feeding 0–23 months
	17. Infant feeding area graphs

Source: WHO (2021)

2.3 Minimum Dietary Diversity trends

The World Health Organization (WHO) describes Minimum Dietary Diversity (MDD) as the proportion of children aged 6–23 months who consume foods from at least five out of eight defined food groups within a 24-hour period (WHO, 2021). These groups include breast milk; grains, roots, and tubers; legumes and nuts; dairy products; flesh foods like meat, fish, poultry, and organ meats; eggs; vitamin A-rich fruits and vegetables; and other fruits and vegetables. A diverse diet is associated with better linear growth in young children, while a lack of dietary variety raises the risk of micronutrient deficiencies, which can negatively impact physical and cognitive development (WHO, 2021).

Globally, the prevalence of Minimum Dietary Diversity (MDD) is 34%, but this figure drops to 23% in sub-Saharan Africa (UNICEF, 2023). In East Africa, 19% of children achieve the recommended MDD, a rate higher than that of Uganda but lower than the 36% observed in Kenya (UNICEF, 2023). Furthermore, among children aged 6–23 months who live with their mothers but are no longer breastfeeding, 50% meet the minimum milk feeding frequency, 29% meet the minimum dietary diversity, and only 20% meet the minimum acceptable diet (KNBS & ICF, 2023).

2.4 Nutritional Status of Children Aged 6-59 Months

Child malnutrition can be defined as a condition that results from taking an unbalanced diet in which certain nutrients are deficient (undernutrition), in excess (overnutrition), or in the wrong proportions (Mehta *et al.*, 2013). This research will focus on child undernutrition which is a major public health problem in sub Saharan Africa (Lachat *et al.*, 2015). Poor availability and access to food of adequate nutritional quality or the exposure to conditions that impair absorption and use of nutrients can lead to undernutrition, with poor micronutrient status or being overweight and obese among children. Undernutrition of children within the first 1000 days can irreversibly affect physical, mental, and cognitive growth, health, and development (Akombi *et al.*, 2017). Therefore, constant assessment of nutritional status is necessary especially in areas that are prone to food insecurity such as northern Kenya.

2.4.1 Measurement of Nutritional StatusChild nutritional status indices are calculated based on growth standards established by the World Health Organization (WHO, 2006). These standards were developed through a study of 8,440 children across six countries to illustrate ideal growth patterns under optimal conditions (Frison *et al.*, 2016; WHO, 2006). As a result, the WHO Child Growth Standards serve as a global tool for assessing children's growth, independent of their ethnicity, socioeconomic background, or feeding practices.

Table 2.2 Common anthropometric measurements and indices in children aged 6-59 months

Index	Nutritional problem	Indicator (Z scores)*
Weight-for-	Severe wasting	WFH/L < −3 SD
Height/Length	Moderate wasting	WHZ/L < −3 SD and WFH/L ≥ −2 SD
	Global wasting	WFH/L < −2 SD
	Overweight	WHZ/L > +2 SD
Height/Length-for-age	Severe stunting	HAZ/LFA < −3 SD
	Moderate stunting	HAZ/LFA < −2 SD to/LFA −3 SD
	Global stunting	HAZ/LFA < −2 SD
Weight-for-age (WAZ)	Severe underweight	WAZ< −3 SD
	Moderate underweight	WAZ< −2 SD and WFA≥ −3 SD
	Global underweight	WAZ< −2 SD
MUAC	Severe wasting	MUAC < 115 mm
	Moderate wasting	MUAC < 125 mm and ≥ 115 mm
	Global wasting	MUAC < 125 mm
Oedema	Oedematous malnutrition	Bilateral oedema below the ankles: +
		Bilateral oedema up to knees: ++
		Bilateral oedema up to arms and higher:+++
Overweight		

* Z score of ≥ -2 and MUAC ≥ 125 with no bilateral oedema is considered normal nutritional status

Source: Frison *et al.* (2016).

Table 2.2 summarizes the indices, nutritional issues, and relevant indicators utilized for assessing the nutritional status of children aged 6-59 months. The basic anthropometric information measured for assessment of malnutrition include: mid upper arm circumference (MUAC), weight, age, height/length and sex, and clinical indicators of bilateral edema and visible wasting (Frison *et al.*, 2016; WHO, 2006). Stunting, defined as a height-for-age measurement below -2 standard deviations from the median of the WHO Child Growth Standards, indicates growth deficits in children cumulatively and reflects linear growth retardation. Wasting is identified when the weight-for-height measurement is below -2 standard deviations from the median of the WHO Child Growth Standards, and it assesses

body mass relative to height. Wasting signifies acute undernutrition and can result from insufficient food intake or a recent illness that leads to weight loss and the onset of malnutrition. Children with weight-for-height z-scores (WHZ) below -2 standard deviations (-2 SD) are classified as thin or wasted, indicating acute malnutrition. Children with weight-for-height z-scores (WHZ) falling below -2 standard deviations (-2 SD) are classified as thin or wasted, indicating they are acutely malnourished.

Additionally, WFH/L below -3 SD is considered as severe wasting in children (WHO, 2006). Consequently, wasting adversely affects immune system function, leading to greater severity and duration of infectious diseases, increased susceptibility to infections, and a higher risk of mortality. Underweight, defined as a weight-for-age measurement below -2 standard deviations (SD) from the median of the WHO Child Growth Standards, serves as a composite indicator that encompasses both height-for-age and weight-for-height. This index reflects both acute malnutrition (wasting) and chronic malnutrition (stunting) but does not differentiate between the two (Akombe *et al.*, 2017). Additionally, o*verweight* —weight-for-height >+2 SD of the WHO Child growth standards median

2.4.2 Trends in Child Nutritional Status

Globally, malnutrition remains a major challenge to both health and development. A policy brief by UNICEF, WHO, and the World Bank (2023) reports that approximately 148.1 million (22.3%) children below the age of five are affected by stunting, while an additional 37 million (5.6%) are classified as either overweight or obese. Wasting, often a consequence of severe hunger or disease, affects 45 million children, accounting for 6.8% of this population (UNICEF/WHO/World Bank, 2023). Undernutrition is linked to an estimated 3.1 million deaths annually, representing 45% of all deaths in this age group (WHO & FAO, 2018). Unhealthy diets are identified as a leading risk factor contributing to the global burden of disease (WHO, 2015b)

Figure 2.2 provides a summary of trends in stunting among children under five years across sub-regions in Africa. Although there has been a steady decline in the percentage of stunted children from 2000 to 2017, and again from 2017 to 2022, more than one-third of the world's stunted children still reside in sub-Saharan Africa (UNICEF/WHO/World Bank, 2018; 2023). Central Africa reports the highest stunting prevalence at 37.4%, followed closely by East Africa, compared to other sub-regions in Africa.

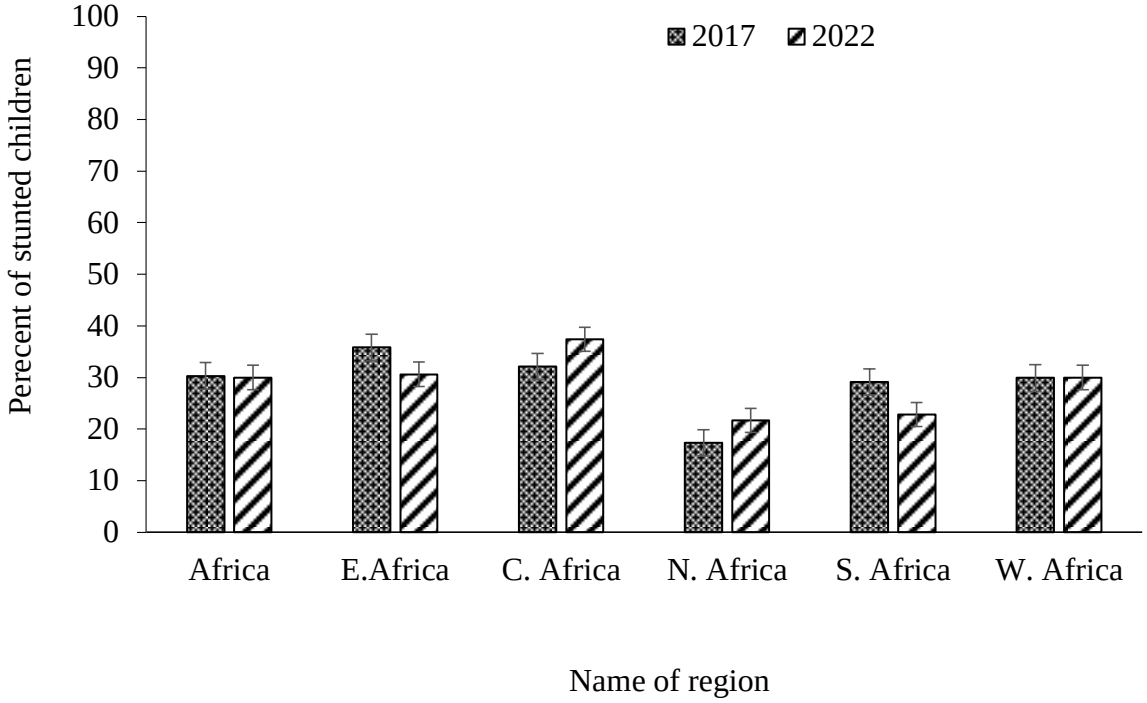


Figure 2 2: *Trends in % of stunted children aged under 5 years in Africa from –2017-2023*

Source: UNICEF/WHO/World Bank (2023)

Figure 2.3 illustrates the nutritional status of children under five years in pastoral regions of Kenya, with stunting serving as a key indicator. According to recent KDHS data, the national prevalence of stunting is 18%, although pastoral counties such as Mandera (26.8%), Marsabit (23.8%), and Turkana (30.3%) exhibit notably higher rates (KNBS & ICF, 2023). Furthermore, more than half of stunted children fall within the critical 6-23 month age bracket, with 14.4% experiencing severe stunting. The data further indicate that boys (24.7%) are more affected by stunting compared to girls (18.9%) (KNBS & ICF, 2023).

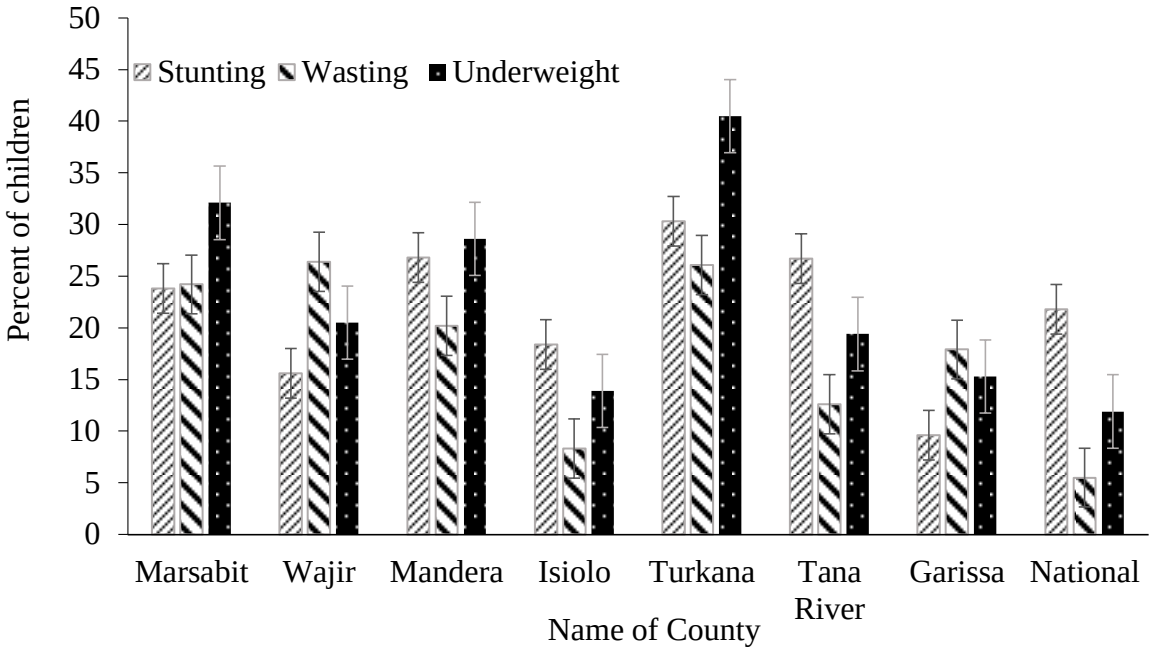


Figure 2.3 *Nutritional status of under 5 children in northern Kenya*

Source: KNBS& ICF (2023)

Severe stunting is notably higher among children with low birth weight or those small in size at birth (43–50.1%) compared to children born with average or larger sizes (12.9–24%) (KNBS & ICF, 2023). Despite significant food subsidies provided through humanitarian aid in arid and semi-arid lands (ASAL), the prevalence of global acute malnutrition (GAM) among pastoral households remains elevated relative to national figures (KNBS & ICF, 2023). This situation may be exacerbated by persistent food insecurity, especially among settled pastoral households with children aged 6 to 59 months. Although various studies have examined the nutritional status of women and children in northern Kenya (Adongo *et al.*, 2012; Opiyo, 2018), few have critically addressed the underlying causes of malnutrition from a food quality and safety perspective, particularly in terms of nutrient density and biological contaminants. Previous studies have documented factors associated with underweight, wasting and stunting (Afaw *et al.*, 2015; Alemayehu *et al.*, 2015; Habaasa, 2015; Sen *et al.*, 2017). Several factors have been linked to malnutrition, including low maternal education, increasing age of the child, male gender, low socioeconomic status, breastfeeding for less than 12 months, low birth weight, maternal age under 20 years, consumption of contaminated drinking water, maternal body mass index (BMI) below 18.5, small birth size, episodes of

diarrhea, low paternal education, and rural residence, among others (Fekadu *et al.*, 2015). More data is still required to explain the latent underlying factors associated with food quality and safety currently missing in many existing documentations.

Nationally, 5% of children are classified as wasted, with 1% experiencing severe wasting. The rate of wasting rises to 7% among children aged 48 to 59 months. During this stage, children begin to receive complementary foods, which can differ significantly in quality and quantity, making them more susceptible to diseases (Gong *et al.*, 2015; KNBS & ICF, 2023). Among pastoralists in Marsabit county in North-Eastern Kenya, 24% of children under five are wasted compared to Western, Nyanza, and Central regions with only 2% of wasting among children under five (KNBS & ICF, 2023).

2.5 Microbial Factors Influencing Quality of Complementary Food and Child Nutritional Status

Diseases and pests frequently affect food commodities like cassava, yam, barley, sorghum, millet and maize both in the field and during storage. Furthermore, stored and processed food products can harbor various microorganisms, including bacteria, yeasts, and filamentous fungi. The introduction of poorly processed complementary foods especially in resource-poor settings can expose children to nutritionally inadequate diets which are microbiologically unsafe (WHO, 2015b).

Possible consequences of this practice may include many nutrient deficiencies and exposure to foodborne microorganisms causing diseases. Some of the risk factors associated with foodborne illness include use of unsafe water, inadequate cooking processes, contaminated equipment, and poor personal hygiene especially of the complementary food handler. Studies have demonstrated association between malnutrition and occurrence of diseases in children (Rodriguez-Morales *et al.*, 2015; Vonaesch *et al.*, 2018; WHO, 2015b). Significantly higher risk of stunting has been associated partly with introduction of family diet to infants, hence may easily be exposed to food-borne pathogens (Sulaiman *et al.*, 2018).

In pastoral households, common ways that infant complementary foods can become contaminated include the use of raw or inadequately cooked animal-derived foods. Additionally, consumption of milk and meat from animals fed contaminated feed concentrates can lead to consumption of mycotoxins. This study will focus on the prevalence of *Escherichia coli*, *Salmonella* spp, aflatoxin and fumonisin as major causative agents of

contamination of complementary foods. It will also evaluate any association with indicators of malnutrition.

2.5.1 Occurrence of Aflatoxins and Fumonisins

Aflatoxins (AF) are secondary metabolites of fungi of the genera aspergillus subspecies *A. parasiticus* and *A. flavus*. Aflatoxins are potent, naturally occurring carcinogenic mycotoxins. While *Aspergillus parasiticus* is mostly associated with contamination of groundnuts, *A. flavus* is mostly found in maize (Gnonlonfin *et al.*, 2013). In terms of toxins production, *A. flavus* produces AFB_1 and AFB_2 whereas *A. parasiticus* produces AFB_1, AFB_2, AFG_1 and AFG_2. Both *A. flavus* and *A. parasiticus* infect their hosts while still in the field, either during growth or drying and continue to proliferate postharvest when stored with moisture content above 13% (FAO, 2011b). flatoxin B1 is regarded as the most potent naturally occurring carcinogen identified (Kang *et al.*, 2015; Ostry *et al.*, 2017). Aflatoxin $M_{1,}$ a hydroxylated form of $AFB_{1,}$ s excreted in the milk of both humans and animals after the consumption of food contaminated with Aflatoxin B1 (AFB1), hence can affect children if risk factors are not identified and eliminated.

Human exposure and adverse effects of AF on human health have been documented, in Kenya (Gong *et al.*, 2012; Kang'ethe *et al.*, 2017), Tanzania (Magoha *et al.*, 2016; Shirima *et al.*, 2015) and in West African countries (Watson *et al.*, 2016). These studies reported an association between aflatoxin biomarkers and hepatomegaly and stunting in children. In Kenya, complementary foods are primarily cereal-based hence can be prone to aflatoxin contamination. Consequently, the introduction of complementary food and family food to children aged below five years marks a significant exposure in aflatoxin levels (Gong *et al.*, 2015).

Fumonisins are secondary metabolites of the fungi *Fusarium verticillioides* (Sacc.) Nirenberg and *F. proliferatum* (Matsush) Nirenberg, commonly found in maize and maize-based products (Wild *et al.*, 2015). Fumonisins have toxic effects by inhibiting ceramide synthases, which disrupts the de novo synthesis of ceramides. This reduction in ceramide levels leads to decreased concentrations of complex sphingolipids and causes an accumulation of free sphingoid bases and sphingoid base 1 phosphates (Chen *et al.*, 2018). This can lead to a global reallocation of lipid substrates into various pathways and products, which can influence numerous signaling systems that are essential for cellular regulation. Studies have

shown relationship between consumption of fumonisin especially FB_1 and stunting (Chen *et al.*, 2018; Shirima, 2015) and cancer (Wild *et al.*, 2015).

2.5.2 Occurrence of *Escherichia coli* and *Salmonella Spp* in Complementary foods

Humans are the primary reservoirs of *Salmonella enterica*, a significant microbiological agent responsible for foodborne illnesses. Transmission occurs through contaminated water, food, or direct person-to-person contact. The foods most commonly associated with Salmonella outbreaks include dairy products, particularly raw milk, and meat products, which are essential components of pastoralists' diets. Globally, foodborne illnesses are estimated to cause around one billion episodes annually, with the majority being diarrheal diseases affecting children (Matofari, 2007). The risk factors linked to Salmonella infections that can result in food poisoning outbreaks are primarily related to individuals and are connected to the distribution of contaminated food products, especially those produced for large groups of people.

The genus *Salmonella* belongs to the family enterobactericeae. *Salmonellae* are Gram-negative, non-spore forming rods, which are aerobic or facultatively anaerobic, catalase positive, oxidase-negative and motile with peritrichous flagella. Notable examples of pathogenic significance include *Salmonella enterica Paratyphi A* and *Salmonella enterica* Typhi that mainly affect humans' species. In humans, *Salmonellae* can cause two diseases called salmonellosis and present differently depending on root of infection. Enteric fever (typhoid) occurs due to bacterial invasion of the bloodstream, while gastroenteritis is caused by foodborne infections, which can be classified as intoxications (Matofari, 2007).

Salmonellosis is zoonotic hence can be contracted from infected animals. Pastoralists are more susceptible to salmonellosis given their dependence on livestock products. Consumption of raw milk among pastoralists children in Kenya has been reported (Wayua, 2017). *Salmonella* organisms can contaminate milk by releasing endotoxins or through the introduction of fecal material during handling. Additionally, the use of contaminated water to wash milk containers can also contribute to contamination. Animals affected by salmonellosis can excrete viable *Salmonella* organisms in both their milk (Napoleoni *et al.*, 2021) and meat (Rukambile *et al*., 2019).

Escherichia coli is a bacterial species belonging to the genus *Escherichia*, which primarily comprises motile, gram-negative bacilli within the family *Enterobacteriaceae* and the tribe

Escherichia (Yu *et al*., 2021). The organism normally colonizes the intestines of an infant within hours of birth, thereafter both host and the microorganism derive mutual benefit. However, in the event of compromised gastrointestinal tract barriers, various strains of *E. coli* can cause infection to the host. Virulent strains of *E. coli* exist, broadly categorized as: 1) Enterohemorrhagic *E. coli* (EHEC), 2) Enteropathogenic *E. coli* (EPEC), 3) Enteroaggregative *E. Coli* (EAEC), 4) Enteroinvasive *E. coli* (EIEC) and 5) Enterotoxigenic *E. coli* (ETEC).

Enteropathogenic *Escherichia coli* (EPEC) remains one of the common causes of diarrhoea among children under five years in developing world (Saeed *et al.*, 2015). The pathogenicity of EPEC involves a multiple stage process (Yu *et al*., 2021). According to Yu *et al*. (2021), the first stage involves an initial, relatively distant interaction between bacteria and the enterocyte layer of the cytoskeletal components of the microvilli. In the second stage, the activation of the eae gene and other related genes leads to the breakdown of the normal microvilli structure. The third stage is characterized by the bacteria binding closely to the epithelial membrane through the protein intimin, resulting in the death of epithelial cells and the loss of intestinal microvilli. This process ultimately compromises intestinal integrity and leads to diarrhea.

Salmonella and *Escherichia coli* strains can be detected using both phenotypic and genotypic methods. Genotypic testing for Enteropathogenic Escherichia coli (EPEC) involves the use of DNA probes and PCR primers to detect three primary characteristics: the attaching and effacing (A/E) ability, the presence of the EAF plasmid, and the absence of Shiga toxin. Typical EPEC strains carry the *eae* gene associated with A/E and either the EAF probe or *bfp* sequences, signifying the EAF plasmid. In contrast, atypical EPEC strains contain only the *eae* gene without the EAF plasmid (Saeed *et al.*, 2015). *Escherichia coli* can be recovered from samples using selective media at 37°C under aerobic conditions. Recovery of enteric organisms can be achieved using MacConkey or eosin methylene blue agar, which selectively support the growth of Enterobacteriaceae and allow differentiation based on colony morphology. Biochemical tests such as indole test can be used as confirmatory tests for phenotypic characterization.

2.6 Conceptual Framework

Figure 2.4 gives an illustration of a conceptual framework developed for this study. This conceptual framework on causes of malnutrition has been modified from the WHO

conceptual framework on child malnutrition (Stewart *et al.*, 2013). It shows the causes of child malnutrition due by multisectoral factors. Dietary diversity and nutrient intakes have a direct effect on nutritional status of child. Consumption of contaminated foods sourced from poor environments can expose children to infection and diarrhoea. The framework will thus serve and guide in assessing and analyzing the causes of child malnutrition among the pastoral children in Marsabit County.

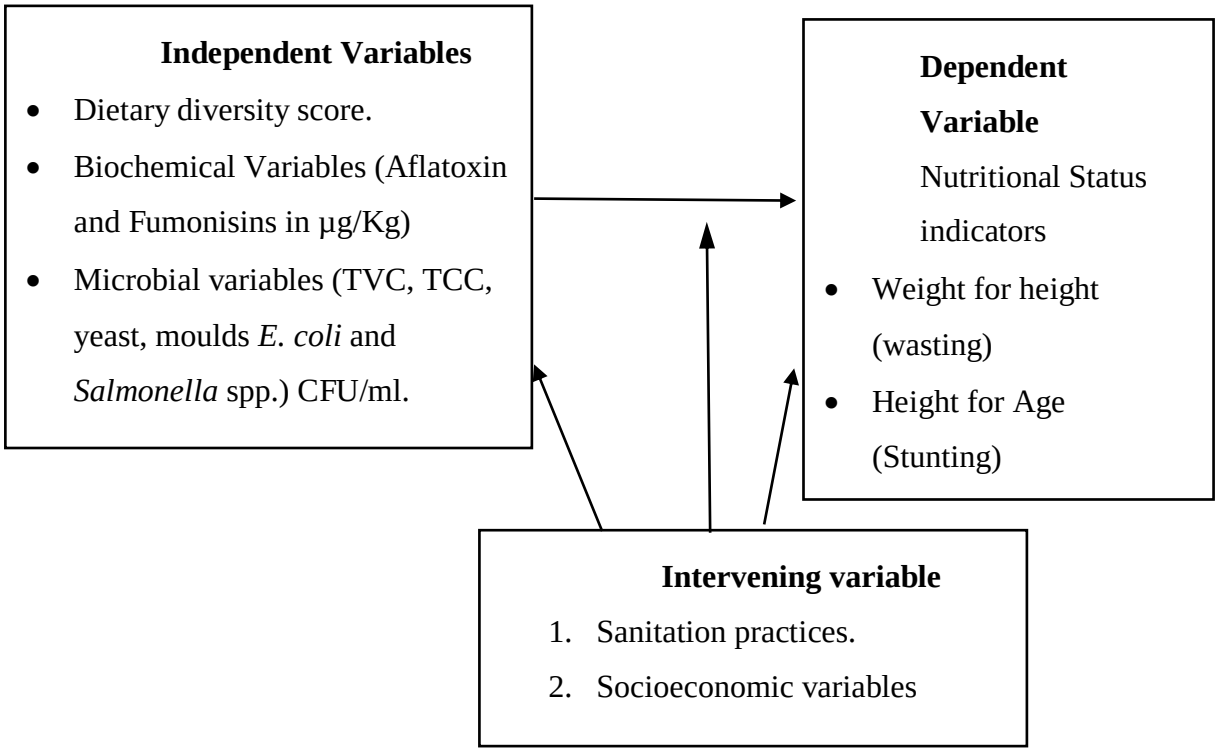


Figure 2.4 *Conceptual framework*

2.7 Research Gap

The transition from nomadic to sedentary lifestyles among pastoral communities has profound implications for the dietary habits and nutritional status of young children. Existing research is limited in its exploration of the specific effects of this transition on the nutritional quality of home-based pastoral livestock products, particularly when supplemented with additional feeds. Furthermore, there is a dearth of information regarding microbial and mycotoxin contamination in complementary foods consumed by children in northern Kenya. The relationship between persistent stunting, underweight, and wasting, and the quality and safety parameters of these complementary foods, particularly in Marsabit County, remains largely unexplored.

CHAPTER THREE

DETERMINANTS OF UNDERNUTRITION OF SETTLED PASTORALISTS' CHILDREN AGED 6-59 MONTHS IN MARSABIT COUNTY, KENYA

Abstract

The shift from a nomadic to a sedentary lifestyle has led to dietary changes, resulting in endemic undernutrition among settled pastoral households. This study investigated the factors contributing to stunting, underweight, and wasting among children aged 6-59 months in Marsabit County, Kenya. A cross-sectional household survey was conducted across six wards, representing pastoral, agro-pastoral, and urban livelihood practices. Using a multistage sampling approach, 394 children aged 6-59 months participated, with caregivers providing written consent. Data collection involved a pretested questionnaire and anthropometric measurements. Population characteristics were summarized using means and proportions, while chi-square tests and analysis of variance assessed associations between variables. Binary logistic regression was applied to identify predictors of stunting, underweight, and wasting. Results showed average Height-for-Age, Weight-for-Age, and Weight-for-Height Z-scores of -1.51, 1.54, and 1.02, respectively. Stunting, underweight, and wasting prevalence were 38.1%, 23.0%, and 18.5%, respectively. Key factors influencing stunting included child age, drinking water source, and waste disposal practices. Additionally, higher caregiver income and education level of the household head were linked to reduced odds of underweight. Safe disposal of child fecal waste and the education level of the household head were associated with lower wasting risk. In conclusion, stunting, underweight, and wasting prevalence were elevated compared to WHO cut-off values and KDHS data, with contributing factors including household hygiene practices, caregiver income, and education levels. The study highlights that the transition to a more cereal-based diet has intensified stunting, underweight, and wasting rates among children.

3.1 Introduction

The diets of nomadic children have traditionally been rich in animal-based foods, such as milk, meat, and occasionally blood, supplemented seasonally with wild fruits and vegetables when available (Oniang'o *et al.*, 2003). However, frequent droughts that devastate livestock populations have prolonged high levels of poverty, which has led many nomadic communities to adopt a sedentary lifestyle to survive (Asiimwe *et al.*, 2020; Burns *et al.*, 2022; KNBS, 2023). As these former nomads settle, they rely intermittently on famine relief

food and shift away from traditional animal-based diets, now depending more on purchased staples, especially grains and pulses, with occasional additions of animal-source foods. While the entire household generally shares similar meals, the preparation and handling of food for young children between the ages of 6 and 59 months differ from that of adults, involving distinct processing levels and specific feeding practices. Suboptimal complementary feeding practices by caregivers are a leading cause of undernutrition in young children, contributing to malnutrition indicators such as stunting, wasting, and underweight in children in this age group.

Across the globe, approximately 22% of children under five (148.1 million) are impacted by stunting, and 6.8% (or 45 million) experience wasting as a result of malnutrition (UNICEF/WHO/World Bank, 2023). This reflects a slight rise in wasting from the 6.7% (45.4 million) documented in 2021 (UNICEF/WHO/World Bank, 2021). High levels of undernutrition continue to be prominent in regions like sub-Saharan Africa, Southeast Asia, and the Eastern Mediterranean, contributing to nearly half of child deaths in these areas (de Onis *et al.*, 2016; UNICEF, 2019). Stunting affects around 30.6% of children in sub-Saharan Africa, with rates at 30.5% in East Asia and 26% in Southeast Asia (UNICEF/WHO/World Bank, 2023). In Kenya, rates of stunting and underweight have declined from 26% and 11% in 2015 (KNBS, 2015) to 18% and 10% in 2023 (KNBS, 2023). However, stunting remains prevalent in Arid and Semi-Arid Land (ASAL) regions, with high rates observed in counties like West Pokot (34%), Turkana (23%), and Marsabit (19%) (KNBS, 2023; Young *et al.*, 2024).

Undernutrition remains a major concern for young children's linear growth, health, and cognitive development, especially in those under five (Kassa *et al*., 2016; Matonti *et al*., 2020). Despite the significance of this issue, there is limited research on how settlement influences underlying causes of undernutrition in this age group. Various studies have established connections between children's nutritional outcomes and foundational factors. Research in Uganda, for instance, highlights that male children, certain age categories, and inadequate sanitation are linked with higher odds of wasting among under-fives (Kinyoki *et al*., 2015; Obeng-Amoako *et al*., 2020; Okidi *et al*., 2021). Additional influences on child malnutrition include the income and education levels of parents (Khan *et al*., 2019). Although nutritional data has been gathered to support emergency interventions in pastoral communities, knowledge is scarce regarding the root causes of malnutrition, particularly

among settled pastoral groups. This study, therefore, aimed to examine the prevalence and underlying determinants of nutritional status in children from settled pastoral households in northern Kenya, focusing on Marsabit County. Findings from this study could guide policies that reinforce nutrition-sensitive development for communities transitioning to settled lifestyles.

3.2 Materials and Methods

3.2.1 Study Area

Figure 3.1 shows the study area in which the study was conducted.

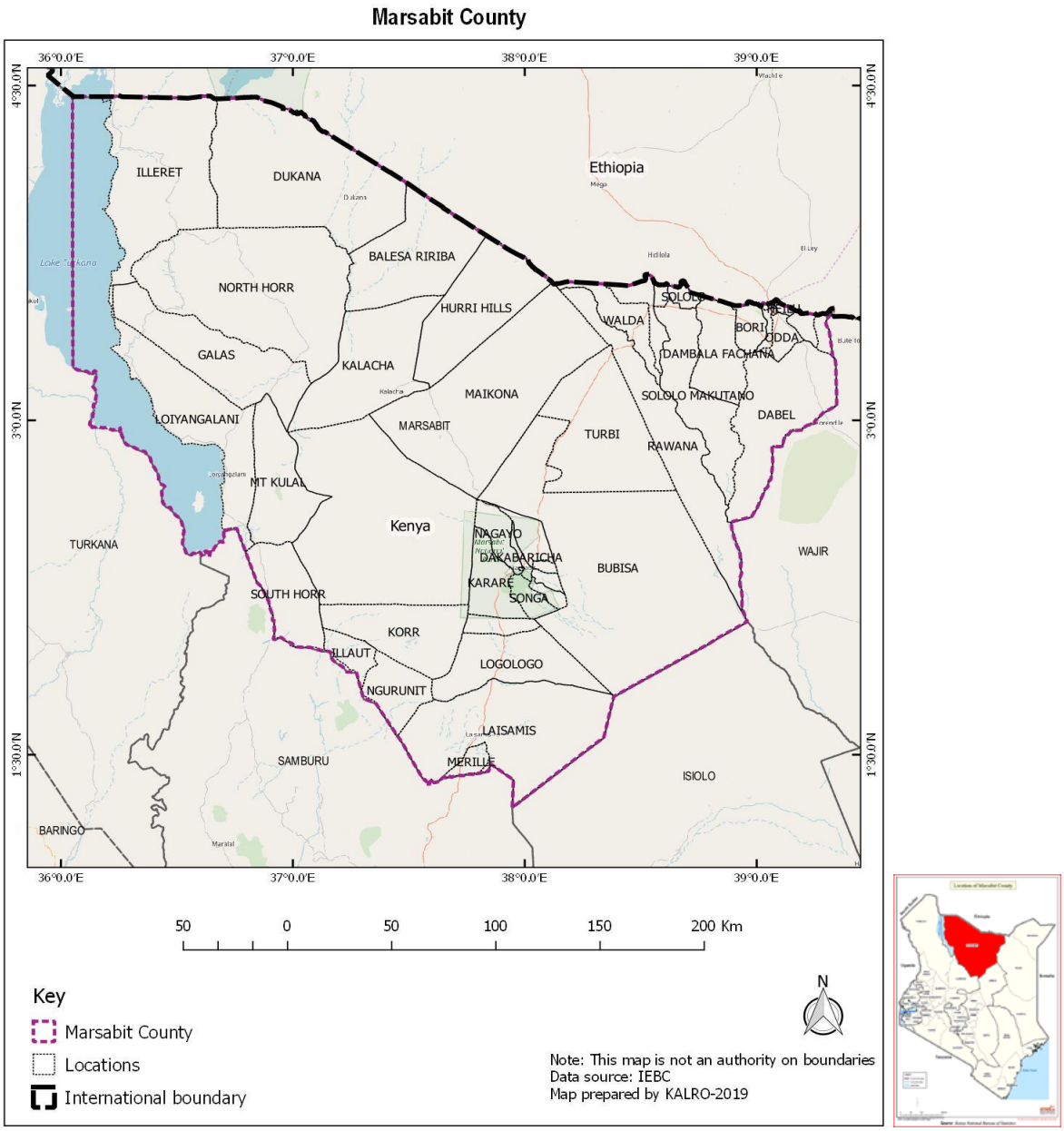


Figure 3.1 *Map of Marsabit County*

Source: KALRO (2019)

The study was conducted in Marsabit County (Figure 3.1) in the months of October and November 2020. Marsabit County was purposively selected because sedentarization is currently an ongoing process and peri urban pastoral production system is emerging alongside nomadic pastoralism (Noor, 2013). Marsabit County comprises of four sub counties namely, North Horr, Laisamis, Moyale and Saku. Marsabit lies between latitude 37°57' and 38° 59' E and longitude 02° 45' and 04° 27'N. About 97 per cent of the county is Arid and Semi-Arid Land (ASAL), capable of supporting only livestock and wildlife (UNDP/GoK, 2013). It covers a total area of about 70,961.2 square kilometers with annual mean rainfall values varying from 200 mm in lowlands and over 1000 mm in Marsabit mountain (UNDP/GoK, 2013). Average temperatures range between 24°C in mountain areas and over 30°C in lowland areas (Herlocker *et al.,* 1995). Specifically, the study was conducted in Laisamis, Logologo, Karare, Central, Sagante/Jaldesa and Bubisa wards respectively representing the different agro-ecological zones, social, cultural and livelihoods changes (Figure 3.1). Central ward is within county headquarters and more cosmopolitan with trade in goods and service being the main economic practice in addition to limited urban agriculture. Karare and Sagante/Jaldesa constitute agro pastoral livelihood zones while Laisamis, Logologo and Bubisa are located in the lowlands where livestock keeping is the main economic mainstay.

3.2.2 Experimental design and sampling procedure

The study was a cross-sectional research design where households with children aged 6 - 59 months were randomly selected and studied at the same point in time. The household was considered a sampling unit. The study used descriptive survey to assess anthropometric measurements for evaluating nutritional status of children aged 6 to 59 months. The focus was on children aged 6 to 59 months because, by the sixth month, breast milk can only provide half of the energy required, and by the second year, it provides only one-third. During this critical period, children experience rapid linear growth and have underdeveloped immunity to diseases. Therefore, suboptimal nutritional practices during this time can lead to irreversible effects on linear growth and cognitive development

3.2.3 Sample Size

The number of subjects for the study was identified according to Magnani (1997) where critical indicators in this case, dietary diversity scale expressed as proportions or percentage. Accordingly, the sample size was calculated based on the formula below

$$n = D\left[\frac{(Z_\alpha + Z_\beta)^2 * P_1(1 - P_1) + P_2(1 - P_2)}{(P_2 - P_1)^2}\right]$$

Where: n = Minimum sample size per survey round or comparison group; D = Design effect (a default of 2 is assumed in this study); P_1 = Estimated level of indicator measured as a percentage taken at the first survey in Moyale (49% of minimum meal frequency in terms of DDS in Marsabit county (Opiyo, 2018); P_2 = Expected level of the indicator either at some future date such that the quantity ($P_1 - P_2$) is the size of the magnitude of change to be detected (an increase of 10% of children aged 6 - 59 months taking minimum meal frequency = 59%; Z_α= Z-score corresponding to the degree of confidence with which it is desired to be able to conclude the an observed change of size ($P_1 - P_2$) would not have occurred by chance (**α**= Level of statistical significance =95% = 1.645); Z_β = Z-score corresponding to the degree of confidence with which it is desired to be certain of detecting a change of size ($P_1 - P_2$) if one actually occurred (β= statistical power = 80% =0.840).

n = 2 $[(1.645+ 0.840)^2 * (0.49(.51) + (0.59)(0.41) / (0.25)^2]$ = 357.0 + 10% attrition (36). Hence total sample size = 393.0

3.3.2 Sampling Procedure

The sample size was established using the approach recommended by Magnani (1997), which concentrated on a vital indicator—specifically, the minimum meal frequency of 49% observed in Moyale sub county (Opiyo, 2018), with an expected increase of 10% in this frequency. A multistage sampling technique as described by Mugenda and Mugenda (2003) was employed for this study. Ultimately, 394 households with an index child aged between 6 and 59 months were selected. The first stage consisted of intentionally choosing counties, sub counties, and wards based on specific criteria to ensure relevant representation. Next, simple random sampling was utilized to select sampling clusters at the local level. A comprehensive list of targeted children from different locations within each of the six wards was created with the assistance of health officials and local leaders familiar with the study areas. A systematic sampling approach was then implemented, treating each household as a sampling unit. Within

each chosen household, the index child and their primary caregiver were randomly selected for interviews, following the acquisition of informed consent. The distribution of index children across each ward was allocated proportionally based on population size, which established the sampling frame. When multiple children aged between two and five were present, the selected index child was the youngest, specifically the one who was 6 months old and the last born among the target group. In situations involving twins, their names were written on separate pieces of paper, folded, and the caregiver was allowed to randomly select one. The consent form was translated into Kiswahili and, when necessary, orally translated into local dialects to ensure understanding.

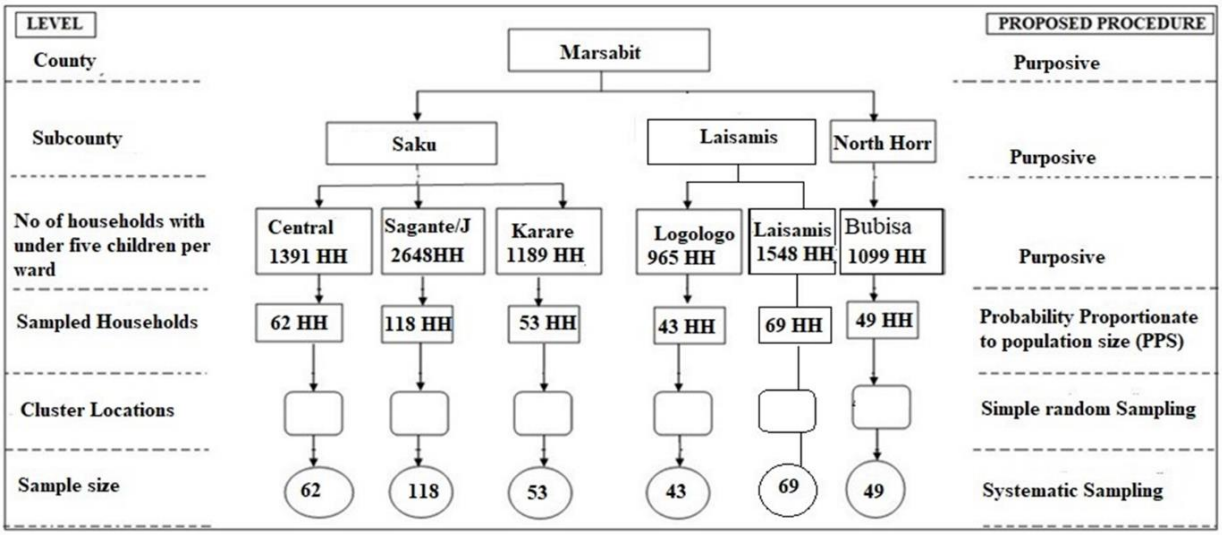


***Figure 3.2**: Schematic diagram of sampling procedure.*

3.2.4. Ethical Approval

Ethical clearance was granted by the Egerton University Review and Ethics Committee (approval No. EUREC/APP/088/2019). Additionally, a research permit was secured from the National Commission for Science, Technology, and Innovations (NACOSTI) in Nairobi (License No: NACOSTI/P/20/2972). Written consent was obtained from the child's caregiver or mother prior to the collection of nutrition data. To comply with COVID-19 protocols, data collection was conducted with the assistance of trained Ministry of Health officials stationed at health facilities in each ward.

3.2.5 Exclusion criteria

Children below six months were excluded as well as children who were chronically sick and terminally ill.

3.2.6 Children demographic and socio-economic data

Information regarding children's birth date, birth weight, sex, and vaccination status was collected from their health clinic cards. A pre-tested semi-structured questionnaire was administered to each child's mother or caregiver to gather data on various factors, including parents' education levels, occupations, marital status, number of children, and family size. Additionally, data on livestock ownership, economic activities, food sources, and handling practices were obtained, as these factors are potential determinants of microbial contamination in food and the resulting exposure through consumption.

3.2.7Anthropometric Measurements

The children's date of birth was established using immunization cards and calendar of events and age recorded in months. All anthropometric measurement was taken according to WHO (2006). Children's recumbent length (6 to 23 months' age) and height (24 to 59 months' age) were measured using a portable stadiometer to the nearest 0.1cm (UNICEF). The length of children was measured while they were lying flat on a measuring board positioned on a hard, flat surface. Readings were taken when the child's head and feet were gently pressed against the base of the board and the foot piece, respectively. For children older than 24 months, height was measured while they stood upright on the measuring board, which was placed against a wall on a flat surface, ensuring that the line of sight was perpendicular to the horizontal plane. The measurement was obtained by carefully lowering the headpiece onto the top of the child's head and recording the height between the headpiece and the base of the board to the nearest 0.1 cm. Weight was recorded using a standard electronic scale (seca GmbH & Co. KG, Hamburg, Germany) with a precision of 100 grams. To ensure accuracy, children's clothing was minimized as much as possible, and shoes were removed prior to weighing. For children unable to stand on the scale independently, a mother-baby weight recording method was employed. The reading was taken twice, and the average recorded for each child. The scale was regularly standardized by measuring objects of known weight.

3.2.8 Data Analysis

Data were organized, managed, and analyzed using SPSS software version 20 (IBM Statistics, Chicago, IL, USA). Anthropometric measurements, including age, weight, and height, were processed with the ENA for SMART (2018) software. These measurements were then transformed into three summary indices of nutritional status: weight-for-age (underweight), height-for-age (stunting), and weight-for-height (wasting), based on the Z-

scores established by the WHO criteria from 2006 (WHO, 2006). Wasting was characterized by a weight-for-height Z score below −2 standard deviations (SD) of the median from the WHO child growth standards, while underweight was defined as a weight-for-age Z score lower than −2 SD of the same standards. Stunting was identified as a height-for-age Z score of less than −2 SD of the WHO child growth standards median. The data analysis was conducted at a 95% confidence level. Both descriptive and inferential statistics were employed to analyze the data. Descriptive statistics, including mean, standard deviation, and frequencies, were utilized to summarize and characterize the population in terms of social, economic, and demographic factors. The chi-square test was applied to assess whether there were differences in population characteristics across the various study sites. Additionally, Analysis of Variance (ANOVA) was used to identify mean differences among population variables, particularly for continuous data, while Tukey's Honestly Significant Difference (HSD) test was applied to establish mean separations. Backward linear regression was utilized to identify the social, economic, demographic, and environmental factors affecting Height-for-Age (HAZ) and Weight-for-Age (WAZ), employing Tukey's HSD for mean separation. Additionally, binary logistic regression analysis was conducted to evaluate potential social, economic, and demographic determinants of stunting, underweight, and wasting as outcome variables. The predictors of child nutritional status, specifically stunting, underweight, and wasting, were examined both for the overall population and within each individual ward. The following was the statistical model used in this study;

$$\mathbf{Y}_{ijk} = \boldsymbol{\mu} + \mathbf{A}_i + \mathbf{B\,(A)}_{j\,(i)} + \mathbf{R}_k + \boldsymbol{\varepsilon}_{ijklm}$$

Where; Y_{ijklm} is Observation on the response variable, μ is Overall mean, A_i is effect of the i^{th} sedenteral ward, $B(A)_{ij}$ is effect of the j^{th} sedenteral household within i^{th} sedenteral ward, R_l is effect of the k^{th} replicate, and ε_{ijklm} is random error associated with Y_{ijk}.

3.3. Results

3.3.1 Population Characteristics

Tables 3.1, 3.2 and 3.3 give a summary of general population characteristics of the study areas. This section describes variables observed among household head, Care giver, child characteristics and environmental characteristics of the study areas.

Household head Characteristics

Table 3.1 summarizes the characteristics of household heads across the six administrative wards in Marsabit County. The study sampled a total of 394 households with children aged 6–59 months, distributed as follows: Karare (13.5%), Laisamis (17.5%), Logologo (10.9%), Central (15.7%), Sagante/Jaldesa (29.9%), and Bubisa (12.4%). Most households were led by males (86.8%), with an average age of household heads at 36.79 ± 9.1 years, indicating no significant differences in age among the wards ($p = 0.194$). Notably, there was a higher prevalence of female-headed households in the agro-pastoral and urban areas of Marsabit Central and Sagante, in contrast to the lowland wards of Bubisa, Logologo, Laisamis, and Karare. The overall mean family size, excluding the household head, was 4.2 ± 1.9. Karare had a significantly higher family size compared to Logologo, Central, Sagante/Jaldesa, Bubisa, and Laisamis ($p < 0.001$). The illiteracy level among household heads was significantly higher in Logologo, Karare, and Bubisa ($p < 0.001$). Overall, 53.3% of household heads were illiterate, while 24.1% had completed primary education, and 22.6% had attained secondary or higher levels of education. Logologo had the highest illiteracy rate, followed by Karare, Bubisa, and Laisamis. Wards closer to Marsabit town, such as Central and Sagante/Jaldesa, showed relatively lower illiteracy levels.

Livestock rearing was the main source of livelihood for most households, accounting for 38.7%, particularly in the lowland wards: Logologo (69%), Bubisa (65.3%), Karare (58%), Laisamis (56.5%), and Sagante/Jaldesa (17.8%). Notably, no households in the urban Central ward reported engaging in livestock rearing. Other livelihood sources included labor and self-employment in small to medium-sized enterprises, which comprised 16.8% of households. Formal employment was present in 11.7% of households, primarily in government positions and local non-governmental organizations (NGOs), with a higher prevalence in Marsabit Central, the county headquarters, and the peri-urban ward of Sagante/Jaldesa. The overall unemployment rate stood at 10.7%, with significantly elevated levels in Sagante/Jaldesa, followed by Marsabit Central, Karare, Laisamis, Bubisa, and Logologo ($p < 0.001$).

Caregiver Characteristics in Marsabit County

Table 3.2 provides summary of caregiver characteristics in the six study sites. A cross-sectional analysis of caregiver characteristics across six administrative wards in Marsabit County indicated that most caregivers were married women, comprising 87% of the sample, with an average age of 28.9 years. Divorce rates were significantly higher in the urban ward of Marsabit Central, reaching 11.3%, in contrast to the lower rates observed in rural and peri-

urban areas. A significant proportion of caregivers (66%) were illiterate, particularly in Logologo, Karare, Bubisa, Laisamis, and Sagante.

Regarding occupation, over half of the caregivers were housewives. Livestock keeping and related activities were the primary source of income for 32% of caregivers, while others relied on salaried employment or self-employment. Unemployment rates were highest in Bubisa, followed by Sagante/Jaldesa, Central, Laisamis, Karare, and Logologo. Formal employment was concentrated in the urban central ward, while self-employment was more common in Central, Karare, and Sagante/Jaldesa. Agro-pastoralism was the primary occupation for 23% of caregivers, primarily in Sagante, Karare, and Central wards.

Most caregivers (67.8%) were categorized within the lowest income bracket, earning less than KES 5,000.00 per month. The wards of Sagante/Jaldesa, Central, and Karare exhibited the highest proportions of caregivers in this income category ($p < 0.001$), followed by Logologo, Bubisa, and Laisamis. Conversely, caregivers belonging to the higher income bracket of KES 5,000 and above were more commonly found in Logologo, Bubisa and Laisamis.

Breastfeeding was widely practiced across all study sites, with only Central, Sagante/Jaldesa, and Logologo reporting less than 100% compliance. Handwashing before feeding was observed in 91.4% of caregivers, with Bubisa demonstrating the highest compliance rate. These findings underscore the need for targeted interventions to improve the socioeconomic status and health outcomes of caregivers and their children in Marsabit County.

Table 3.1: Household Head Characteristics

		Name of Wards							
		Karare (n=53)	Laisamis (n=69)	Logologo (n=43)	Central (n=62)	Sagante (n=118)	Bubisa (n=49)	Total (N=394)	P ≤0.05
Age (years)	Mean ± SE	37.13±11.0	34.94±8.5	38.33±11.0	36.35±8.66	36.48±7.62	39.02±9.4	36.79±9.1	0.194
Family size	Mean ± SE	4.9±2.4[b]	3.4±1.3[a]	4.6±1.7[b]	4.5±2.3[b]	4.3±1.9[b]	4.0±1.7[ab]	4.2±1.9	<0.001
		[n (%]	[n (%]	[n (%]	[n (%]	[n (%]	[n (%]	[n (%]	χ^2
Education	Illiterate [n(%]	38 (71.7)	42 (60.9)	34 (79.1)	15 (24.2)	50 (42.4)	31 (63.3)	210 (53.3)	
	Primary	6 (11.3)	11 (15.9)	2 (4.7)	26 (41.9)	42 (35.6)	8 (16.3)	95 (24.1)	<0.001
	≥ Secondary	9 (17)	16 (23.2)	7 (16.3)	21 (33.9)	26 (22)	10 (20.4)	89 (22.6)	
Gender	Male	46 (86.8)	63 (91.3)	37 (86)	50 (80.6)	100 (84.7)	46 (93.9)	342 (86.8)	0.319
	Female	7 (13.2)	6 (8.7)	6 (14)	12 19.4)	18 (15.3)	3 (6.1)	52 (13.2)	
Marital status	Married	48 (90.6)	62 (89.9)	37 (86.0)	48 (77.4)	102 (86.4)	46 (93.9)	343 (87.1)	
	Divorced	1 (1.9)	3 (4.3)	2 (4.7)	7 (11.3)	7 (5.9)	2 (4.1)	22 (5.6)	0.163
	Single	1 (1.9)	2 (2.9)	0 (0.0)	5 (8.1)	2 (1.7)	1 (2.0)	11 (2.8)	
	Widowed	3 (5.7)	2 (2.9)	4 (9.3)	2 (3.2)	7 (5.9)	0 (0.0)	18 (4.6)	
Main occupation	Livestock	31 (58.5)	39 (56.5)	30 (69.8)	0 (0.0)	21 (17.8)	31(63.3)	152 (38.6)	
	Labour/herder	10 (18.9)	7 (10.1)	6 (14.0)	17 (27.4)	39 (33.1)	5 (10.2)	84 (21.4)	<0.001
	Employed	4 (7.5)	9 (13.0)	2 (4.7)	11 (17.7)	16 (13.6)	4 (8.2)	46 (11.7)	

	Name of Wards							
	Karare (n=53)	Laisamis (n=69)	Logologo (n=43)	Central (n=62)	Sagante (n=118)	Bubisa (n=49)	Total (N=394)	P ≤0.05
Self employed	2 (3.8)	8 (11.6)	1 (2.3)	27 (43.5)	24 (20.3)	4 (8.2)	66 (16.8)	
Pensioner	0 (0.0)	0 (0.0)	2 (4.7)	0 (0.0)	1 (0.8)	1 (2.0)	4 (1.0)	
Unemployed	6 (11.3)	6 (8.7)	2 (4.7)	7 (11.3)	17 (14.4)	4 (8.2)	42 (10.7)	

Table 3.2: Care Giver Characteristics

		Name of Ward (95% C.I)							
Variable	Category	Karare (n=53)	Laisamis (n=69)	Logologo (n=43)	Central (n=62)	Sagante (n=118)	Bubisa (n=49)	Total (N=394)	p≤0.05
Age (years)	Mean ± SEM	29.79±0.98	27.15±0.73	29.28±0.94	28.77±0.85	29.22±0.56	29.55±1.23	28.91±0.34	*F*; 0.256
		[n (%)]	[n (%)]	[n (%)]	[n (%)]	[n (%)]	[n (%)]	[n (%)]	$\chi 2$, p≤0.05
Marital status of	Married	48 (90.6)	62 (89.9)	37 (86)	48 (77.4)	102 (86.4)	46 (93.9)	343 (87.1)	
care giver	Single	1 (1.9)	2 (2.9)	0 (0.0)	5 (8.1)	2 (1.7)	1 (2.0)	11 (2.8)	0.163
	Divorced	1 (1.9)	3 (4.3)	2 (4.7)	7 (11.3)	7 (5.9)	2 (4.1)	22 (5.6)	
	Widowed	3 (5.7)	2 (2.9)	4 (9.3)	2 (3.2)	7 (5.9)	0 (0.0)	18 (4.6)	
Education	None	40 (75.5)	47 (68.1)	37 (86)	21 (33.9)	79 (66.9)	36 (73.5)	260 (66)	
	Primary	8 (15.1)	13 (18.8)	3 (7.0)	25 (40.3)	30 (25.4)	10 (20.4)	89 (22.6)	<0.001
	>Secondary	5 (9.4)	9 (13.0)	3 (7.0)	16 (25.8)	9 (7.6)	3 (6.1)	45 (11.4)	
Primary	Livestock	8 (15.1)	25 (36.2)	26 (60.5)	0(0)	8 (6.8)	6 (12.2)	73 (18.5)	
occupation	Labour/herder	8 (15.1)	5 (7.2)	5 (11.6)	5 (8.1)	15 (12.7)	1 (2.0)	39 (9.9)	
	Sale milk	0 (0.0)	6 (8.7)	2 (4.6)	0 (0.0)	3 (2.5)	0 (0.0	11 (2.8)	
	Employment	1 (1.9)	2 (2.9)	1 (2.3)	8 (12.9)	3 (2.5)	2 (4.1)	17 (4.3)	<0.001
	Self employed	10 (18.9)	6 (8.7)	3 (7.0)	13 (21.0)	16 (13.6)	2 (4.1)	50 (12.7)	
	unemployed	26 (49.1)	25 (36.2)	6 (14.0)	36 (58.1)	73 (61.9)	38 (77.5)	204 (51.8)	
Estimated	< 5,000	39 (73.6)	32 (46.4)	25 (58.1)	45 (72.6)	103 (87.3)	23 (46.9)	267 (67.8)	<0.001

		Name of Ward (95% C.I)							
Variable	Category	Karare (n=53)	Laisamis (n=69)	Logologo (n=43)	Central (n=62)	Sagante (n=118)	Bubisa (n=49)	Total (N=394)	p≤0.05
Monthly income	5,001-10,000	12 (22.6)	22 (31.9)	13 (30.2)	8 (12.9)	9 (7.6)	14 (28.6)	78 (19.8)	
(KES*)	10,000-15,000	1 (1.9)	13 (18.8)	5 (11.6)	3 (4.8)	2 (1.7)	5 (10.2)	29 (7.4)	
	15,001-20,000	0 (0.0)	0 (0.0)	0 (0.0)	2 (3.2)	4 (3.4)	3 (6.1)	9 (2.3)	
	>20,000	1 (1.9)	2 (2.9)	0 (0.0)	4 (6.5)	0 (0.0)	4 (8.2)	11 (2.8)	
Hand washing	Yes	37 (69.8)	55 (79.7)	39 (90.7)	56 (90.3)	96 (81.4)	48 (98.0)	331 (84.0)	<0.01
	No	16 (30.2)	14 (20.3)	4 (9.3)	6 (9.7)	22 (18.6)	1 (2.0)	63 (16.0)	
Breastfeeding	Yes	53 (100)	69 (100)	42 (97.7)	62 (100)	117 (100)	49 (100)	392 (99.5)	0.511
	No	0 (0.0)	0 (0.0)	1 (2.3)	0 (0.0)	1 (0.8)	0 (0.0)	2 (0.5)	
Grow crops	Yes	19 (35.8)	0 (0.0)	3 (7.0)	19 (30.6)	53 (44.9)	0 (0.0)	94 (23.9)	<0.001
	No	34 (64.2)	69 (100)	40 (93.0)	43 (69.4)	65 (55.1)	49 (100)	300 (76.1)	

***** USD1.00 = KES 145; SE means Standard Error of mean

Child Characteristics

Table 3.3 gives summary of index child characteristics with reference to weight, height, age, gender, vaccination and prevalence of diarrheal episodes two weeks preceding caregiver interview. Overall, the mean weight of index child was 9.95 ± 0.10 Kg. Children in Karare ward showed relatively higher weight compared to other wards but the differences were insignificant (F=2.056; p= 0.07). The study indicates a significant difference in height across the wards (F=2.808, p=0.017). Pairwise comparison using Turkey's HSD revealed children in Karare were significantly (p =0.023) taller compared to their counterpart in Bubisa.

Overall, the study shows (Table 3.3) a significant difference in age among children in the four study areas (F=4.585, p<0.001). Comparatively, Children in Karare were older compared to Logologo (p<0.001) and Bubisa (p<0.01) and their counterparts in the remaining wards. In terms of gender, there were more males than females. Higher number of male children were observed in Bubisa, Laisamis and Sagante/Jaldesa wards compared to Logologo, Karare and Central wards respectively (table 3.3). However, the differences in population of male and females were insignificant (p=0.06). In terms of age categories, 49.0% of children fell within the age bracket, 6-23 months (or 1000 days after birth). About 30.2, 16 and 4.8% were within the age brackets of 24-35, 36-47 and 48-59 months respectively.

About 91.4% of the children had vaccination cards compared to a paltry 8.6% (p=0.011) of children who had no evidence of vaccination. Bubisa ward had the highest vaccination rates followed by Central, Sagante/Jaldesa, Karare, Logologo and Laisamis wards respectively (Table 1c). The proportion of children experiencing consistent diarrheal episodes two weeks preceding the interview time was significantly low, 17.5% against 82.5% who did not across the wards (p<0.001). Bubisa had the highest prevalence of diarrhoea (69.4%) followed by Laisamis, Karare and Logologo. Central and Sagante/Jaldesa had least occurrence of diarrheal cases, two weeks to the time of the survey.

Table 3.3: Child Characteristics

Variable		Karare (n=53)	Laisamis (n=69)	Logologo (n=43)	Central (n=62)	Sagante/J (n=118)	Bubisa (=49)	Total (N=394)	p≤0.05
Weight (Kg)	Mean ± SE	10.39±0.22	10.07±0.21	9.35±0.25	9.82±0.28	10.10±0.18	9.60±0.28	9.95±0.10	0.07
Height (cm)	Mean ± SE	83.74±1.01^{b}	81.54± 0.84^{ab}	79.90±1.04^{ab}	80.52±1.05^{ab}	82.32±0.77^{ab}	78.83±1.16^{a}	81.39±0.40	0.017
Child age	Mean ± SE	30.43±1.55^{b}	24.66±1.4^{ab}	21.03±1.48^{a}	24.21±1.6^{a}	26.91±1.23^{ab}	21.41±1.61^{a}	25.24±0.62	<0.001
		n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	N (%)	χ^2, p≤0.05
Sex of Child	Male	24 (45.3)	43 (62.3)	19 (44.2)	29 (46.8)	68 (57.6)	33 (67.3)	216 (54.8)	0.06
	Female	29 (54.7)	26 (37.7)	24 (55.8)	33 (53.2)	50 (42.4)	16 (32.7)	178 (45.2)	
Age category	6-12	4 (7.5)	10 (14.5)	10 (23.3)	15 (24.2)	20 (16.9)	13 (26.5)	72 (18.3)	
(Months)	13-23	14 (26.4)	26 (37.7)	15 (34.9)	17 (27.4)	32 (27.1)	17 (34.7)	121 (30.7)	0.355
(%)	24-35	17 (32.1)	21 (30.4)	14 (32.6)	18 (29.0)	36 (30.5)	13 (26.5)	119 (30.2)	
	36-47	14 (26.4)	10 (14.5)	3 (7.0)	9 (14.5)	22 (18.6)	5 (10.2)	63 (16.0)	
	48-59	4 (7.5)	2 (2.9)	1 (2.3)	3 (4.8)	8 (6.8)	1 (2.0)	19 (4.8)	
Vaccination	Yes	47 (88.7)	57 (82.6)	37 (86.0)	60 (96.8)	111 (94.1)	48 (98.0)	360 (91.4)	0.011
	No	6 (11.3)	12 (17.4)	6 (14.0)	2 (3.2)	7 (5.9)	1 (2.0)	34 (8.6)	
Diarrhoea	Yes	8 (15.1)	11 (15.9)	5 (11.6)	3 (4.8)	8 (6.8)	34 (69.4)	69 (17.5)	<0.001
	No	45 (84.9)	58 (84.1)	38 (88.4)	59 (95.2)	110 (93.2)	15 (30.6)	325 (82.5)	

3.3.2 Water Utilization, Sanitation and Hygiene Practices (WASH)

Main Sources of water for both general use and drinking

Figure 3.2 gives summary of main sources of water for general household use. Overall, 41.9% of households use boreholes, followed by water bowsers (21.6%). Tap water was mainly found in urban centres of Marsabit central and Sagante/Jaldesa. Other households especially in the lowlands Bubisa, Laisamis) and peri urban (Karare and Sagante/Jaldesa) wards use protected and unprotected wells. Use of boreholes as main source of water for general use was significantly (χ^2; p<0.001) high in Bubisa (91.8%) compared to Logologo (79.0%), Laisamis (62.3%) and Karare (47.2%) respectively. Water tracking was mainly used in the wards around Marsabit Mountain such as Sagante/Jaldesa, Marsabit central and Karare respectively. Use of tapped water was confined mainly in Marsabit central (town) and partly in Bubisa ward.

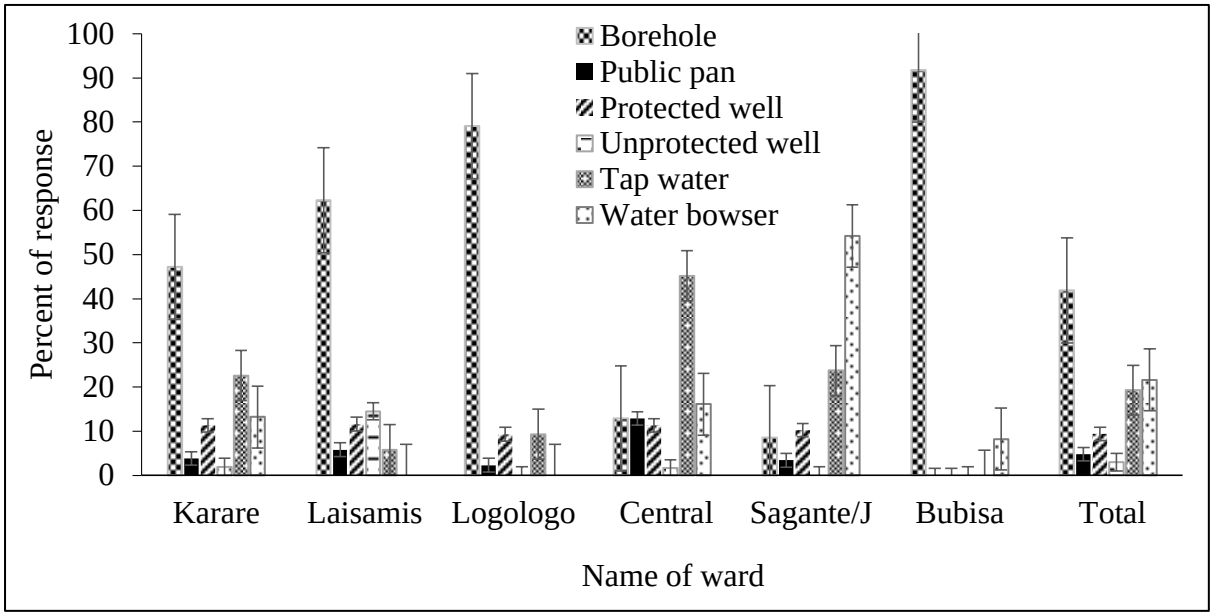


Figure 3.1 *Main water for general use by ward*

Error bars represent 95% confidence interval: $\chi^{2;}$ p<0.001

Figure 3.3 presents an overview of the main sources of drinking water utilized by households. A total of 43.9% of households depend on borehole water, while other sources include water delivered by trucks (19.5%), tap water (18.8%), protected wells (10.2%), and both unprotected wells and public water pans, each accounting for 3.8%. The use of borehole water was notably higher (χ^2; $p < 0.001$) in Bubisa, where it reached 95.9%, in contrast to Logologo (76.7%), Laisamis (60.9%), Karare (45.3%), Central (21%), and Sagante/Jaldesa

(11%). Water delivered by trucks was mainly sourced in Marsabit Central (50%) and Sagante/Jaldesa (16.1%), with minimal use in Karare. Additionally, tap water was predominantly used in Marsabit Central (38.7%), followed by Sagante/Jaldesa (24.6%), Karare (22.6%), Logologo (11.6%), and Laisamis (5.8%). The use of unprotected wells as a drinking water source was primarily noted in Laisamis (18.8%), while it was rarely utilized in Karare and Sagante/Jaldesa. Protected wells were also accessed for drinking water in Marsabit Central (12.9%), compared to Sagante/Jaldesa (11.9%), Laisamis (11.6%), Karare (11.3%), and Logologo (9.3%), with no reported use in Bubisa. Public water pans were frequently utilized in Sagante/Jaldesa.

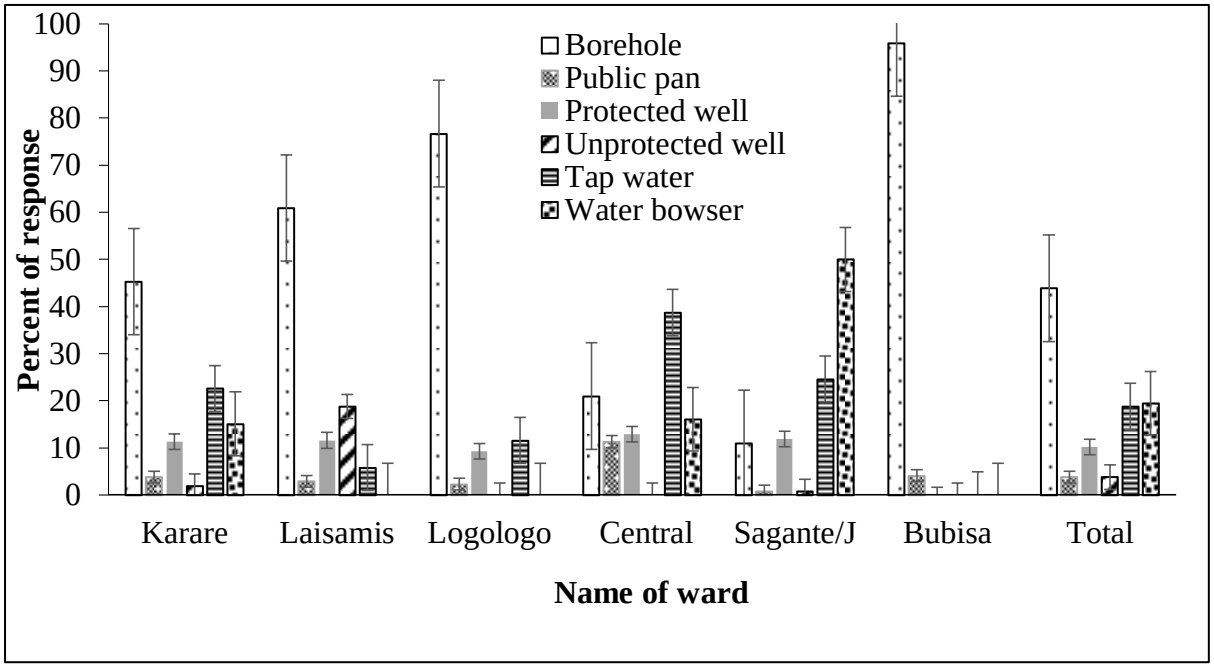


Figure 3.2: *Main source of drinking water by ward (N=394)*

Error bars represent 95% confidence interval: $\chi^{2;}$ p<0.001

Water Treatment methods

Figure 3.3 illustrates the various water treatment methods employed by households in the study regions. Three distinct methods of water treatment were identified: boiling (12.7%), chemical treatment (23.4%), and decanting (0.3%). Notably, a significant 63.7% of households consumed untreated, raw water. Chemical treatment was predominantly practiced in Sagante/Jaldesa (38.1%), followed by Marsabit Central (35.5%), Karare (30.2%), Bubisa (16.3%), and a mere 1% in Laisamis. Notably, households in Logologo reported no use of chemical treatment for their water. Heat treatment methods were more commonly observed in the peri-urban areas of Marsabit Central, Sagante/Jaldesa, and Karare compared to the

lowland wards of Laisamis, Bubisa, and Logologo. A paltry 1.4% of the households in Laisamis ward use decantation to clean water before drinking.

Overall, 64% of households in the wards reported consuming untreated raw water. The consumption of raw water was notably higher (χ^2; $p < 0.001$) in Logologo (97.7%), followed by Laisamis (91.3%) and Bubisa (77.6%). Furthermore, a significant portion of households in Karare (52.8%), Sagante/Jaldesa (46.6%), and Marsabit Central (41.6%) did not treat their water prior to boiling.

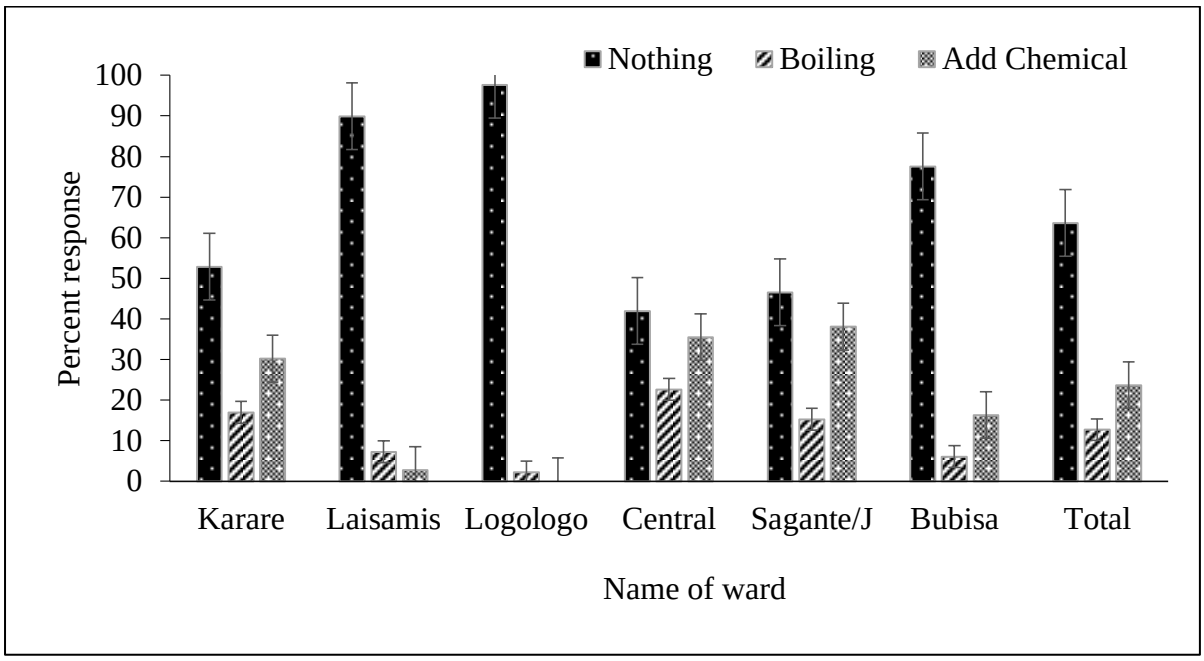


Figure 3.4: *Percent of households using different water treatment methods by ward*

N=394: χ^2; p<0.001.

Water access by households

Table 3.4 presents a summary of household accessibility to water in the study areas. The results of this study indicates that daily Mean ± SE of time taken by caregiver to fetch water including waiting time was 58.37 ± 2.68 minutes (*F*=24.131*; P*<0.001, *N*=394, 95% C.I). Caregivers in Karare ward reported significantly longer times spent accessing water, followed by those in Bubisa and Marsabit Central. In contrast, households in Sagante/Jaldesa, Laisamis, and Logologo experienced comparatively shorter durations when fetching water from their respective sources. On average, households in Marsabit consume 61.17 ± 1.47 l of water per day (*F*=7.752; P<0.001). Households in Logologo significantly consumed higher volumes of water compared to their counterparts in Marsabit central, Sagante/Jaldesa, Karare, Laisamis and Bubisa respectively.

Table 3.4: Household water access, purchase and utilization in Marsabit

		95% C.I		
	Mean ± SE	Lower	Upper	P value (p≤0.05)
Time taken to water source (Minutes)				
Karare (n=53)	116.79 ± 10.26[d]	96.20	137.38	
Laisamis (n=69)	41.30 ± 3.59[ab]	34.14	48.47	
Logologo (n=43)	28.02 ± 2.31[a]	23.36	32.69	
Marsabit Central (n=62)	62.52 ± 6.80[bc]	48.91	76.12	
Sagante/Jaldesa (n=118)	46.38 ± 3.2[ab]	39.91	52.85	
Bubisa (n=49	69.49 ± 8.46[bc]	52.49	86.49	
Total (N=394)	58.37 ± 2.68	53.10	63.65	*F=24.131;P*<0.001
Quantity of water consumed per household per day (Littres)				
Karare (n=53)	58.49 ± 4.48[ab]	49.50	67.48	
Laisamis (n=69)	54.78 ± 2.06[a]	50.67	58.89	
Logologo (n=43)	79.07 ± 6.28[c]	66.40	91.74	
Marsabit Central (n=62)	70.32 ± 3.75[bc]	62.82	77.82	
Sagante/Jaldesa (n=118)	60.00 ± 2.29[ab]	55.46	64.54	
Bubisa (n=49	48.57 ± 3.60[a]	41.34	55.80	
Total (N=394)	61.17 ± 1.47	58.29	64.05	*F=7.27;P*<0.001

C.I. means Confidence Interval.

Trend: Highest time taken to water source and back was about 2 hours while quantity of water used by households were less than recommended volumes per person per household.

Sanitation practices among households in the study sites

Figure 3.4 summarizes household access to toilet facilities across the different wards. The findings indicate that 54.8% of households in Marsabit had access to toilets, while 45.2% lacked any form of toilet structure (χ^2; $p < 0.001$). Marsabit Central ward had the highest proportion of households with toilet access, followed by Sagante/Jaldesa ward. In contrast, the prevalence of households without toilets was highest in Logologo, followed by Laisamis, Karare, and Bubisa.

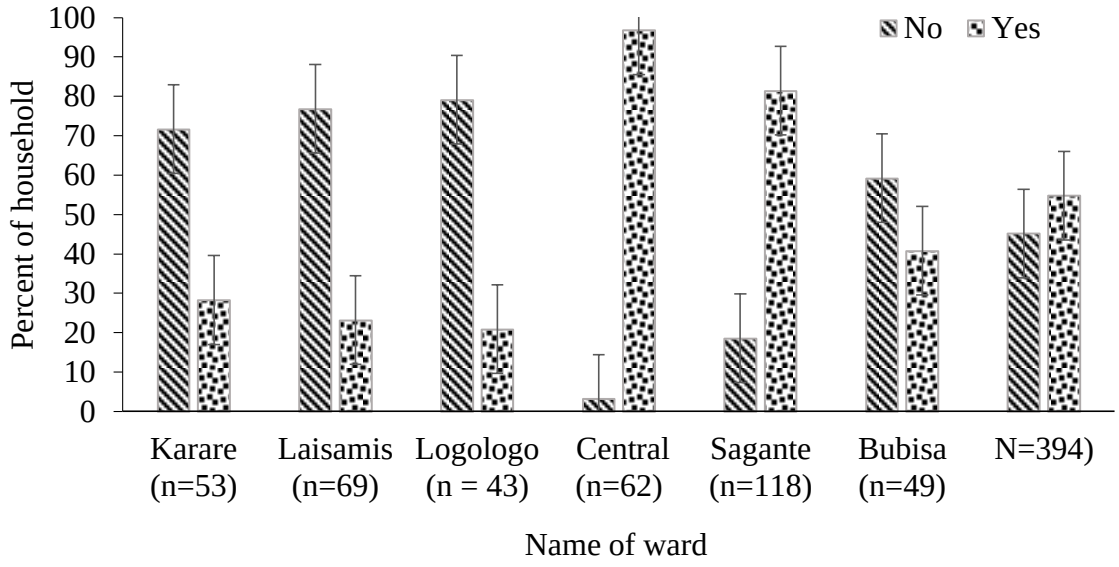


Figure 3.3: *Percent of household with access to toilet facility ($\chi^{2;}$ $p < 0.001$)*

Figure 3.5 presents a summary of the percentage of households utilizing various types of toilet facilities. The study found that the highest proportion of households using pit latrines was in Sagante/Jaldesa ward, followed by Marsabit Central, Laisamis, Karare, and Logologo. Notably, Bubisa did not report any households with pit latrines; however, there were communal pit latrines constructed by development agencies. The absence of toilets was particularly prevalent in the agro-pastoral and lowland wards (Laisamis, Karare, Logologo, Sagante/Jaldesa, and Bubisa) compared to the urban ward of Marsabit Central. In such situations, the majority of affected households resorted to open defecation, either in open fields or bush areas (94.9%, n = 144; χ^2 $p < 0.001$). Only 5.1% of households without toilets opted to use neighboring facilities. Open defecation was more common in the pastoral lowland wards, such as Karare, Laisamis, Bubisa, Logologo, and Sagante/Jaldesa (Table 3.5).

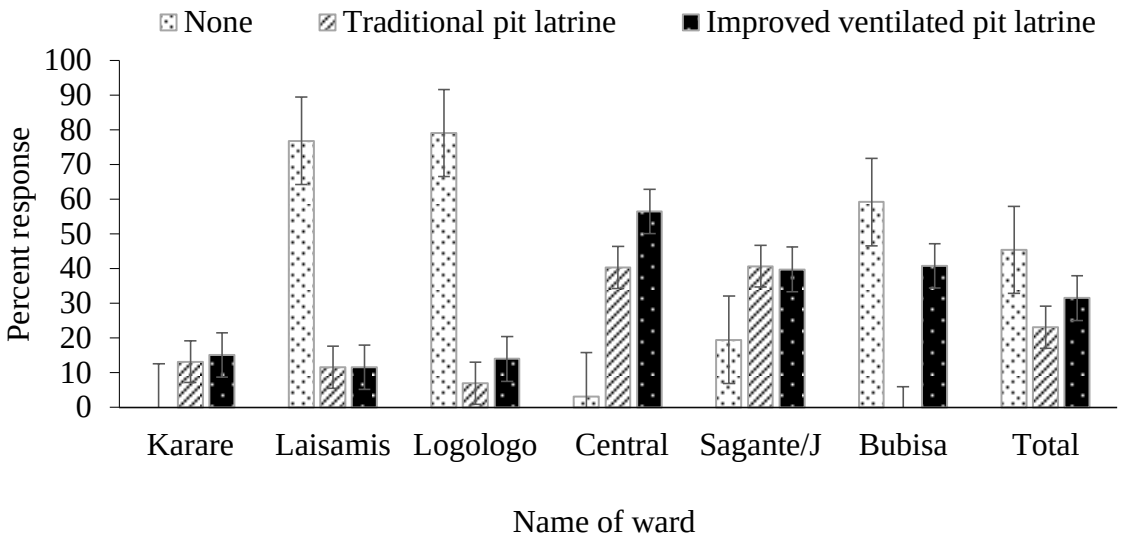


Figure 3.4: *Percent of households using different types of toilet facilities*

Error bars represent 95% confidence interval: χ^2; $p< 0.001$(N=394).

Table 3.5: Percent of households using different waste disposal method (N=394). χ^2; p<0.001)

	Name of wards (n (%))						
	Karare	Laisamis	Logologo	Marsabit Central	Sagante/ Jaldesa	Bubisa	Total
Open defecation	38 (100)[a]	53 (100)[a]	30 (88.2)[a]	0 (0.0)[b]	22 (100)[a]	26 (89.7)[a]	169 (94.9)
Neighbour's	0 (0.0)[a]	0 (0.0)[a]	4 (11.8)[a]	2 (100)[b]	0 (0.0)[a]	3 (10.3)[a]	9 (5.1)

Each subscript letter indicates a subset of ward categories where the column proportions are not significantly different from one another at a significance level of $p \leq 0.05$.

Trend: A majority of households use open defecation as faecal disposal means.

3.3.3. Nutritional Status of Children aged 6-59 months in the study areas

Figure 3.6 summarizes the anthropometric indicators of nutritional status among children in Marsabit. The overall mean ± SE values for height-for-age Z score (HAZ), weight-for-age Z score (WAZ), and weight-for-height Z score (WHZ) were -1.51 ± 0.05, 1.54 ± 0.04, and 1.02 ± 0.04, respectively. Children in Logologo and Laisamis exhibited significantly higher mean HAZ compared to those in Central, Sagante/Jaldesa, and Bubisa wards. The mean WHZ

values for Karare, Laisamis, Logologo, Central, Sagante/Jaldesa, and Bubisa wards were -1.06 ± 0.19, -0.87 ± 0.11, -1.32 ± 0.17, -0.98 ± 0.12, -1.08 ± 0.10, and -0.81 ± 0.15, respectively. However, the differences in mean WHZ were not statistically significant across the various wards.

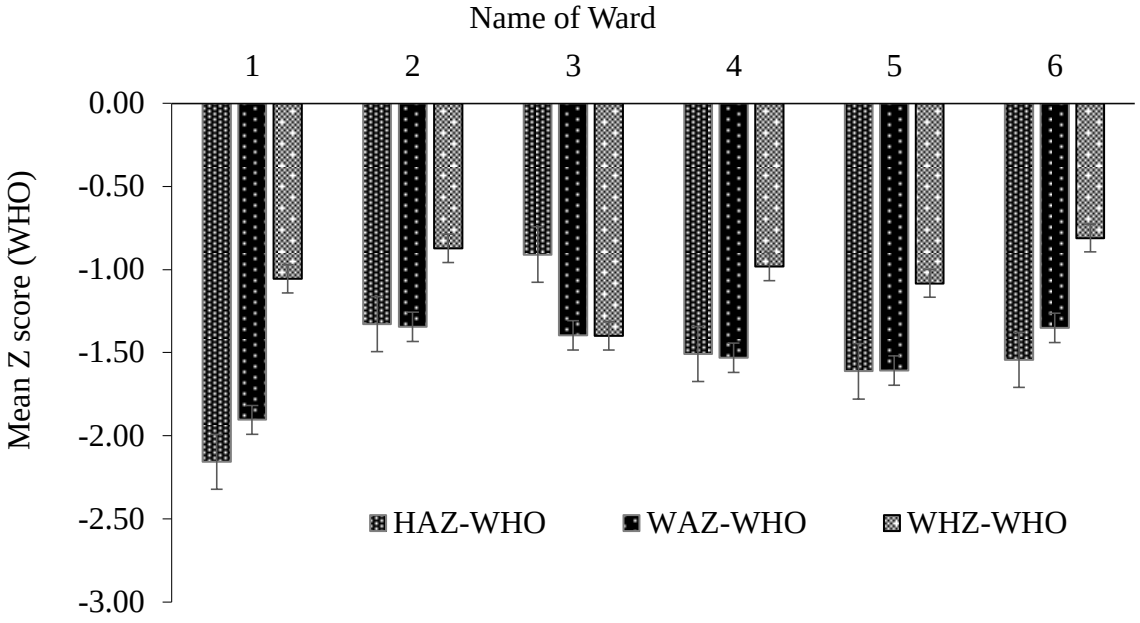


Figure 3.5: *Mean nutritional status of children by ward (N=394).*

Key: 1 (Karare), 2 (Laisamis), 3 (Logologo), 4 (Marsabit Central), 5 (Sagante/Jaldesa and 6 (Bubisa)

Table 3.6 gives summary of prevalence of stunting, wasting and underweight by age categories of children in the six wards. The study shows that stunting differed significantly across the ward. Overall, moderate and severe stunting was 34.3and 3.8% respectively ($p<0.01$). High number of children with moderate to severe stunting was observed in Karare (49.1%) followed by Marsabit central (41%), Sagante/Jaldesa (34.7%), Bubisa (28.6) respectively. Laisamis ward registered moderate stunting. Conversely, 61.9% of children across the wards showed better nutritional status in terms of stunting. Specifically, Logologo had the highest number of children with normal stunting (≥-2SD Z scores) compared to Bubisa, Sagante/Jaldesa, Marsabit central, Karare and Laisamis respectively Regarding gender differences in nutritional status, males displayed a marginally better nutritional profile than females. Specifically, approximately 37.5% of male children experienced moderate to severe stunting, while the prevalence was slightly higher at 38.8% among female children.

Underweight differed across the wards substantially (p=0.023). About 72.8% of children were within normal weight while 26.1 and 1.0% had moderate and severe underweight respectively. Specifically, Karare exhibited the highest rates of underweight in children aged 6-59 months, followed by Sagante/Jaldesa, Marsabit Central, Logologo, and Bubisa, respectively (Table 4). In terms of gender, 26.9% of male children and 25.3% of female children were classified as moderately underweight, while severe underweight affected 0.5% of males and 1.7% of females. Notably, the prevalence of moderate to severe underweight among female children was recorded at 34.6% in Laisamis, 34.5% in Karare, 26.0% in Sagante/Jaldesa, 24.2% in Marsabit Central, 20.9% in Logologo, and 18.7% in Bubisa. Likewise, moderate to severe underweight among male children was 58.3, 33.8, 27.5, 21.2, 11.6 and 10.5% in Karare, Sagante/Jaldesa, Central, Bubisa, Laisamis and Logologo respectively.

The result of this study also showed no significant differences in wasting among children in all the six wards. About 16.2% were wasted and 2.3% were severely wasted ($p>0.05$). In terms of gender, the study indicates that wasting among female children was 25, 22, 21.3, 18.7, 13.7 and 7.7% in Logologo, Sagante/Jaldesa, Marsabit central, Bubisa, Karare and Laisamis respectively ($p>0.05$). Similarly, the proportion of male children that were wasted was 31.6, 20.6.18.2.17.2, 16.7, and 11.6% in Logologo, Sagante/Jaldesa, Bubisa, Marsabit central, Karare and Laisamis respectively ($p>0.05$).

Table 3.6: Prevalence of stunting, wasting and underweight among children by sex

Sex	Indicators	Name of wards: Karare (n=53)	Laisamis (n=69)	Logologo (n=43)	Central (n=62)	Sagante (n=118)	Bubisa (n=49)	N=394	$p \leq$ 0.05
Stunting [n (%)]									
Male	Moderate	7 (29.2)	21 (48.8)	3 (15.8)	14 (48.3)	20 (29.4)	6 (18.2)	71 (32.9)	
	severe	2 (8.3)	0 (0.0)	3 (15.8)	2 (6.9)	1 (1.5)	2 (6.1)	10 (4.6)	0.01
Female	Moderate	17 (58.6)	13 (50)	2 (8.3)	8 (24.2)	18 (36)	6 (37.5)	64 (36.0)	
	severe	0 (0.0)	0 (0.0)	1 (4.2)	2 (6.1)	2 (4.0)	0 (0.0)	5 (2.8)	0.02
Total	**Moderate**	**24 (45.3)**	**34 (49.3)**	**5 (11.6)**	**22 (35.5)**	**38 (32.2)**	**12 (24.5)**	**135 (34.3)**	
	severe	**2 (3.8)**	**0 (0.0)**	**4 (9.3)**	**4 (6.5)**	**3 (2.5)**	**2 (4.1)**	**15 (3.8)**	0.002
Underweight [n (%)]									
Male	Moderate	14 (58.3)	5 (11.6)	2 (10.5)	7 (24.1)	23 (33.8)	7 (21.2)	58 (26.9)	
	severe	0 (0.0)	0 (0.0)	0 (0.0)	1 (3.4)	0 (0.0)	0 (0.0)	1 (0.5)	0.001
Female	Moderate	10 (34.5)	8 (30.8)	4 (16.7)	8 (24.2)	13 (26.0)	2 (12.5)	45 (25.3)	
	severe	0 (0.0)	1 (3.8)	1 (4.2)	0 (0.0)	0 (0.0)	1 (6.2)	3 (1.7)	0.509
Total	**Moderate**	**24 (45.3)**	**13 (18.8)**	**6 (14.0)**	**15 (24.2)**	**36 (30.5)**	**9 (18.4)**	**103 (26.1)**	
	severe	**0 (0.0)**	**1 (1.4)**	**1 (2.3)**	**1 (1.6)**	**0 (0.0)**	**1 (2.0)**	**4 (1.0)**	**0.023**
Wasting [n (%)]									

Sex	Indicators	Name of wards							
		Karare (n=53)	Laisamis (n=69)	Logologo (n=43)	Central (n=62)	Sagante (n=118)	Bubisa (n=49)	N=394	$p \leq$ 0.05
Male	Moderate	4 (16.7)	5 (11.6)	5 (26.3)	4 (13.8)	13 (19.1)	6 (18.2)	37 (17.1)	
	severe	0 (0.0)	0 (0.0)	1 (5.3)	1 (3.4)	1 (1.5)	0 (0.0)	3 (1.4)	0.716
Female	Moderate	3 (10.3)	2 (7.7)	5 (20.8)	5 (15.2)	10 (20.0)	2 (12.5)	27 (15.2)	
	severe	1 (3.4)	0 (0.0)	1 (4.2)	2 (6.1)	1(2.0)	1 (6.2)	6 (3.4)	0.837
Total	**Moderate**	**7 (13.2)**	**7 (10.1)**	**10 (23.3)**	**9 (14.5)**	**23 (19.5)**	**8 (16.3)**	**64 (16.2)**	
	severe	**1 (1.9)**	**0 (0.0)**	**2 (4.7)**	**3 (4.8)**	**2 (1.7)**	**1 (2.0)**	**9 (2.3)**	0.446

Table 3.7, 3.8 and 3.9 provide a summary of the prevalence of stunting, wasting, and underweight according to WHO age groups. Overall, 38.1% of children across the wards were stunted ($p = 0.002$). According to this study, 35.6% of stunted children were within the age bracket of 6-23 months. Both moderate and severe stunting were high in Laisamis (49.3%), followed by Karare (45.3%), Marsabit Central (42%), Sagante/Jaldesa (34.7%), Bubisa (28.6%), and Logologo (21.1%). In terms of WHO age brackets, stunting was highest within the 35-47 months' age bracket, followed by 48-59 months, 24-35 months, 12-23 months, and 6-11 months, respectively. Except for children within the 35-47 months' age bracket, differences in stunting were significant ($p < 0.05$). About 18.5% of children were wasted or thin across the wards, with 45.9% of cases falling within the age bracket of 6-23 months. Approximately 27% of children were underweight, with underweight being more prevalent in the age bracket of 36-59 months. Underweight was most prevalent in Sagante/Jaldesa wards, followed by Marsabit Central, Karare, Bubisa, Laisamis, and Logologo. However, there were no significant differences in underweight across the age brackets.

Table 3.7: Prevalence of stunting by age and ward ([n (%)]; 95% C.I)

		Name of wards							
Age	Indicator	Karare (n=53)	Laisamis (n=69)	Logologo (n=43)	Central (n=62)	Sagante (n=118)	Bubisa (n=49)	N= 394)	$P \leq 0.05$
6-12	Moderate	1(25.0)	0 (0.0)	0 (0.0)	2 (13.0)	1 (5.0)	2 (15.4)	6 (8.3)	0.428
13-23	Moderate	7 (50.0)	8(30.8)	2 (13.3	3 (17.6)	8 (25.0)	3 (17.6)	31(25.6)	
	Severe	0 (0.0)	0 (0.0)	0 (0.0)	2 (11.8)	0 (0.0)	0 (0.0)	2 (1.7)	0.038
24-35	Moderate	8 (47.1)	15 (71.4)	1(7.1)	8 (44.4)	13 (36.1)	4 (30.8)	49 (41.2)	
	Severe	0 (0.0)	0 (0.0)	3(21.4)	1 (5.6)	2 (5.6)	2 (15.4)	8 (6.7)	0.018
36-47	Moderate	6 (42.9)	9 (90.0)	2 (66.7)	7 (77.8)	13 (59.1)	3 (60.0)	40 (63.5)	
	Severe	2 (14.3)	0 (0.0)	0 (0.0)	1(11.1)	1 (4.5)	0 (0.0)	4 (6.3)	0.531
48-59	Moderate	2 (50.0)	2 (100)	0 (0.0)	2 (66.7)	3 (37.5)	0 (0.0)	9 (47.4)	
	Severe	0 (0.0)	0(0.0)	1 (100)	0 (0.0)	0 (0.0)	0 (0.0)	1 (5.3)	0.011
Total	Moderate	24 (45.3)	34 (49.3)	5 (11.6)	22 (35.5)	38 (32.2)	12 (24.5)	135 (34.3)	
	Severe	2 (3.8)	0 (0.0)	4 (9.3)	4 (6.5)	3 (2.5)	2 (4.1)	15 (3.8)	0.002

C.I means Confidence Interval at 95%

Table 3.8: Prevalence of Wasting by age and ward ([n (%)]; 95% C.I)

		Name of wards							
Age	Indicator	Karare (n=53)	Laisamis (n=69)	Logologo (n=43)	Central (n=62)	Sagante (n=118)	Bubisa (n=49)	N= 394)	$p \leq 0.05$
6-12	Moderate	0 (0.0)	2 (20.0)	2 (20.0)	3 (20.0)	4 (20.0)	4 (30.8)	15 (20.8)	0.943
	Severe	0 (0.0)	0 (0.0)	0 (0.0)	1 (6.7)	1 (5.0)	0 (0.0)	2 (2.8)	
13-23	Moderate	2 (14.3)	2 (7.7)	4 (26.7)	5 (29.4)	8 (25.0)	1 (5.9)	22 (18.2)	0.08
	Severe	0 (0.0)	0 (0.0)	2 (13.3)	2 (11.8)	0 (0.0)	1 (5.9)	5 (4.1)	
24-35	Moderate	2 (11.8)	2 (9.5)	4 (28.6)	0 (0.0)	8 (22.2)	3 (23.1)	19 (16.0)	0.442
	Severe	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.8)	0 (0.0)	1 (0.8)	
35-47	Moderate	2 (14.3)	1 (10.0)	0 (0.0)	1 (11.1)	2 (9.1)	0 (0.0)	6 (9.5)	0.897
	Severe	1 (7.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.6)	
48-59	Moderate	1 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (12.5)	0 (0.0)	2 (10.5)	0.883
Total	Moderate	7 (13.2)	7 (10.1)	10 (23.3)	9 (14.5)	23 (19.5)	8 (16.3)	64 (16.2)	0.446
	Severe	1 (1.9)	0 (0.0)	2 (4.7)	3 (4.8)	2 (1.7)	1 (2.0)	9 (2.3)	

Table 3.9: Prevalence of Underweight (WAZ <-2SD) by age and Ward ([n (%)]; 95% C.I)

Age	Indicator	Name of wards							
		Karare (n=53)	Laisamis (n=69)	Logologo (n=43)	Central (n=62)	Sagante (n=118)	Bubisa (n=49)	N= 394)	$p \leq 0.05$
6-12	Moderate	2 (50.0)	1 (10.0)	1 (10.0)	6 (40.0)	4 (20.0)	4 (30.8)	18 (25.0)	0.303
13-23	Moderate	7 (50.0)	4 (15.4)	1 (6.7)	4 (23.5)	7 (21.9)	3 (17.6)	26 (21.5)	0.188
	Severe	0 (0.0)	0 (0.0)	1 (6.7)	1 (5.9)	0 (0.0)	1 (5.9)	3 (2.5)	
24-35	Moderate	5 (29.4)	4 (19.0)	2 (14.3)	1 (5.6)	11 (30.6)	2 (15.4)	25 (21.0)	0.309
35-47	Moderate	8 (57.1)	4 (40.0)	1 (33.3)	4 (44.4)	9 (40.9)	0 (0.0)	26 (41.3)	0.393
	Severe	0 (0.0)	1 (10.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.6)	
48-59	Moderate	2 (50.0)	0 (0.0)	1 (100)	0 (0.0)	5 (62.5)	0 (0.0)	8 (42.1)	0.206
Total	Moderate	24 (45.3)	13 (18.8)	6 (14.0)	15 (24.2)	36 (30.5)	9 (18.4)	103 (26.1)	
	Severe	0 (0.0)	1 (1.4)	1 (2.3)	1(1.6)	0 (0.0)	1 (2.0)	4 (1.0)	

3.3.4. Socioeconomic and demographic Factors influencing Nutritional status (HAZ) of children aged 6-59 months in Marsabit

Tables 3.10 provide a summary of the backward linear regression results of social, economic, demographic, and environmental factors influencing Height-for-Age (HAZ) of children aged 6-59 months in the six sites (wards). Predictor variables regressed against HAZ and WAZ included social, economic, demographic, and environmental factors (Tables 3.1, 3.2, and 3.3).

The variables factored into the model included: distance to the nearest market (in km), family size excluding the household head, age of the household head (years), household head's highest level of education (categorical), primary occupation of the household head (categorical), whether the household head kept livestock (categorical), whether the household head grew crops (categorical), marital status of the caregiver (categorical), caregiver's highest level of education (categorical), caregiver's primary occupation (categorical), caregiver's grouped income (categorical), total number of children under five years of age, sex of the index child (categorical), weight of the index child, height of the index child, source of drinking water (categorical), time taken to the water source, waiting and return, quantity of water used by the household per day, price of water per unit in KES, whether the household treated water before drinking (categorical), disposal of child faecal waste (categorical), whether the household compound was clean (categorical), and consistent diarrhoeal episodes in the two weeks prior to the survey (categorical).

The results of this study showed that distance to nearest trading centre, height of index child, main source of drinking water, livestock ownership, number of children below 5 years in the household, crop production, caregiver primary occupation, caregiver highest level of education, and household head highest level of education completed significantly accounted for the variance in HAZ in Karare (F (26, 9) = 9.73, p < 0.001) with an $R^2$of 0.771. This indicated that 77.1% of the model explained the variation of HAZ in Karare ward.

In Laisamis ward, price of water per unit (in KES), caregiver income, livestock ownership and height of index child significantly predicted HAZ (F (4, 55) = 15.294, p< 0.001) with $R^2$of 0.0.527 accounting for 52.7% of variance in the model. Comparatively significant predictors of HAZ outcome in Logologo ward comprised; number of children under 5 years old in the household, Sex of Index Child, livestock ownership, disposal of children's faeces, Age of household head, water treatment before drinking and price of water per unit (F (7, 21) = 7.370, p<0.001) with $R^2$of 0.711, accounting for 71% of the variance in the model. In

Marsabit central ward, significant predictors of HAZ included crop production, cleanliness of respondent compound, Sex of Index Child, Weight in Kg, Water consumed per household per day ($F(5, 39) = 7.348$, $p<0.001$) with $R^2$of 0.485 explaining 48.5% of variations in outcome from the predictor variables. In Sagante/Jaldesa ward, only care giver occupation, weight, height of index child and time taken to water source significantly contributed to variations in HAZ among children ($F(4, 96) = 9.937$; $p < 0.001$) with R^2 of 0.293 accounting for 29.3% of variance in the model.

Significant predictors of HAZ in Bubisa comprised; Diarrheal episodes in past two weeks, weight of index child in Kg, cleanliness of respondent compound, number of children under 5 years in the household, price of water per unit (in KES), caregiver income, time taken to water source (Minutes), caregiver primary occupation, household size excluding household head, marital status of care giver, height of index child in cm and livestock ownership ($F(12, 27) = 7.469$, $p< 0.001$) with R^2 of 0.768 indicating that 76.8% of total variance in the outcome variable can be explained the explainable variables.

The results of this study reveal that distance to nearest trading centre had a significant but negative effect on HAZ in Karare ward ($p = 0.046$). Every unit increase in distance to nearest trading centre in Km reduced HAZ by 0.014 units (table 6). Household head highest level of education had a positive and significant influence of HAZ ($p < 0.01$). Keeping of livestock by household had a negative but significant effect on HAZ in Karare ($p = 0.008$), Laisamis ($p< 0.001$), Logologo ($p = 0.001$) and Bubisa ($p = 0.006$) respectively. Crop production also showed a significant and positive effect on HAZ among children in Karare ward but had a negative but significant effect on HAZ in Marsabit Central ward ($p = 0.026$).

Although the caregiver's main occupation had a positive and significant effect on HAZ in Bubisa ward ($p = 0.052$) and a positive but insignificant effect in Sagante/Jaldesa ward (p = 0.090), it was inversely related to HAZ in Karare ($p< 0.001$). The caregiver's education level had a significant and negative effect on HAZ in Karare ward ($p = 0.010$). However, the number of children under five years of age ($p = 0.001$) and the main source of drinking water ($p< 0.001$) had a positive and significant influence on HAZ among children in Karare. The marital status of the caregiver had a positive and significant effect on HAZ among children in Bubisa only ($p = 0.004$) compared to other wards. Similarly, the age of the household head showed a positive and significant relationship with HAZ in Logologo ward but not in other wards ($p = 0.001$). The study also shows an inverse relationship between the caregiver's

income and HAZ outcome in Laisamis ward ($p < 0.001$) and a positive but insignificant relationship with HAZ in Bubisa ($p = 0.990$). There was also a positive and significant effect of the sex of the index child on HAZ outcome in Logologo ($p < 0.001$) and Marsabit Central ($p = 0.040$).

The results of this study also indicated that weight had a negative effect on HAZ outcome in Sagante/Jaldesa ward ($p< 0.001$) and Bubisa ($p< 0.001$) respectively. Although height had a positive and significant effect on HAZ in Karare ward ($p < 0.001$), Bubisa ward ($p = 0.001$) respectively, it had a negative and significant effect on HAZ outcome in Laisamis ward ($p< 0.001$). Time spent fetching water had a positive and significant effect on HAZ in Sagante/Jaldesa ward ($p = 0.005$), but an insignificant effect in Bubisa ward ($p = 0.081$). The cost of purchasing water for domestic use positively predicted the HAZ outcome in Logologo ward ($p = 0.001$). Water treatment practices among households were found to have a negative and significant effect on the HAZ outcome in Logologo ($p = 0.004$). The cleanliness of the respondent's compound had a positive effect on HAZ in Bubisa ($p = 0.003$) but predicted a negative HAZ outcome in Marsabit Central ward ($p = 0.001$). Incidences of diarrheal episodes in the two weeks preceding the survey had a negative and insignificant effect on the HAZ outcome in Bubisa ward.

3.3.5. Socioeconomic and demographic Factors influencing Nutritional status (WAZ) of children aged 6-59 months in Marsabit

Table 3.11 gives a summary of main predictors for regression equation. The main predictors for Weight-For Age Z scores (WAZ) in Karare included; height of index child (cm), number of household members (excluding household head), sex of index child, main source of drinking water, marital status of care giver, quantity of consumed per household per day (littres), if respondent compound was clean, if respondent treated water before drinking, caregiver primary occupation, Age of Household Head (years), household head highest level of education completed, water treatment method used by respondent before drinking it and weight of index child (in Kg).

A significant regression equation was observed thus ($F (13, 22) = 12.614$), $p< 0.001$) and R^2 of 0.882 implying that the independent variables explained 88.2% variance in WAZ in Karare ward. In Laisamis ward, the following predictor variables had a significant influence on the overall regression model; thus, weight of index child (Kg), caregiver primary occupation, number of children are under 5 years old in the household, caregiver income, if household

owned livestock and height of index child (cm).Giving a regression equation of (F (6, 53) = 27.653, p< 0.001 and R^2 of 0.758 explaining 75.8% of variance in WAZ in Laisamis ward. Independent variables such as number of children are under 5 years old in the household, sex of index child, weight of index child (Kg), if respondent owned livestock, disposal of children's faecal waste, if household grew crops, Age of household head (years), caregiver income, water treatment methods before drinking, price of water per unit (KES), family size excluding household head and height of index child (cm). There was significant regression equation for all the predictor variables in Logologo giving a regression equation of (F (12, 16) = 16.744, p< 0.001) and R^2 of 0.926 hence the model explains 92.6% of variance in WAZ among children in Logologo.

The general predictor variables of WAZ in Marsabit central included the following-: if household grew crops, distance to nearest trading centre (Km), if the respondent compound was clean, weight of index child (Kg), if respondent treated water before drinking, height of index child (cm) and water treatment methods used by households. In this model, there was a significant regression equation (F (7, 37) = 6.726, p< 0.001) and R^2 of 0.56, indicating that the model can explain 56% of the variance in WAZ among children in Marsabit central ward. The variance in WAZ in Sagante/Jaldesa ward was predicted by time taken by respondent to water source, height of index child (cm), caregiver primary occupation and weight (Kg). Thus, giving a regression equation of (F (4, 96) = 52.097, p< 0.001 and R^2 of 0.685 explaining 68.5% of variance in WAZ among children in Marsabit central ward. In Bubisa ward, weight of index child (Kg), caregiver primary occupation, marital status of care giver, height of index child (cm) and if household owns livestock gave a positive and significant regression equation (F (5, 34) = 9.346, p< 0.001) and R^2 of 0.579. The model therefore accounts for 57.9% of variance in WAZ among children in Bubisa ward.

The results from the specific predictor variable coefficients indicated distance to nearest market centre had a positive but insignificant effect on HAZ in Marsabit central ward (p> 0.05). Family size had a negative and significant effect on WAZ in Logologo (p = 0.011). Indicating that every increase in the number of household members resulted into a unit decrease in WAZ. Same case in Karare but with insignificant effect on WAZ (p = 0.082). Likewise, increase in age of household head resulted into decrease in WAZ among children in Logologo (p< 0.001). Household head education has a positive and significant effect in WAZ among children in Karare (p< 0.001). Interestingly, livestock keeping was negatively

associated with WAZ in Laisamis (p = 0.002), Logologo (p< 0.001) and Bubisa (p< 0.001) wards where pastoralism is the keys economic activity.

Similarly crop farming was negatively associated with WAZ in Marsabit central (p = 0.013) and Logologo (p = 0.011) wards respectively. Marital status of caregiver was positively associated with WAZ in Karare (p = 0.027) and Bubisa (p< 0.001) respectively.

Caregiver occupation had a negative effect on WAZ among children in Karare ward (p < 0.001), Laisamis ward (p = 0.020), Sagante/Jaldesa (p = 0.013) but had a positive and significant effect in Bubisa (p = 0.011) respectively. Caregiver income also had a negative and significant effect on WAZ in Laisamis (p = 0.006) and in Logologo ward (p = 0.017) respectively. The number of children under five years old in the household had a positive and significant effect on WAZ among children in Laisamis (p = 0.038) and Logologo (p = 0.009) respectively. Similarly, sex of index child showed a positive and significant influence on WAZ in Karare (p = 0.014) and Logologo (p< 0.001). Weight of the index had a strong and positive relationship with WAZ in Karare (p< 0.001), Laisamis (p < 0.001), Logologo (p< 0.001), Marsabit central (p=0.003), Sagante/Jaldesa (p< 0.001) and in Bubisa (p< 0.001) respectively. On the other hand, every unit increase in height of the index child resulted into reducing effect on WAZ in Karare (p< 0.001), Laisamis (p < 0.001), Logologo (p < 0.001), Marsabit central (p = 0.013), Sagante/Jaldesa (p< 0.001) and Bubisa (p< 0.001) respectively.

The source of water for domestic use was only positively correlated to WAZ in Karare ward (p = 0.001) while time taken spent in fetching water predicted a positive influence on WAZ in Sagante/Jaldesa ward (p = 0.011). However, the daily quantity of water consumed by household per unit was negatively related to WAZ in Karare ward (p = 0.090). Every unit increase in price of drinking water per unit of sale resulted into positive and significant increase in WAZ in Logologo ward (p< 0.001). Whether household treated water before drinking negatively influenced WAZ in Logologo (p< 0.001). The water treatment methods among households were negatively related to WAZ in Karare ward (p = 0.005) but the influence in Marsabit central ward was insignificant (p = 0.093). The result of this study also indicate that disposal of child waste had a positive and significant effect on WAZ indicating that every unit increase in disposal of waste resulted into 0.644kg in weight. Cleanliness of household compound also had an incremental effect on weight of the index child in Karare (p = 0.005) but, had insignificant negative effect on WAZ in Marsabit central ward (p = 0.071) but, had insignificant negative effect on WAZ in Marsabit central ward (*p* = 0.071).

Table 3.10: Backward Linear Regression of social, economic, demographic and environmental factors influencing Height for Age (HAZ)

Predictor variables	Karare	Laisamis	Logologo	Central	Sagante	Bubisa
	β (S.E.)	β (S.E)	β (S.E)	β (S.E)	β (S.E)	β (S.E.)
Constant	4.304 (0.801)***	6.643 (1.346)***	.781 (1.512)	2.546 (0.951)*	-1.136 (0.854)	-2.224 (1.611)
Distance to market (Km)	-.014 (0.007)*					
Family size						.113 (0.062)
Household head age (years)			-.056 (0.015)**			
Household head education	.458 (0.116)***					
Household head occupation						
Do you own livestock	-.405 (0.130)*	-.919 (0.235)***	-1.77 (0.430)**			-4.204 (1.399)**
Marital status of care giver						1.986 (0.629)**
Caregiver education	-.334 (0.120)**					
Caregiver occupation	-.108 (0.024)***				-.048 (0.028)	.081 (0.040)*
Caregiver Income		-.479 (0.108)***				-.106 (0.062)
Sex of Index Child			1.63 (0.336)***	.460 (0.217)*		
Source of drinking water	.141 (0.031***					
Faecal waste disposal			.736 (0.372)			
Is the compound clean				-1.14 (0.324)**		1.785 (0.558)**

***p< 0.001; **p < 0.01; *$p \leq 0.05$; C.I. means Confidence Interval

Table 3.11: Backward Linear Regression of social, economic, demographic and environmental factors influencing Weight for Age

	Karare	Laisamis	Logologo	Marsabit Central	Sagante/Jaldesa	Bubisa
Predictor Variables	β (S.E.)	β (S.E)	β (S.E.)	β (S.E)	β (S.E)	β (S.E.)
Constant	2.43 (0.758)**	8.80 (1.066)***	5.83(1.056)***	3.62 (1.540)*	4.51 (.533)***	3.10 (1.012)**
Family size	-.039 (0.021		-.129 (.045)*			
Age of Household Head (years)		.010 (.005)		-.027 (.005)***		
Household head education	.37(.068)***					
livestock ownership		-.45 (.138)**	-1.41 (.161)***			-4.06 (1.022)***
Do you grow crops			-.541 (.189)*	-.445 (.171)*		
Marital status of care giver	.140 (057)*					1.901 (.484)***
Caregiver occupation	-.077 (.017)***	-.047 (.020)*			-.044 (.018)*	.087 (.032)*
Caregiver Income		-.19 (.064)**	-.23 (.088)*			
Sex of Index Child	.23 (.087)*		1.09 (.111)***			
Main source of drinking water	.10 (.026**					
Water treatment before drinking		-.316 (.167)		-1.74 (.256)***	-.702 (.404)	
Water treatment methods	-.31 (.099)**			-.388 (.225)		
Disposal of child faeces			.644 (.122)***			
Is the compound clean	.373 (.122)**			-.418 (.225)		

***p< 0.001; **p < 0.01; *$p \leq 0.05$; C.I means Confidence Interval

3.3.5 Binary logistic regression of social, economic, demographic and environmental factors influencing children in Marsabit County

Table 3.12 presents the household factors affecting stunting in pastoral children in Marsabit. Key predictors of stunting identified in the analysis included the child's age, the source of drinking water, and the caregiver's occupation.

Table 3.12: Overall household factors influencing stunting among children in Marsabit County

	Stunting (HAZ<-2SD)			
Predictors	COR (95% CI)	*Sig*	AOR (95% CI)	*Sig*
Household education				
None	Ref			
Primary	0.641 (0.39,1.07)	0.086	1.125 (0.45, 2.17)	0.793
HH occupation				
Livestock keeping	Ref			
Labour/herder	0.49 (0.24,0.99)	0.05	0.475 (0.18, 1.26)	0.14
Child age (mean)	1.078 (1.056, 1.099)	0.00	1.082 (0.98, 1.19)	0.11
Grouped Child age				
6-12	Ref	0.00		0.00
13-17	0.051 (0.01, 0.19)	0.00	0.023(0.00, 1.31)	0.07
18-23	0.118 (0.038, 0.368)	0.00	0.099 (0.00, 3.38)	0.20
Drinking water Source				
Borehole	Ref	0.02		0.00
Public pan	1.468 (0.82, 2.63)	0.20	3.704 (1,59, 8.61)	0.00
Unprotected well	1.346 (0.595, 3.046)	0.48	3.131 (1.05, 9.38)	0.04
Access to toilet facility	1.783 (1.173, 2.712)	0.01	3.797 (1.86, 7.74)	0.00
Faecal waste disposal	0.660 (0.36, 1.21)	0.18	0.257 (0.10, 0.65)	0.00

Younger children aged between 6 and 23 months were found to be more susceptible to stunting (COR = 1.078, 95% CI: 1.06 - 1.10, $p < 0.001$). Furthermore, children residing in households that sourced drinking water from public pans (AOR = 3.704, 95% CI: 1.59 - 8.61, $p = 0.002$) or unprotected wells (AOR = 3.13, 95% CI: 1.05 - 9.38, $p = 0.042$) faced a higher risk of stunting. In contrast, children with unemployed caregivers exhibited a reduced likelihood of being stunted (AOR = 0.60, 95% CI: 0.44 - 0.83, $p = 0.002$). Additionally,

children from households with inadequate access to toilet facilities had a 3.8-fold increased risk of stunting (AOR = 3.797, 95% CI: 1.86 - 7.74, p < 0.001). Moreover, proper disposal of child fecal waste was linked to a significantly lower chance of stunting (AOR = 0.257, 95% CI: 0.10 - 0.65, p = 0.004).

In Karare ward, a greater distance to the nearest market center was significantly linked to a higher likelihood of stunting in children, with an odds ratio of 1.2 [AOR = 1.151, 95% CI: 1.03 - 1.29, p = 0.012] (Table 3.12). Additionally, the age of the child was found to significantly influence stunting in both Sagante/Jaldesa [AOR = 1.088, 95% CI: 1.03 - 1.15, p = 0.005] and Bubisa wards [AOR = 1.116, 95% CI: 1.03 - 1.21, p = 0.008] (Table 3.13).

Table 3. 13: Household factors influencing stunting among children by ward

Ward	Predictor variables	OR (95% C.I)	*p*-value
Karare	Distance to market	1.151(1.031, 1.285)	0.012
Laisamis	Child age in Months	6.846 (0.669, 70.084)	0.105
Sagante/Jaldesa	Child age in Months	1.088 (1.026, 1.153)	0.005
Bubisa	Child age in Months	1.116 (1.029, 1.210)	0.008

The primary predictors of underweight among children included the highest level of education of the household head, the child's age, the source of drinking water, caregiver income, and the child's weight (Table 3.14). Children living in households where the head attained at least primary education showed a decreased likelihood of being underweight [COR = 0.544, 95% CI: 0.32 - 0.93, p = 0.025]. Conversely, the age of the child was identified as a significant factor associated with an increased probability of underweight, with an adjusted odds ratio of 1.844 [AOR = 1.844, 95% CI: 1.50 - 2.26, p < 0.001]. Interestingly, children from households that accessed drinking water from public water pans had a reduced likelihood of experiencing underweight [AOR = 0.32, 95% CI: 0.11 - 0.93, p = 0.035]. Additionally, higher caregiver income correlated with a lower likelihood of the child being underweight [AOR = 0.036, 95% CI: 0.003 - 0.47, p < 0.05]. Moreover, the child's weight significantly affected underweight status [AOR = 0.013, 95% CI: 0.01 - 0.04, p < 0.001], indicating that as weight increases, the likelihood of underweight decreases. Additionally, every unit increase in age corresponded to a reduction in underweight by 0.031 units (Table 3.14).

Table 3.14: Overall household factors influencing underweight among children in Marsabit County

	Underweight (WAZ<-2SD)			
Predictors	COR (95% CI)	*Sig*	AOR (95% C.I)	P value
HH education				
None				
Primary	0.544 (0.32, 0.93)	0.03	0.582 (0.19, 1.79)	0.345
HH occupation				
Livestock keeping	Ref			
Labour/herder	0.508 (0.24, 1.08)	0.08	1.523 (0.39, 5.99)	0.547
Child age (mean)	1.025 (1.01, 1.04)	0.01	1.844 (1.50, 2.26)	0.00
Grouped Child age				
6-12	Ref			
13-17	0.407 (0.15,1.13)	0.08	0.182 (0.00, 74.23)	0.578
18-23	0.224 (0.08, 0.67)	0.01	0.939 (0.00, 213.20)	0.982
36-47	0.338 (0.13, 0.88)	0.03	0.827 (0.02, 30.95)	0.918
Drinking water Source				
Borehole		0.03		0.17
Public pan	0.453 (0.25, 0.83)	0.01	0.318 (0.11, 0.93)	0.04
Unprotected well	0.538 (0.22, 1.29)	0.17	0.458 (0.11, 1.84)	0.27
Access to toilet facility	1.503 (0.96, 2.36)	0.08	1.175 (0.47, 2.97)	0.73
Faecal waste disposal	1.152 (0.58, 2.31)	0.69	0.719 (0.21, 2.49)	0.60
Caregiver income				
< 5,000 per month		0.04		0.04
5,001-10,000	0.232 (0.07, 0.81)	0.02	0.036 (0.00, 0.47)	0.01
10,000-15,000	0.125 (0.03, 0.49)	0.00	0.017 (0.00, 0.26)	0.00
15,001-20,000	0.218 (0.05, 0.95)	0.04	0.053 (0.00, 0.90)	0.04
>20,000	0.163 (0.02, 1.20)	0.08	0.018 (0.00, 0.62)	0.03

In Sagante/Jaldesa, a smaller family size was associated with a lower likelihood of underweight among children, as indicated by an adjusted odds ratio (AOR) of 0.091 [AOR = 0.091, 95% CI: 0.02 - 0.39, p = 0.001]. In contrast, an increase in the caregiver's age was linked to a higher risk of child underweight, with an AOR of 1.447 [AOR = 1.447, 95% CI: 1.125 - 1.860, p = 0.004]. In Bubisa ward, a low monthly income for caregivers was

significantly associated with a higher likelihood of underweight in children [AOR = 1.000, 95% CI: 1.00 - 1.00, p = 0.049]. Additionally, greater child weight was found to be linked to reduced odds of underweight [AOR = 0.517, 95% CI: 0.29 - 0.92, p = 0.026] (Table 3.15).

Table 3.15: Household factors influencing underweight among children by ward

Site/Ward	Predictor variables	AOR (95% C.I)	p-value
Laisamis	Household head education	874820951.412 (0.000)	0.998
	Sex of Child (Females)	0.000 (0.000)	0.998
Logologo	Price of water per unit (KES)	0.003 (0.000)	0.994
Sagante/Jaldesa	Family size	0.091 (0.021, 0.393)	0.001
	Age of Care Giver (years)	1.447 (1.125, 1.860)	0.004
	Caregiver monthly income (KES)	1.000 (1.000, 1.000)	0.067
Bubisa	Caregiver monthly income (KES)	1.000 (1.000, 1.000)	0.049
	Weight in Kg	0.517(0.290, 0.923)	0.026

The results highlight significant associations between various factors and the likelihood of children experiencing wasting. In particular, a child's age was found to be a key predictor of increased risk for wasting, as indicated by an adjusted odds ratio (AOR) of 31.34 [AOR = 31.34, 95% CI: 1.16 - 1.55, p < 0.001] (Table 3.14). This suggests that as children age, they may become more vulnerable to nutritional deficiencies. Conversely, several elements were identified as linked to a decreased risk of wasting. For instance, a child's weight was inversely related to the likelihood of wasting, with an AOR of 0.128 [AOR = 0.128, 95% CI: 0.07 - 0.24, p < 0.001]. Furthermore, the level of education attained by the household head played a crucial role in reducing the chances of wasting, with an AOR of 0.287 [AOR = 0.287, 95% CI: 0.10 - 0.87, p = 0.027]. This indicates that better-educated caregivers may provide improved nutritional support and care. Additionally, the proper disposal of child faecal waste was associated with a significantly lower likelihood of wasting, as indicated by an AOR of 0.274 [AOR = 0.274, 95% CI: 0.12 - 1.02, p = 0.054]. These findings emphasize the importance of enhancing educational opportunities for caregivers and promoting effective sanitation practices.

Table 3.16 presents an overview of the factors that influence wasting among children at the ward level. The findings indicate that in the Laisamis ward, the child's weight was identified as the only significant predictor of wasting (AOR = 0.066, 95% CI: 0.00 - 0.98, p = 0.048). In contrast, in the Sagante/Jaldesa ward, caregiver monthly income (AOR = 1.000, 95% CI: 1.00

- 1.00, p = 0.014) and child age (AOR = 1.370, 95% CI: 1.01 - 1.86, p = 0.044) were associated with an increased likelihood of wasting. Moreover, weight (AOR = 0.046, 95% CI: 0.00 - 0.71, p = 0.027) also emerged as a significant factor in the Sagante/Jaldesa ward. Additionally, family size (AOR = 0.216, 95% CI: 0.06 - 0.77, p = 0.018) was a predictor of wasting in the Bubisa ward (Table 3.17).

Table 3.16: Overall household factors influencing wasting among children

Predictors	Wasting (WHZ<-2SD)			
	COR (95% CI)	*Sig*	AOR (95% CI)	P value
HH education				
None				
Primary	0.478 (0.25, 0.90)	.023*	0.287 (0.10, 0.87)	.027*
HH occupation				
Livestock keeping				
Labour/herder	0.840 (0.33, 2.13)	0.712	2.278 (0.63, 8.28)	0.21
Child age (mean)	0.975 (0.95, 0.10)	0.032	1.341 (1.16, 1.55)	0.00
Grouped Child age				
6-12		0.087		0.06
13-17	3.511 (0.74, 16.70)	0.115	21.852 (0.10, 4901.11)	0.26
18-23	1.279 (0.24, 6.71)	0.771	24.005 (0.179, 3224.81	0.20
36-47	1.805 (0.39, 8.40)	0.452	19.94 (0.72, 551.10)	0.08
Drinking water				
Source				
Borehole		0.882		0.72
Public pan	0.731 (0.36, 1.47)	0.381	0.844 (0.32, 2.23)	0.73
Unprotected well	0.590 (0.20, 1.76)	0.345	0.438 (0.10, 1.88)	0.27
Access to toilet facility	1.071 (0.63, 1.84)	0.802	0.948 (0.42, 2.14)	0.90
Faecal waste disposal	0.531 (0.26, 1.09)	0.083	0.347 (0.12, 1.02)	0.05

Table 3. 17: Factors influencing wasting among children by ward

Site/Ward	Predictors of Wasting	OR (95% C.I)	*p*-value
Laisamis	Weight in Kg	0.066 (0.004, 0.979)	0.048
Sagante	Caregiver monthly income (KES)	1.000 (1.000, 1.000)	0.039
	Child age in Months	1.370 (1.009, 1.861)	0.044
	Weight in Kg	0.046 (0.003, 0.706)	0.027
	Wash hands before feeding child	0.058 (0.002, 1.531)	0.088
Bubisa	Family size	0.216 (0.061, 0.770)	0.018

P- Value Mean Significant at $p < 0.05$

3.4. Discussion

The prevalence rates of stunting, wasting and underweight identified in this study (refer to Tables 3.7, 3.8 and 3.9) surpass the World Health Organization's recommended thresholds of less than 10% for underweight, less than 20% for stunting, and less than 5% for wasting (de Onis, 2019; WHO, 2006). Moreover, the rates of stunting, wasting, and underweight observed are higher than those reported in the Kenya Demographic and Health Surveys (KNBS & ICF, 2023). The elevated levels of undernutrition noted in this research may be linked to insufficient dietary intake and impaired digestion due to childhood illnesses, which can impede muscle mass development and lead to significant linear growth delays.

Research conducted in various regions has indicated diverse levels of undernutrition. For example, Okidi *et al*. (2022) reported higher rates of stunting (ranging from 48.3% to 58.4%), underweight (46% to 54%), and wasting (36.4% to 52.1%) among pastoral children in Karamoja, Uganda. In contrast, Khan *et al.* (2019) found elevated rates of stunting (44.4%), underweight (29.4%), and wasting (10.7%) among children aged 6 to 59 months in Pakistan. When comparing the findings of this study with research conducted in Uganda (Nankinga et al., 2019) and Senegal (Badiane *et al.*, 2021), the prevalence of undernutrition was notably higher in the current research. On the other hand, Ma'alin *et al.* (2021) reported lower rates of underweight (24.5%), stunting (33.4%), and wasting (20%) in the Shinille Woreda of Ethiopia. Similarly, Poudel *et al.* (2022) noted comparatively lower rates of stunting (26.7%), wasting (7%), and overall undernutrition (17.7%) in rural Kaski district, Nepal. The variations in prevalence rates may stem from differences in household socioeconomic

conditions and child feeding practices among caregivers. Understanding the variations in undernutrition prevalence across different regions is vital for the development of targeted interventions and policies to address the specific challenges faced by each population. This highlights the need for context-specific approaches that consider the unique socioeconomic, cultural, and environmental factors contributing to undernutrition. Moreover, these findings emphasize the importance of ongoing monitoring and evaluation of nutrition interventions to ensure their effectiveness in combating undernutrition among settled pastoral children in northern Kenya.

In the current study, children who depended on public water pans or unprotected wells for drinking water showed a greater likelihood of stunting when compared to those with access to safer water sources. These open water bodies in arid regions are vulnerable to contamination from frequent sandstorms, which can expose children to diarrhoeal pathogens. Additionally, the limited availability of toilets in the study areas was linked to increased rates of stunting. This situation may lead to open defecation, further polluting the environment with harmful enteric pathogens. Children who drink water tainted with these bacteria are at a heightened risk of diarrheal diseases, which are known to hinder growth and contribute to stunting. The significant occurrences of diarrheal illness in Bubisa ward can be attributed to its location in the Chalbi Desert, where frequent sandstorms are common, and open defecation is more prevalent. Such conditions may result in poor, dusty environments that increase children's exposure to foodborne microorganisms that cause diarrhea.

Numerous studies have explored the connection between stunting and various factors related to caregivers, children, and their environments (Ireri *et al.*, 2021; Mbijiwe *et al.*, 2022; Odeyonu *et al.*, 2022). The consumption of contaminated water and inadequate access to toilets can expose children to enteric diarrheal pathogens, including *E. coli* and *Salmonella* spp., which are commonly linked to the ingestion of contaminated food and water (Okidi *et al.*, 2022). The findings of this study are consistent with previous research conducted among non-pastoral children in the South Nikuman District of Cambodia (Blaney *et al.*, 2019) and in Indonesia (Lukman *et al.*, 2022), as well as in pastoral households in the Karamoja region (Okidi *et al.*, 2022), rural areas of North Sudan (Sulaiman *et al.*, 2021), and pastoral communities in the Mieso-Mulu District of the Somali Regional State in Eastern Ethiopia (Geletaw *et al.*, 2021). Additionally, the results of the current study align well with those of

Nsubuga *et al.* (2022), which identified a link between stunting and diarrhea among children in Uganda, and with findings from Sinha *et al.* (2018) regarding children in India.

In pastoral households, prevalent routes for the microbial contamination of infant complementary foods often involve the consumption of raw or inadequately cooked animal-derived foods. Infection from foodborne pathogens can lead to damage of the intestinal mucosal layer, which triggers the activation of eae and other associated genes, resulting in the breakdown of the normal microvilli structure. The bacteria subsequently adhere tightly to the epithelial membrane through the protein intimin, leading to the destruction of epithelial cells and the loss of intestinal microvilli. This process contributes to nutrient loss, ultimately resulting in wasting and hindering physical growth (Yu *et al*., 2021).

These results underscore the critical need to improve access to safe drinking water, adequate toilet facilities, caregiver income, and child weight management in the fight against stunting among children in northern Kenya. Furthermore, the findings draw attention to the inadequate waste disposal practices prevalent in the region, where many households resort to open defecation and rely on poorly ventilated temporary pit latrines, particularly in lowland areas with a higher incidence of households lacking toilets. Ensuring access to well-ventilated improved pit latrines in rural settings and modern flushable toilets in urban areas is essential for enhancing hygiene, curbing the spread of diseases, and promoting the overall health of the community.

Recent research has indicated that factors such as maternal unemployment, the presence of wage-earning heads of households, and the child's age are associated with a decrease in stunting rates. This finding implies that mothers who can dedicate more time to childcare are less likely to experience issues with child stunting. A study conducted in Dhaka, Bangladesh, found that children of working mothers had nearly double the likelihood of being stunted compared to those with non-working mothers (Win *et al.*, 2020). However, several studies have also shown that children from employed households tend to be less prone to stunting (Ahmed *et al.*, 2022; Yani *et al.*, 2023). Moreover, income derived from employment can significantly affect food accessibility, enhancing food security and consequently leading to lower rates of stunting among children.

The elevated stunting rates observed in the current study among children aged 24-35 months and 48-59 months may be linked to short birth intervals that prioritize younger siblings, as well as the early introduction of inadequately formulated complementary foods within

pastoral communities. This aligns with findings from Kang *et al*. (2018), which highlighted the relationship between age and stunting in Bhutan. In contrast, a study among children in the Karamoja region indicated that children aged 12-23 months, 36-47 months, and 48-59 months had lower odds of being simultaneously wasted and stunted as they aged (Obeng-Amoako et *al.*, 2020). This discrepancy could be due to suboptimal initiation of complementary feeding practices in the pastoral households of Marsabit (Galgallo, 2017).

The relationship between the proximity to the nearest market center and stunting rates in the Karare and Laisamis wards was evident (Table 3.11). Having access to nearby markets can indirectly influence the nutritional health of young children. This is largely due to the limited ability to regularly obtain fresh and nutritious foods from these markets, along with constraints on employment opportunities and the fluctuating prices of agricultural products (Agyei-Boakye, 2022;Weatherspoon *et al.*, 2019;).

The predictor model identified the age of the index child as a critical factor affecting stunting, wasting, and underweight across various wards. The elevated levels of stunting observed in Laisamis, in comparison to other wards, can be linked to the drought conditions prevalent during the study period (Table 2). Households with children under five years old faced substantial challenges in accessing livestock products, as either the livestock were driven far in search of pasture and water, or they perished due to inadequate feed and water supplies. The Rendille community residing in this ward largely depends on livestock for both nutrition and income. Despite substantial food aid provided through humanitarian efforts in pastoral regions, the rates of global acute malnutrition remain alarmingly high, likely exacerbated by ongoing food insecurity among settled households.

The current research demonstrates that an increase in the mean age of children is associated with a higher likelihood of being underweight, with a factor of 1.8. This trend may be linked to food insecurity and inadequate weaning practices that tend to prioritize infants over older siblings within the family (Wolde *et al.*, 2015). It is noteworthy that this study took place during the dry season when caregivers faced challenges in accessing milk from livestock. Conversely, factors such as the education level of the household head, proper disposal of faecal waste, and the child's weight were associated with a decreased likelihood of underweight status in children.

In the Sagante/Jaldesa ward, our research identified a significant relationship between caregiver age and the prevalence of underweight children under five. Specifically, younger

caregivers were linked to an increased likelihood of undernutrition. The youngest caregiver recorded in the study was just 16 years old (data not shown in the table), highlighting the prevalence of early marriages among pastoral girls, which can lead to teenage motherhood. This situation often results in inadequate feeding practices, contributing to a higher incidence of undernutrition in children. These results align with earlier studies conducted by Mbijiwe *et al.* (2022) and Morakinyo *et al.* (2020), which also found a connection between younger caregivers and undernutrition among young children.

With an average caregiver age of 28 years, it is evident that a significant number of children in this ward are at a heightened risk of undernutrition. This risk may be further exacerbated by the elevated illiteracy rates within households, which are as high as 66%. Existing literature suggests that the educational attainment of caregivers plays a critical role in influencing childhood undernutrition (Clark *et al.*, 2021; Stamenkovic *et al.*, 2016; Paul & Saha, 2022). Education is vital for empowering women to obtain essential healthcare information, which can improve nutritional practices for their children (Iftikhar *et al.*, 2017). Moreover, increased education enhances women's prospects for securing stable employment and income, thereby providing them with greater independence in making food-related decisions for their children (Adeyonu *et al.*, 2022; Iftikhar *et al.*, 2017).

Furthermore, the current study has indicated that family size significantly impacts underweight among children in the Sagante/Jaldesa ward and wasting in the Bubisa ward. The size of the family directly affects how food resources are distributed within households, with younger children often receiving priority over those aged two years and older. These results align with a previous study conducted by Abera *et al.* (2021) in Ethiopia, which found a notable relationship between larger family sizes and the prevalence of undernutrition among non-pastoral children under the age of five in Tigray. Similarly, research by Ahmad *et al.* (2020) in Pakistan highlighted a significant association between family size and various indicators of undernutrition. Their findings suggested that family sizes of one to five members were linked to reduced rates of stunting and wasting.

Additionally, caregiver monthly income was shown to have a significant effect on both wasting and underweight in the Sagante/Jaldesa ward, while it only predicted underweight in the Bubisa ward. Higher income levels enable caregivers to make informed choices about food purchases, which improves dietary diversity, especially for complementary foods.

Notably, in this study, 69% of caregivers fell into the low-income category, earning an average monthly income of just 33 USD.

3.5 Conclusion and Recommendation

This study has indicated that the prevalence of stunting, wasting, and underweight exceeds the standards set by the World Health Organization (WHO) as well as recent figures from the Kenya Demographic and Health Survey (KDHS) at both the national level and in Marsabit County. Key predictors of undernutrition identified in this research include the age and weight of the index child, the source of drinking water, waste disposal methods, and various caregiver characteristics such as age, income, education, and family size. In conclusion, the findings reveal a concerning prevalence of stunting, underweight, and wasting, which can be attributed to a shift in dietary practices towards a more cereal-based diet.

CHAPTER FOUR

DETERMINANTS OF DIETARY DIVERSITY AND EFFECT ON NUTRITIONAL STATUS OF AMONG CHILDREN AGED 6-59 MONTHS IN TRANSITIONAL PASTORALISTS HOUSEHOLDS IN MARSABIT COUNTY, NORTHERN KENYA

Abstract

Sedentarization among pastoral communities is expected to enhance access to vital services. However, there is a lack of information regarding how this transition affects dietary practices and undernutrition among children aged 6 to 59 months. This research aimed to assess the factors influencing dietary diversity in children aged 6-59 months within settled pastoral households. A cross-sectional survey was conducted, involving a sample of 394 households with an index child, selected through a multistage random sampling technique. Data on household characteristics and dietary diversity were gathered using a pre-tested questionnaire and a checklist to determine a 7-point dietary diversity score. Dietary diversity scores were calculated by summing the number of food groups (ranging from 0 to 7) consumed by the child in the 24 hours prior to the survey. A minimum dietary diversity was defined as consumption of at least four food groups. Categorical variables were presented as proportions, while continuous data were reported as means with standard errors. Chi-square tests and analysis of variance were used to investigate population differences, and linear regression was employed to analyze the relationship between household characteristics and dietary diversity. Logistic regression was applied to examine the connection between food group consumption and the nutritional status of children. The findings indicated that cereals, roots, and tubers were the most commonly consumed food group, with a prevalence of 97%, followed by legumes and nuts (61.9%), dairy products (61.4%), and other fruits and vegetables (19%). The mean dietary diversity score for the children was 3.43 ± 0.89, ranging from 2.79 ± 0.21 in Karare ward to 5.2 ± 0.12 in Bubisa ward among settled pastoral areas. In conclusion, the study found that more than half of the children did not meet the recommended dietary diversity, primarily associated with household income levels. It is recommended that current policies focused on nutrition education, particularly regarding child feeding guidelines, be implemented for settled pastoral caregivers in northern Kenya.

4.1. Introduction

Optimal infant and young child feeding (IYCF) practices are essential for the health and survival of young children. Recommended IYCF practices encompass the early initiation of

breastfeeding within the first hour after birth, exclusive breastfeeding for the initial six months, and the timely introduction of nutritious solid and semi-solid foods while continuing breastfeeding up to two years or longer. Additionally, it is crucial for children to consume a diet that meets minimum diversity standards (UNICEF/WHO/World Bank, 2021). Minimum dietary diversity (MDD) is defined as the consumption of at least four out of seven specific food groups that are both safe and nutritionally adequate for a growing child aged 6-23 months (MOH, 2017; WHO, 2018). The seven food groups include: 1) grains, roots, and tubers; 2) legumes and nuts; 3) dairy products (such as milk, yogurt, and cheese); 4) flesh foods (including meat, fish, poultry, and organ meats); 5) eggs; 6) vitamin A-rich fruits; and 7) other vegetables and fruits (WHO, 2018). These foods, alongside breast milk, provide a balanced diet that supplies essential macro- and micronutrients, thereby enhancing a child's chances of survival. Any deviation from these recommended practices can lead to undernutrition during early childhood.

Undernutrition in children under five years of age continues to pose a significant public health challenge, primarily attributed to inadequate complementary feeding practices (MOH, 2017). Suboptimal complementary feeding adversely affects children's mental, social, and cognitive development as well as their linear growth (Georgieff *et al.*, 2018; Muhoozi *et al.*, 2018; Mutuku *et al.*, 2020). Globally, approximately 22.3% of children under five—equating to 148 million—are stunted, and 6.8% (or 45 million) experience wasting due to malnutrition (Matonti *et al*., 2020; UNICEF/WHO/World Bank, 2023). This marks an increase from the previous year, where 22% of children (149.2 million) were stunted, and 6.7% (45.4 million) were wasted in 2021 (UNICEF/WHO/World Bank, 2021).In Africa, the rate of stunting rose from 41% (54 million) to 43% (61.3 million), with East and West Africa—regions predominantly inhabited by pastoralists—reporting a stunting prevalence of 30% (Matonti *et al.*, 2020). Although there has been a slight decrease in wasting, with prevalence recorded at 5% down from 5.3% in East Africa (Matonti *et al.*, 2020; UNICEF/WHO/World Bank, 2021), the situation in Kenya reflects mixed outcomes. Stunting and underweight rates have dropped from 26% and 11% to 18% and 10%, respectively (KNBS & ICF, 2023). However, the prevalence of stunting among children in pastoral Arid and Semi-Arid Lands (ASAL) remains above the national average of 18%, with counties like West Pokot (33.5%) and Marsabit (23.8%) showing particularly high rates (KNBS & ICF, 2023). Therefore, dietary intake, encompassing diversity, quality, and safety of foods, is crucial in addressing undernutrition in children under five.

Optimal dietary intake, particularly in terms of food quality and safety, is essential for addressing undernutrition in children under five. However, globally, fewer than 25% of children in this age group meet the recommended criteria for Minimum Dietary Diversity (MDD), with only a small fraction receiving a nutritionally adequate diet (KNBS & ICF, 2023; WHO, 2018). According to the latest Kenya Demographic and Health Survey (KDHS), only 54% of children aged 6–23 months had an adequately diverse diet, consuming foods from the appropriate number of food groups. This figure significantly declines in rural areas, where only 32.5% of children achieve the MDD, compared to 50% in urban settings (KNBS & ICF, 2023). Consequently, over 50% of children are subjected to suboptimal complementary feeding practices. These statistics are particularly alarming in northern Kenya, where a recent study by Young *et al.* (2024) found extremely low levels of MDD among children aged 6–23 months. In Garbatulla, the highest proportion of children meeting the required MDD (≥4 food groups) was only 13%, followed by Loiyangalani at 4%, Laisamis at 3%, and Ngaremara at a mere 1%. This highlights the urgent need for interventions to improve dietary diversity and nutritional practices in these vulnerable populations.

Pastoralists have traditionally relied heavily on livestock milk as a primary source for complementary feeding (Little, 2015). However, the transition from nomadism to sedentism has led many pastoral households to alter their dietary practices, moving away from their traditional diets that included milk, meat, and blood (Khamis *et al.*, 2019; Oniang'o *et al.*, 2003). Increased engagement with markets has influenced these dietary shifts, often resulting in the adoption of different food preferences that may prioritize lower-quality foods. This transition is particularly concerning during prolonged drought periods, which create shortages of traditional foods. In such times, pastoralists are compelled to rely more on cash-based economies, further exacerbating their vulnerability to nutritional deficiencies (Prall & Scelza, 2023).

The reliance on cash-based purchases may lead to less diverse diets, as households may prioritize affordability over nutritional quality. As a result, children from these communities could face increased risks of undernutrition due to insufficient intake of essential nutrients necessary for their growth and development. This highlights the need for targeted interventions to promote dietary diversity and ensure access to high-quality foods, especially during periods of environmental stress.

Although there is limited data on the dietary shifts and their effects on children's nutritional status, this study seeks to answer the pivotal question: *"What is the current level of dietary diversity and nutrient intake among children aged 6-59 months in settled pastoralist communities?"* The results from this investigation will provide essential insights that can aid in the development of maternal nutrition education programs focused on optimal complementary feeding practices within northern Kenya. Evaluating the dietary diversity and nutritional intake of children in this population is vital for pinpointing deficiencies in their diets and guiding targeted interventions. The findings of this study will not only help assess the existing nutritional conditions of these children but also inform health practitioners and policymakers in crafting effective strategies to encourage improved dietary habits among settled pastoralist households. Ultimately, the objective is to enhance the health and well-being of young children in these areas by ensuring they receive adequate nutrition for proper growth and development.

4.2. Materials and Methods

Population sampling, social and demographic data collection, nutritional status assessment methods are captured in Chapter three of this report.

4.2.1 Child Dietary Diversity Assessment

The caregiver was asked only once by trained enumerators about the various foods the index child consumed in the 24 hours leading up to the interview. A comprehensive list of common complementary foods was developed with the assistance of Key Informants (KIs) from the study areas. These foods were organized into seven primary food groups as outlined by WHO (2018) in their guidelines for Infant and Young Child Feeding, used to calculate the Child Individual Dietary Diversity Score (CIDDS). The food groups included: (1) grains, roots, and tubers; (2) legumes and nuts; (3) flesh foods (meat, fish, poultry, and organ meats); (4) eggs; (5) vitamin A-rich fruits and vegetables; (6) dairy products (milk, yogurt, cheese); and (7) other fruits and vegetables.

A score of one (1) was assigned if the child consumed at least one item from a particular food group during the 24-hour recall period. Conversely, a score of zero (0) was given if no items from that group were consumed. These scores for each child were then summed to obtain the Common Individual Dietary Diversity Score (CIDDS), which ranged from zero to seven, where zero indicates no consumption of any food items from the groups, and seven signifies the intake of foods from all seven groups. A Minimum Dietary Diversity Score (MDD) was

determined if a child consumed foods from at least four or more food groups (≥4) out of the seven during the previous 24 hours before the interview. This score was further categorized as low (1-3), medium (4-5), or high (6-7) (FAO, 2018).

4.2.2 Data Analysis

The data collected were pre-coded and entered into a computer for analysis using the Statistical Package for Social Sciences (SPSS version 20). Categorical variables were expressed as proportions, while continuous variables were presented as means with standard error (Means ± standard error). Analysis of Variance (ANOVA) was utilized for continuous variables, with means being compared using Tukey's HSD test. Chi-square tests were employed for categorical variables to assess differences among populations. A linear regression model was applied to identify the influence of household socio-economic factors on dietary diversity scores. Bivariate and multivariate logistic regression models were used to evaluate the impact of consumed food groups on child nutritional outcomes (stunting, wasting, and underweight). Results were deemed significant at $p \leq 0.05$. All statistical analyses were conducted using SPSS software version 20. For further details, refer to Chapter Three, which discusses the analysis of social, economic, demographic, and anthropometric data.

4.3. Results

4.3.1 Proportion of children who foods from different food groups

Table 4.1 displays the results regarding the proportion of children who consumed foods from the seven food groups across the six wards. The study's findings reveal that an impressive 97.6% of children in these wards consumed foods from cereals, tubers, and roots, which constitute the primary staple in their diet. There were no statistically significant differences in consumption levels among the wards ($p = 0.170$). In total, approximately 62% of children reported consuming legumes and nuts. When examining the wards, a significantly higher proportion of children in Bubisa consumed beans and pulses ($p < 0.001$), followed by those in Logologo, Laisamis, Marsabit Central, Karare, and Sagante/Jaldesa wards, in that order (see Table 4.1). Furthermore, proportion of children consuming dairy products was significantly below average (31.1%; $p< 0.001$), with Bubisa and Logologo accounting for 57.1% and 51.2%, respectively. The lowest proportion of children who consumed dairy products was registered in Karare, followed by Sagante/Jaldesa, Marsabit Central, and Laisamis wards respectively.

Consumption of fresh meat (including beef, camel, lamb, goat, chicken, liver, kidney, heart, or other organ meats) was generally low, with only 35.0% of children reporting regular intake. A significantly higher consumption of flesh foods was observed in Bubisa, with 91.8% of children partaking. In contrast, the intake of flesh foods was markedly lower in Marsabit Central (41.2%), Logologo (37.2%), Laisamis (23.1%), and Sagante/Jaldesa (21.6%), while Karare ward recorded the lowest consumption levels. Egg consumption was notably infrequent across nearly all study sites, with only 19.2% of children consuming eggs overall. However, slightly higher rates of egg consumption were found in urban wards, such as Marsabit Central (41.2%) and Sagante/Jaldesa (24.3%). In pastoral wards, egg consumption was particularly low, with figures of 17.2% in Laisamis, 14.0% in Logologo, 6.1% in Bubisa, and just 5.8% in Karare.

Overall, proportion of children who consumed vitamin A-rich fruits and vegetables was 61.4%, with significant differences observed across the wards (p<0.001). Interestingly, Bubisa ward, located furthest from the main sources of fresh fruits and vegetables, had the highest proportion of children with intakes (91.8%) compared to the agro-pastoral areas of Sagante/Jaldesa and Karare wards. Marsabit Central and Logologo exhibited above-average intake levels, while the lowest intake was observed in Laisamis (45.3%).

Approximately 58% of children in the study sites consumed other fruits and vegetables. A significantly higher proportion of children in Bubisa reported consuming other fruits and vegetables ($p < 0.001$), followed by those in Sagante/Jaldesa, Marsabit Central, Logologo, Laisamis, and Karare, in that order.

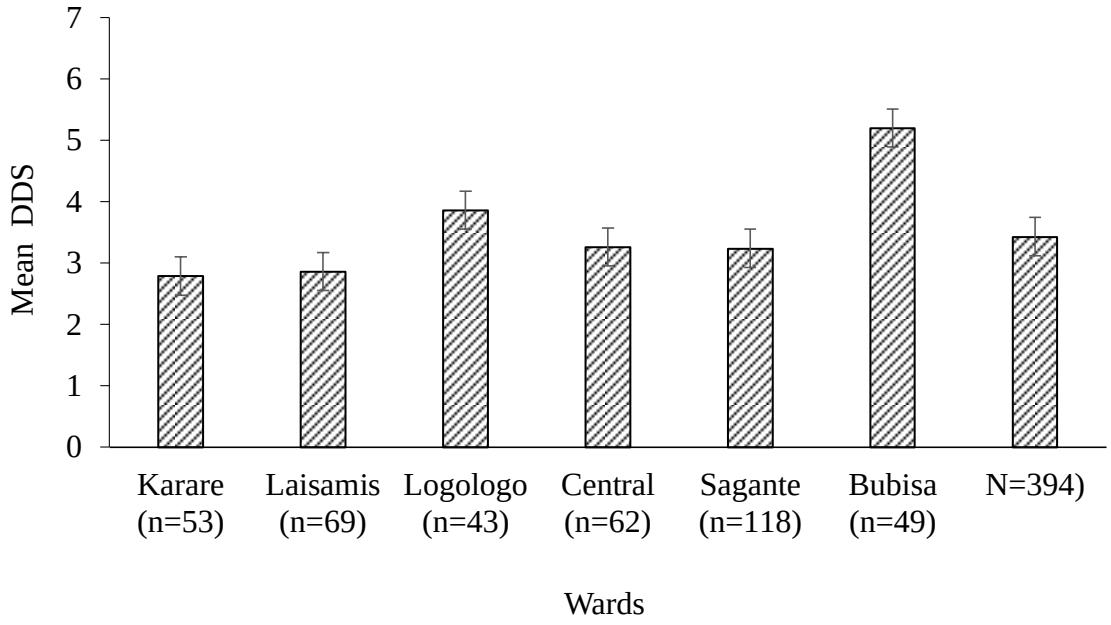
Table 4.1: Proportion of children who consumed foods from different food groups by ward

	Name of wards*								
	Karare (n=53)	Laisamis (n=69)	Logologo (n=43)	Central (n=62)	Sagante (n=118)	Bubisa (n=49)	(N= 394)	χ^2	P≤0.05
Grains, roots and tubers	48 (92.3)a	63 (98.4)a	42 (97.7)a	51 (100)1	109 (98.2)a	48 (98.0)a	361 (97.6)	7.75	0.17
Legumes and nuts	28 (53.8)a,b	39 (60.9)a,b	33 (76.7)a	29 (56.9)a,b	51 (45.9)b	49 (100)1	229 (61.9)	48.15	<0.001
Flesh foods	7 (13.5)a	18 (28.1)a,b	22 (51.2)b,c	18 (35.3)a,b,c	22 (19.8)a	28 (57.1)c	115 (31.1)	38.42	<0.001
Eggs	9 (17.3)a	15 (23.1)a	16 (37.2)a	21 (41.2)a	24 (21.6)a	45 (91.8)b	130 (35.0)	90.42	<0.001
Vit A fruits and vegetables	3 (5.8)a	11 (17.2)a,b	6 (14.0)a,b	21 (41.2)b	27 (24.3)a,b	3 (6.1)a	71 (19.2)	30.14	<0.001
Dairy products	29 (55.8)a	29 (45.3)a	25 (58.1)a	30 (58.8)a	69 (62.2)a	45 (91.8)b	227 (61.4)	27.18	<0.001
Other fruits and vegetables	22 (42.3)a,b	23 (35.9)a	23 (53.5)a,b,c	33 (64.7)b,c	79 (71.2)c	36 (73.5)c,d	216 (58.4)	32.12	<0.001

*Values within the same row that have different subscripts are significantly different at $p < 0.05$ based on the two-sided test of equality for column proportions. The tests assume equal variances and have been adjusted for all pairwise comparisons within a row of each innermost suitable category using the Bonferroni correction.

4.3.2. Children dietary diversity by ward

Figure 4.1 provides a summary of the mean ± standard error (S.E.) of the Dietary Diversity Score (DDS) along with the proportion of children categorized according to their DDS. The overall DDS for the children in the study area varied from 2.79 ± 0.21 to 5.20 ± 0.12, with an average dietary diversity of 3.43 ± 0.89. This indicates that the majority of children across all



study sites exhibited low dietary diversity (Figure 4.1).

Figure 4.1 *The mean dietary diversity score by ward*

(ANOVA, F (5) = 16.288; p < 0.001)

Table 4.2 shows the proportion (%) of children in the seven dietary diversity scores (DDS) in the six wards. Overall, a paltry 2.8% of children consumed foods from all the recommended seven food groups compared to 6.1% who did not of children consumed foods outside the WHO Infant and Young Child Feeding (IYCF) guidelines compared to a paltry 2.8% of children who consumed all the seven food groups. Moreover, 8.9%, 15.5% and 21.1% fell with the DDS of the children consumed foods from of 0, 1, 2 and 3 food groups respectively accounting for about 51.5% of children who did not meet the recommended ≥4 out of 7 food groups DDS Furthermore, only 19.8, 14.7 11.2, 2.8% of children had DDS of 4, 5, 6 and 7 respectively, representing 45.7% of children who met the recommended DDS (p < 0.001).

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Table 4.2 Percent distribution of dietary diversity score by ward

	Name of ward *(χ^2; 159.782 95% C.I; p<0.001)*						
DDS	Karare (n=53)	Laisamis (n=69)	Logologo (n=43)	Central (n=62)	Sagante/ Jaldesa (n=118)	Bubisa (n=49)	Total (N=394)
0	1 (1.9)	5 (7.2)	0 (0.0)	11 (17.7)	7 (5.9)	0 (0.0)	24 (6.1)
1	12 (22.6)	9 (13.0)	3 (7.0)	2 (3.2)	9 (7.6)	0 (0.0)	35 (8.9)
2	13 (24.5)	19 (27.5)	5 (11.6)	7 (11.3)	17 (14.4)	0 (0.0)	61 (15.5)
3	10 (18.9)	18 (26.1)	8 (18.6)	12 (19.4)	33 (28.0)	2 (4.1)	83 (21.1)
4	10 (18.9)	5 (7.2)	14 (32.6)	8 (12.9)	31 (26.3)	10 (20.4)	78 (19.8)
5	5 (9.4)	6 (8.7)	6 (14.0)	14 (22.6)	12 (10.2)	15 (30.6)	58 (14.7)
6	1 (1.9)	2 (2.9)	5 (11.6)	7 (11.3)	8 (6.8)	21 (42.9)	44 (11.2)
7	1 (1.9)	5 (7.2)	2 (4.7)	1 (1.6)	1 (0.8)	1 (2.0)	11 (2.8)

Further analysis classifying DDS into categories showed that children in Bubisa ward had significantly higher mean DDS (5.20 ± 0.12) followed by Logologo (3.86±0.24), Marsabit central (3.26 ± 0.26), Sagante/Jaldesa (3.24 ± 0.14), Laisamis at 2.86 ± 0.22 (Figure 4.2).

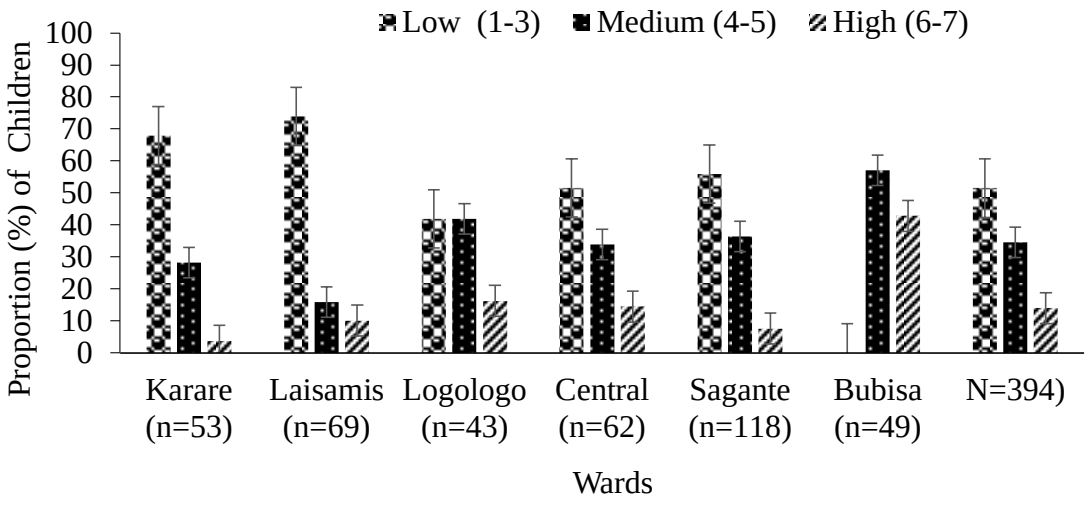

Figure 4.2 *Percent of children falling in different DDS categories*

The distribution of children categorized by dietary diversity revealed that 51.5% were classified as having low dietary diversity, while 34.5% fell into the medium category and 14.0% were identified as having high dietary diversity (Figure 4.2). Notably, low dietary diversity (scores of 1-3) was most prevalent in the Laisamis ward, followed by Karare, Sagante/Jaldesa, Marsabit Central, and Logologo wards. Interestingly, there were no children classified as having low DDS in Bubisa ward. Bubisa ward showed the highest DDS with high proportion of children falling within medium-high dietary diversity followed by Logologo, Sagante/Jaldesa, Marsabit central, and Karare and Laisamis wards respectively. Bubisa exhibited a significantly higher proportion of children consuming more than six food groups, at 43%, compared to Logologo (16.3%), Marsabit Central (14.5%), Laisamis (10.1%), Sagante/Jaldesa (7.6%), and Karare (3.8%), with a statistical significance of $p < 0.001$.

4.3.3. Minimum Dietary Diversity

WHO and FAO sets minimum dietary diversity (MDD) at consumption of >4 food groups from the seven food groups (FAO, 2018; WHO, 2021). The results of this study showed that overall, 48.5% of the children met the recommended MDD while Overall, less than 50.5% did not. Of the children met the required MDD. The highest proportion of children who met MDD was observed in Bubisa followed by Logologo, Marsabit central, Sagante/Jaldesa and Karare wards respectively. In terms of sex of children, more boys (49.2%) than girls (47.8%)

met the MDD. Specifically, while more boys than girls met the recommended MDD in Bubisa and Marsabit central ward, met the recommended MDD. Furthermore, more female children met MDD in Sagante/Jaldesa, Logologo, Karare and Laisamis met the recommended MDD (table 4.3). In terms of age categories of children, significant differences in MDD were observed in all age groups. The results of the current study indicated that 59.7% of children in the age bracket of 6-12 months, followed by 24-35 months (47.9%), 13-23 months and 48-59 months met the MDD in the study areas. While Karare ward had the lowest proportion of children aged 6-23 months who met the minimum dietary diversity, lowest proportion of children who met recommended MDD was recorded in Bubisa ward.

Table 4.3 Minimum dietary diversity distribution by age and sex

		Name of wards							
	MDD	Karare	Laisamis	Logologo	Central	Sagante	Bubisa	Total	χ2 (Sig)
Overall	<4.0	36 (67.9)	51 (73.9)	18 (41.9)	32 (51.6)	66 (55.9)	0 (0.0	203 (51.5)	74.16
	≥4.0	17 (32.1)	18 (26.1)	25 (58.1)	30 (48.4)	52 (44.1)	49 (100)	191 (48.5)	(<0.001)
Sex									
Male	<4.0	17 (70.8)	32 (74.4)	8 (42.1)	12 (41.4)	41 (60.3)	0 (0.0)	110 (50.8)	51.58 (<0.001)
	≥4.0	7 (29.2)	11 (25.6)	11 (57.9)	17 (58.6)	27 (39.7)	33 (100)	106 (49.2)	
Female	<4.0	19 (65.5)	19 (73.1)	10 (41.7)	20 (60.6)	25 (50.0)	0 (0.0)	93 (52.2)	26.18 (<0.001)
	≥4.0	10 (34.5)	7 (26.9)	14 (58.3)	13 (39.4)	25 (50.0)	16 (100)	85 (47.8)	
Age category in Months									
6-12	<4.0	4 (100)	6 (60.0)	3 (30.0)	8 (53.3)	8(40.0)	0 (0.0)	29 (40.3)	17.82 (0.003)
	≥4.0	0 (0.0)	4 (40.0)	7 (70.0)	7 (46.7)	12 (60.0)	13 (100)	43 (59.7)	
13-23	<4.0	9 (64.3)	19 (73.1)	9 (60.0)	12 (70.6)	16 (50.0)	0 (0.0)	65 (53.7)	26.64 (<0.001)
	≥4.0	5 (35.7)	7 (26.9)	6 (40.0)	5 (29.4)	16 (50.0)	17 (100)	56 (46.3)	
24.35	<4.0	12 (70.6)	15 (71.4)	5 (35.7)	7 38.9)	23 (63.9)	0 (0.0)	62 (52.1)	24.38 (<0.001)
	≥4.0	5 (29.4)	6 (28.6)	9 (64.3)	11(61.1)	13 (36.1)	13 (100)	57 (47.9)	
35.47	<4.0	9 (64.3)	9 (90.0)	13 (33.3)	2 (22.2)	15 (68.2)	0 (0.0)	36 (57.1)	17.64 (0.003)
	≥4.0	5 (35.7)	1 (10.0)	2 (66.7)	7 (77.8)	7 (31.8)	5 100)	27 (42.9)	

		Name of wards							
	MDD	Karare	Laisamis	Logologo	Central	Sagante	Bubisa	Total	$\chi 2$ (Sig)
48-59	<4.0	2 (50.0)	2 (100)	0 (0.0)	3 (100)	4 (50.0)	0 (0.0)	11 (57.9)	6.69 (0.244
	≥4.0	2 (50.0)	0 (0.0)	1 (100)	0 (0.0)	4 (50.0)	1 (100)	8 (42.1)	

4.3.4. Social, economic and demographic factors influencing dietary diversity among children in the study areas

The study examined the social and demographic factors that affect dietary diversity among children across different wards. The predictor variables included in the backward linear regression model were as follows: distance to the nearest trading center (market), general livelihood zones (Pastoral lowlands versus Agro-pastoral highlands), marital status of the household head, level of education of the household head, primary occupation of the household head, marital status of the caregiver, level of education of the caregiver, estimated average monthly income of the caregiver, the number of children under five years in the household, and the age of the index child in months. Additionally, factors such as household ownership of livestock, caregiver marital status, and gender of the household head, caregiver occupation, and the sex of the index child were also considered.

Table 4.4 provides a summary of the significant social, economic, and demographic factors that influence Dietary Diversity Scores (DDS) among households in Marsabit. In Karare, a significant linear regression equation was established ($F(6, 45) = 6.289$; $p < 0.001$), with an R^2 value of 0.456, indicating that 45.6% of the variance in the model is explained by the identified factors. The specific explanatory variables affecting DDS in Karare included the distance to the nearest trading center ($p = 0.034$), gender of the household head ($p = 0.017$), marital status of the household head ($p = 0.029$), highest level of education attained by the household head ($p = 0.023$), whether the household owned livestock ($p = 0.037$), and the caregiver's average monthly income ($p = 0.004$).

In Laisamis, the predicted model equation for DDS was ($F(5, 64) = 7.171$; $p<0.001$) and R^2 of 0.306 indication that the model could account 30.6% total variance in the predicted equation. Age of index child ($p = 0.042$), caregiver average monthly income ($p=0.02$), distance to nearest trading centre in ($p < 0.001$) were the main predictors of DDS. Similarly, social and demographic factors associated with DDS in Logologo showed significant relationship ($F3, 39) = 6.745$; $p=0.001$) with R^2 of 0.342 explaining 34.2% of total variance. Main predictor of DDS in Logologo ward were highest level of education completed by household head ($p< 0.001$) and main occupation ($p = 0.029$). The regression equation in Marsabit central was ($F(4, 57) = 3.616$; $p = 0.011$) with R^2 of 0.25 explaining 25% of the variance in DDS among children. Household head marital status ($p= 0.003$), gender ($p=$

0.016), main occupation of household head (p= 0.034) and distance to nearest trading centre in (*p*= 0.054) were the main explanatory variables in the regression model in Marsabit central ward. A significant overall regression model equation was also observed in Sagante/Jaldesa ward thus (F (5,112) = 6.430; p< 0.001, with R^2 accounting for 27.5% of variance in the model. In this ward, caregiver primary occupation (*p*= 0.004) and sex of index child (*p*= 0.042) were the main significant predictors of DDS among children. Lastly, in Bubisa ward, DDS was mainly predicted by household head highest level of education completed (p = 0.013) and distance to nearest trading centre in (p = 0.048) giving a regression model equation of (F (2, 46) = 4.686; p = 0.014) with R^2 of 0.169 indicating the model accounted for 16.9% of variance in the predicted model.

Table 4.4: Backward linear regression of household head, caregiver and child factors influencing DDS

Independent variables	Karare (n = 53)		Laisamis (n = 69)		Logologo (n = 43)		Central (n = 62)		Sagante (n = 118)		Bubisa (n = 49)	
	β (S.E)	95% C.I	β (S.E)	95% C.I	β (S.E)	95% C.I	β (S.E)	95% C.I	β (S.E)	95% C.I	β (S.E)	95% C.I
Constant	1.86 (0.85)	0.15, 3.58	5.59 (1.03)	3.53, 7.65	1.16 (0.83)	0.17, -0.52	2.20 (1.04)	0.11, 4.29	3.9 (0.70)	2.51, 5.29	6.40 (0.65)	5.09, 7.71
Distance to market	-0.04 (0.02)*	-0.07, 0.00	-0.38 (0.09)***	-0.55, 0.21			-0.25 (0.13)*	-0.51, 0.0			-0.05 (0.02)*	-0.09, -0.011
HHH gender	1.95 (0.78)*	37, 3.52	-1.24 (0.69)	-2.61, 0.13			2.04 (0.82)*	0.40, 3.69				
HHH marital status	-0.80 (0.36)*	-1-1.52, -0.08					-1.34 (0.44)**	-2.22, -0.46	-0.359 (0.188)	-0.731, 0.014		
HHH education	0.61 (0.24)*	0.12, 1.10			1.72 (0.39)***	0.93, 2.52			0.29 (0.17)	-05, 0.63	0.29 (0.14)*	0.01, 0.57
HHH occupation					-0.33 (0.15)*	-0.63, -0.04	028 (0.13)*	0.02, 0.53	0.111 (0.06)	-0.23, 0.01		
Keep Livestock?	-0.85 (0.39)*	-1.64, -0.05										
Caregiver occupation									-0.171 (0.06)	-0.287, -0.055**		

Independent variables	Karare (n = 53)		Laisamis (n = 69)		Logologo (n = 43)		Central (n = 62)		Sagante (n = 118)		Bubisa (n = 49)	
	β (S.E)	95% C.I	β (S.E)	95% C.I	β (S.E)	95% C.I	β (S.E)	95% C.I	β (S.E)	95% C.I	β (S.E)	95% C.I
Caregiver income	0.0 (0.0)**	0.0, 0.0	0.0 (0.0)*	0.0, 0.0								
Children <5 yrs.					0.648 (0.369)	-098, 1.394						
Age in Months			-0.03 (0.02)*	0.07, 0.00								
Sex of child									0.55 (0.268)	0.20, 1.081*		
R^2	0.456		0.306		0.342		0.25		0.275		0.169	
S.E	1.16		1.57		1.31		1.86		1.39		0.783	
Durbin-Watson	1.71		1.29		1.52		1.51		1.692		1.977	
F test	6		7.17		6.75		3.62		6.43		4.686	
P-value	<0.001		<0.001		0.001		0.011		<0.001		0.014	

*P < 0.05); **p < 0.01; ***p <0.001: HHH- Household head; S.E means Standard Error; C.I means Confidence Interval

4.3.4 Association between food groups and nutritional status (Stunting, underweight and wasting)

Table 4.5 presents the findings from both univariate and multivariate regression analyses examining the association between food groups consumed by children and their nutritional status. The study revealed that the consumption of legumes and pulses was linked to significantly lower odds of childhood stunting (OR = 0.63, 95% CI: 0.41 - 0.97; p = 0.038). Additionally, the intake of eggs was found to significantly decrease the risk of stunting among children (OR = 0.50, 95% CI: 0.30 - 0.85; p = 0.010). Conversely, the consumption of grains, tubers, and roots—such as porridge, bread, rice, pasta, white potatoes, arrowroot, cassava, or other root-based foods—was associated with increased odds of stunting; however, this effect was not statistically significant (OR = 1.19, 95% CI: 0.26 - 4.86; p = 0.804).

The results also indicate that consumption of dairy products by children had significantly lower odds underweight [OR= 0.58, 95% C.I: 0.34 - 0.98, p = 0.042]. However, when adjusted for distance of households to nearest market, household size excluding household head, gender of household head, marital status household head, education level of household head, main economic activity of household head, age of index child, caregiver education level, primary occupation of caregiver, caregiver estimated average monthly income, there was increased odds of a child becoming underweight [AOR=0.2.09, 95% C.I: 1.16 - 3.79, *p* = 0.015]. Overall, there was no association between food groups consumed by children and wasting (thinness) among children (table 4.5).

4.3.5. Association between dietary diversity and (Stunting (HAZ < -2 SD) and Underweight (WAZ < -2 SD)

Table 4.6 gives summary of univariate and multivariate binary logistic regression of DDS against stunting and underweight. In general, no significant associations were found between the consumption of food groups and nutritional status (stunting and underweight), even after adjusting for various factors such as the distance of households to the nearest market, household size (excluding the head), gender of the household head, marital status of the household head, education level of the household head, primary economic activity of the household head, age and sex of the index child, education level of the caregiver, primary occupation of the caregiver, and the caregiver's estimated average monthly income.

Table 4.5 Binary logistic regression analysis of association between food groups and children nutritional status

	Stunting (HAZ <-2 SD)				Underweight (WAZ <-2SD)			
Food Group	OR (95% C.I)	Sig	[a]AOR (95% C.I)	Sig	OR (95% C.I)	Sig.	AOR (95% C.I)	P value
Grains, tubers roots	1.19 (0.26, 4.86)	0.804	1.69 (0.33, 8.58	0.529	1.3 (0.27, 6.39)	0.743	1.27 (0.25, 6.55)	0.775
Legumes and nuts	0.63 (0.41, 0.97)*	0.038	0.77 (0.46, 1.29)	0.314	1.07 (0.66, 1.71)	0.789	0.74 (0.43, 1.28)	0.284
Flesh foods	1.31 (0.82, 2.08)	0.256	1.37 (0.78, 2.40	0.289	0.58 (0.34, 0.98)*	0.042	2.09 (1.16, 3.79)*	0.015
Eggs	0.94 (0.60, 1.45)	0.771	0.81 (0.47, 0.41)	0.109	1.04 (0.64, 1.67)	0.882	1.16 (0.67, 2.01)	0.595
Vitamin A fruits and vegetables	0.5 (0.30, 0.85)*	0.01	1.86 (0.98, 3.52)	0.059	1.07 (0.60, 1.91)	0.81	0.78 (0.40, 1.50)	0.453
Dairy products	0.72 (0.47, 1.11)	0.142	0.70 (0.41,1.18)	0.179	0.93 (0.58,1.48)	0.745	0.98 (0.58, 1.66)	0.9
Other fruits & Vegetables	0.97 (0.64, 1.49)	0.902	0.84 (0.51, 1.40)	0.496	0.77 (0.48, 1.23)	0.273	1.22 (0.73, 2.04)	0.452

Table 4.6 Binary Logistic regression analysis between DDS and children nutritional status

	Stunting (HAZ <-2 SD)				Underweight (WAZ <-2SD)			
	Univariate		Multivariate		Univariate		Multivariate	
DDS	OR (95% C.I.)	Sig.	*AOR (95% C.I)	Sig.	OR (95% C.I.)	Sig.	*AOR (95% C.I.)	Sig.
0	Ref	.003	Ref	.017	Ref	.849	Ref	.713
1	0.42 (0.10, 1.79)	.240	0.34 (0.07, 1.79)	.203	2.25 (0.39, 13.00)	.364	2.99 (0.47, 19.12)	.248
2	2.08 (0.52, 8.41)	.302	2.20 (0.45, 10.74)	.329	2.06 (0.38, 11.18)	.401	3.33 (0.54, 20.35)	.194
3	0.33 (0.09, 1.23)	.097	0.42 (0.10, 1.83)	.246	1.13 (0.21, 5.90)	.889	1.90 (0.33, 10.86)	.471
4	0.32 (0.09, 1.15)	.081	0.38 (0.09, 1.55)	.176	1.73 (0.35, 8.60)	.506	2.81 (0.52, 15.07)	.229
5	0.53 (0.15, 1.90)	.331	0.75 (1.18, 3.16)	.692	2.04 (0.41, 10.16)	.385	3.86 (0.71, 21.12)	.119
6	0.46 (0.13, 1.68)	.238	0.53 (0.12, 2.24)	.386	1.70 (0.33, 8.68)	.524	2.82 (0.51, 15.47)	.234
7	0.46 (0.12, 1.78)	.261	0.57 (0.12, 2.64)	.471	1.60 (0.30, 8.56)	.585	2.76 (0.47, 16.37)	.264
HAZ[1]	-0.23 (-0.60, 0.048)	.816	1.27 (`-0.081, 0.018)	.206				
WAZ[1]					-061 (`-0.04, 0.04)	.951	-0.86 (`-0.61, 0.02)	.392

[1] Estimated with linear regression model for continuous variables; HAZ- Height-for- Age (<2 SD); WAZ- Weight-for- Age ((<2 SD). [a]Adjusted for Distance to nearest market, Household size excluding household head, Gender of household head, Marital status household head.

4.4. Discussion

This study assessed the various food groups consumed by children in Marsabit County, 24 hours preceding the interview time. Dietary diversity scores were determined based on FAO scoring technique of food groups consumed over a 24-hour recall (FAO, 2018). Based on the findings of this study, overall, 97.6% of children consumed foods from cereals, roots and tubers (group 1). The main food consumed within this food group were maize, wheat, tiff which was consumed in the form of porridge, *ugali* (stiff porridge) and *githeri* (mixture of boiled maize and beans) for older children porridge for children below two years. Consumption of beans and pulses and nuts (62%) and Milk and milk products intake levels (61%) among children. The reported consumption of cereals, roots, and tubers in this study was higher than that found in previous research conducted in Lebanon, which showed a consumption rate of 91.1% (Khalil *et al*., 2020), and in Tanzania, where it was 90.1% (Milanzi *et al.*, 2023). However, this study's consumption levels were lower than those observed in eastern Morogoro, Tanzania (Minja *et al.*, 2021). These findings reinforce the notion that, similar to other developing countries in sub-Saharan Africa, foods derived from cereals, roots, and tubers serve as the staple diet among settled pastoral households, extending beyond just complementary food recipes for children.

The results showing above average intake of beans and milk indicates how the effect of settlement on dietary changes from pure milk and meat among pastoralists to cereal and pulses supplemented with milk. The consumption patterns of both milk and legumes indicate a gradual shift from animal-based staples to purchased legumes and pulses. However, dairy products remain the preferred food choice for children. Comparatively, the findings of Yesuf *et al.* (2021) in Addis Zemen town in Amhara region, Ethiopia reported higher consumption of beans and nuts (84.5%) but lower consumption of dairy products (53%) among children. This study was conducted at the tail end of the drought season hence a majority of pastoral households in the lowlands (Laisamis, Logologo, Bubisa) had limited access to the lactating animals. Most of the livestock including lactating ones had been driven to far areas in search of water and pasture. A fact that may be attributed to low consumption of dairy products intake among pastoral children. However, children in wards in urban and peri urban centres, were fed Ultra Heat Treated (UHT) milk purchased from shops. The dietary changes observed here may be attributed to pastoralists' resilience in coping with food insecurity

occasioned by of asset shock (livestock) due to successive long and frequent droughts (Fratkin *et al.,* 2004; Kirui *et al.,* 2022).

The consumption of eggs by children in the study area was notable low and was observed to be lower among settled children in pastoral wards in Bubisa (6.1%), Logologo (14%) and Laisamis (17.2%) and wards in transition zones (agro-pastoral) such as Karare (5.8%), Bubisa (6.1%), Logologo (14%) and Laisamis (17.2%) and Sagante/Jaldesa (mixed farming communities) compared to Marsabit central (urban centre). The percentage of children consuming eggs in this research was significantly lower than that observed in a study from Burkina Faso (See *et al*., 2018). This limited consumption can be linked to socio-cultural influences that inhibit egg consumption, especially within the traditional Rendille and Gabra communities.

In this study, the average Dietary Diversity Score (DDS) among children was recorded at 3.43 ± 0.89, which falls below the World Health Organization (WHO) and Food and Agriculture Organization (FAO) recommended threshold of ≥4 DDS (FAO, 2018; WHO, 2021). Notably, children in Bubisa ward exhibited a significantly higher mean DDS of 5.20 ± 0.12, followed by Logologo with 3.86 ± 0.24, Marsabit Central at 3.26 ± 0.26, Sagante/Jaldesa with 3.24 ± 0.14, Laisamis at 2.86 ± 0.22, and Karare at 2.79 ± 0.21. The results of this study were more favorable than the average Individual Dietary Diversity Score (IDDS) reported in earlier research from Ethiopia, where the mean DDS was 1.6 (Headey *et al*., 2019), and also among children aged 6-23 months in Busia, an agricultural region in Kenya, who had an average DDS of 2.0 ± 0.52. However, the findings were comparable to those of Adepoju *et al.* (2019) concerning preschoolers in Ibadan, Nigeria.

The age and gender of the index child significantly influenced dietary diversity in this study. These findings align with those from a demographic and health survey conducted in Cambodia, which identified a correlation between the age of children (specifically those aged 12-23 months) and their Dietary Diversity Score (DDS) (Harvey *et al.,* 2018). Conversely, that same study reported no significant relationship between the child's sex and DDS.

Furthermore, minimum dietary diversity (MDD) in this study was considered low—DDS (1-3) accounting for 51.5% of the children who did not meet the MMD of <4 DDS. Moreover, the proportion of children who fell below MDD in this study was lower than that reported in the study conducted in Ethiopian children where87.5% of the children did not me MDD

(Sisay *et al.*, 2022), but higher than the findings of Wang *et al.* (2017) among children in western China (44.5%). Minimum Dietary diversity has been used to evaluate the probability of varied diets. It has also been associated by probability of micronutrient adequacy in the diet (FAO, 2018).
Moreover, the Minimum Dietary Diversity Score (MDDS) serves as a useful indicator of household food access. It has been suggested that a 1% increase in the Dietary Diversity Score (DDS) corresponds to a 0.7% rise in per capita caloric availability for children (FAO, 2018).

The study found a number of social and demographic characteristics that had an influence on the dietary diversity of children in the study area. Distance to nearest market centre in kilometres (Km) had a significant negative effect on dietary diversity in all wards except in Logologo and Sagante/Jaldesa. The result compares well with finding from studies conducted among rural Indonesia (Mehraban & Ickowitz, 2021) and in Kenyan small holder agricultural households (Muthini *et al.*, 2020). Furthermore, time taken to walk to the market (a proxy indicator of distance) was associated with household DDS in rural Ethiopia (Kabeta *et al.*, 2023). Given the over reliance on food stuff not native to the areas, time and distance taken to access may have influenced what a family prepared easily for the child. Long distance travelled to the market therefore could confer negative effects on the choice and selection of diverse and safe foods consumed by a majority of children. For example, Karare has its main food market in Marsabit town, about 25 Km away. In other affected wards, some semi-settled households are located off the main road hence could have experienced challenges in accessing the main food market on a regular basis given the remoteness of the villages.

Furthermore, gender of household head showed a significant and positive influence on dietary diversity score (DDS) in Karare but was negatively associated with DDS Marsabit central, an observation reported in Ethiopia where female gender had a negative but significant association with dietary diversity (Kabeta *et al.*, 2023). In this research, most households were led by males. Additionally, the education level of the household head showed a positive correlation with the Dietary Diversity Score (DDS) in Karare, Logologo, and Bubisa. These findings align with those of Kundu *et al.* (2022), which indicated that household heads with a college education were positively associated with individual dietary diversity among children aged 6-59 months in both rural and slum regions of Bangladesh.

The occupation of the household head was positively linked to the Dietary Diversity Score (DDS) in Marsabit Central; however, it exhibited a negative association with DDS in Logologo. A majority household heads within Marsabit central were civil servants, wage earners or persons engaged in small and medium enterprises while those from Logologo were primarily livestock keepers. These findings were consistent with those of Kundu *et al.* (2022). This study demonstrates a negative but statistically significant association between livestock ownership and the Dietary Diversity Score (DDS) of children in the Karare and Sagante/Jaldesa regions. The two sites comprise of agro-pastoralists hence keep less animals compared to lowland wards. A study conducted among children in Luangwa valley, Zambia looked at relationship between keeping varied number of livestock and child DDS found insignificant association (Dumas *et al.*, 2016). Additionally, within the Maasai community in Kenya, the pastoral herding system restricts women and children from accessing dairy products. This limitation contributes to a negative correlation between livestock ownership in pastoral communities and the nutritional health of these groups (Chege *et al.*, 2015).

Caregiver level of income and occupation were significantly associated with child dietary diversity. Research conducted by Ali *et al.* (2019) identified a significant association between dietary diversity and caregivers employed in skilled professions, in comparison to those whose primary occupation was homemaking. In this study, a majority of caregivers were housewives with high level of illiteracy. Although no association was found between caregiver education and DDS, other studies reported a positive association and significant association between care education and child DDS (Bimpong *et al.*, 2021; Kakwangire *et al.*, 2021). Moreover, low high illiteracy levels among caregivers can be a barrier to adoption of optimal dietary practices (Chege *et al.*, 2015).

The age and sex of index child had a significant effect on dietary diversity. The results of this study compares well with the results of demographic and health survey which found association between age of children (12-23 months) and DDS in Cambodia (Harvey *et al.*, 2018). However same study found insignificant relationship between sex of child and DDS.

This study also attempted to highlight any significant association between the seven food groups fed to the child. The results from the study showed that children who were fed on legumes and nuts and seeds food group and eggs had significant lower odds of being stunted, findings also reported among children in Tanzania (Khamis *et al.*, 2019). A study in East

Java, Indonesia, found that children who consumed fish (p = 0.03) and meat or poultry (p = 0.04) were statistically less likely to experience stunting (Mahmudiono *et al.*, 2017).

Furthermore, significant association was found between consumption of dairy, vegetables and fruits and height-for-weight ―HAZ) among children aged 6-59 months in Ethiopia (Melaku *et al.*, 2018). The current study also recorded significant reducing effect of feeding children flesh foods such as meats (food group 3) on underweight. The current study findings did not find any statistically significant relationship between child DDS and nutritional status. This may be attributed bias in recall of foods fed to children occasionally associated with anticipation of impending food aid. Results in this study compares well with that reported in North West province, South Africa (Modjadji *et al.*, 2020). However, other studies have registered significant association between DDS and stunting in north- east Ethiopia (Chekol *et al.*, 2022) and in Uganda (Madzorera., 2021), underweight (Madzorera, 2021). A study by Khamis*et al.* (2019) indicated a decrease in the likelihood of suffering from stunting, wasting and underweight with increase in number of food groups consumed implying that a more diverse diet confers better nutritional status among under five months old children. The study finding further underscores the role of household characteristics in achieving access to adequate dietary intakes.

4.5. **Conclusion and Recommendations**

4.5.1. Conclusion

In the current study, the mean dietary diversity score among children, particularly those aged 6–23 months, was generally low with significant disparities across the wards. Moreover, over half of the children did not meet the WHO recommended (MDD), which requires consuming foods from more than 4 out of the 7 food groups. Cereals, tubers and roots-based diets were the main staple complementary food of settled pastoralist children. Social and demographic predictors of DDS among children included distance to food markets, marital status education level, occupation and household gender. Caregiver occupation and average monthly income were the main predictors of dietary diversity score. The consumption of legumes, particularly beans and pulses, as well as eggs, was found to reduce the risk of stunting. Additionally, children who consumed more flesh foods, such as meat, were less likely to be underweight.

4.5.2 Recommendations

The low dietary diversity scores highlight the need for a multi-sectoral approach to improve the variety of foods consumed by children in settled pastoral communities. The Ministry of Health (MOH) should enhance nutrition education efforts to raise awareness about the importance of diversifying feeding practices. On the other hand, the ministry of Agriculture and livestock development should develop agricultural technologies, innovations and knowledge management packages that aim to sustain irrigated farming in arable pockets of arid and semi-arid lands (ASALs) inhabited by agro-pastoralists.

CHAPTER FIVE

OCCURRENCE OF AFLATOXIN AND FUMONISIN IN COMPLEMENTARY FOODS CONSUMED BY CHILDREN AGED 6-59 MONTHS IN TRANSITIONAL PASTORAL HOUSEHOLDS IN MARSABIT COUNTY

Abstract

The diet of children in settled pastoralist communities is undergoing a shift from traditional, animal-based foods to a more varied diet focused on cereals, tubers, and root vegetables, with occasional supplementation from locally sourced milk. These foods, however, have a higher risk of contamination by mycotoxin-producing fungi, which pose significant health risks to children. This study aimed to determine the presence of fumonisin and aflatoxin in the complementary foods consumed by children aged 6-59 months. A cross-sectional study design with multistage sampling selected 137 food samples (84 solid/semi-solid foods and 53 milk samples) from households with children in this age range. Initially, clusters were defined based on geographical or administrative divisions. From each cluster, households with eligible children were randomly chosen, and within each selected household, a variety of food samples were collected to ensure a representative sample. Total fumonisin and aflatoxin levels were quantified using immuno-affinity columns (AccuScan Gold®), and specific aflatoxins (B1, G1, B2, G2, M1, and M2) in both food and milk samples were analysed using High-Performance Liquid Chromatography with fluorescence detection. Descriptive statistics for fumonisin and aflatoxin levels were summarized using median, minimum, and maximum values. The Kruskal-Wallis test was applied to investigate differences in median levels of these toxins, while linear regression assessed the impact of demographic factors on aflatoxin presence. Additionally, binary logistic regression was employed to examine links between fumonisin, aflatoxins, and child nutritional status. Findings revealed a median fumonisin concentration of 300 μg/Kg, surpassing the EU safety limit of 200 μg/Kg body weight. The median total aflatoxin concentration was 0.3 μg/Kg, exceeding the EU infant food limit of 0.1 μg/Kg. The highest median values for AFB1 (7.7 μg/Kg), AFM1 (0.31 μg/Kg), and AFM2 (0.67 μg/Kg) also exceeded EU infant standards of 0.005 μg/Kg. The study concludes that the high levels of mycotoxins (fumonisin and aflatoxins) found in complementary foods are associated with the shift towards cereal-based diets in settled households. These findings underscore the importance of improving food handling and monitoring practices to reduce the health risks posed by mycotoxins in the diets of young children.

5.1. Introduction

In the global context, mycotoxins, with over 300 identified types out of over 400 fungal metabolites, pose a significant concern (Ojuri *et al.*, 2019). These secondary metabolites, produced by specific fungi, pervade crops from pre-harvest to post-harvest stages and persist through food processing to consumption. Notable among them are aflatoxins (AFs), fumonisin (FBs), ochratoxins A (OTA), trichothecenes (such as deoxynivalenol (DON) and nivalenol (NIV)), and Zearalenone (ZEN), often co-contaminating various agricultural crops and animal feeds (IARC, 1993; 2015).

Mycotoxins, harmful substances produced by certain fungi, pose significant risks to food safety, particularly aflatoxins and fumonisins, which are commonly found in staple foods such as maize and sorghum. These mycotoxins are associated with both acute and chronic health effects, including mortality and stunting in children (Knipstein *et al.*, 2015; Obonyo & Salano, 2018; Probst *et al.*, 2007). In Marsabit County, which is characterized by arid and semi-arid conditions, the contamination of locally sourced food, particularly cereals and animal feeds, raises concerns for the nutritional status of young children. Limited research has focused on the prevalence of these mycotoxins in foods and feeds commonly used in the region, despite evidence linking dietary exposure to undernutrition, morbidity, and mortality among vulnerable populations (Paudyal *et al.*, 2017).

Sorghum and maize are vital staple crops for many households in Marsabit County, where food insecurity is prevalent due to unreliable rainfall and harsh environmental conditions (Orr *et al.*, 2016). Recent reports indicate that high rates of undernutrition persist among children under five years, with alarming statistics revealing underweight, stunting, and wasting in this age group (Kipyego & Mugalavai, 2019). Although initiatives by the Kenyan government and development partners have aimed to improve food security and nutritional outcomes through agricultural interventions, these efforts have yet to significantly reduce undernutrition rates in the county.

The co-occurrence of aflatoxins and fumonisins in sorghum and maize-based foods and animal feeds is particularly concerning, as it may contribute to stunting and other health complications through additive effects on child health, possibly resulting in liver and intestinal injury or impaired immune function (Knipstein *et al.*, 2015; Leroy *et al.*, 2015; WHO, 2018). This study aims to investigate the knowledge and practices related to aflatoxin and fumonisin contamination among caregivers in Marsabit County, focusing on postharvest

handling and storage practices that may contribute to the persistence of these harmful mycotoxins in food and feed. By addressing these factors, the study seeks to provide insights into the underlying causes of persistent undernutrition in the region.

Aflatoxins, derivatives of difurocoumarin, primarily stem from molds like *Aspergillus flavus*, *A. parasiticus*, and *A. nominus* (Chen *et al.*, 2018; Monson *et al.*, 2015; Payne & Brown, 1998). They manifest in four main groups: AFB_1, AFB_2, AFG_1, and AFG_2, commonly found in cereals and nuts. AFB_1 and AFB_2 metabolize into AFM_1 and AFM_2, predominantly present in animal-derived foods like milk (Goldblatt, 2012; IARC, 2015). Fumonisin, primarily produced by pathogenic fungi, including *Fusarium verticillioides*, *Fusarium proliferatum*, and similar species. Fumonisin B1 (FB1) typically constitutes the majority of fumonisin contamination, accounting for approximately 70% of the total, often accompanied by lesser quantities of fumonisin B_2 (FB_2) and B3 (FB_3) (Damiani *et al.*, 2019; Rheeder *et al.*, 2002). Aflatoxins and fumonisin thrive in diverse crops, including staple cereals and nuts, and their contamination spans different stages, from field to post-processing. Optimal conditions for *Aspergillus* spp. and *Fusarium* spp. proliferation include temperatures around 33.8 ºC and water activity (aw) of about 0.82, exacerbated by factors like drought, humidity, insect presence, and inadequate storage practices ((Pitt & Hocking, 2009).

Pastoralists have embraced the practice of supplementing home-retained lactating animal feeds with commercially available concentrates, primarily cereal-based, obtained from agro-vet shops in urban centers. These concentrates often include locally dried pasture range cubes, dairy meal, and grass hay (Lengarite *et al.*, 2014). However, these feeds have been linked to the prevalence of mycotoxins in animal feeds and products, particularly in milk. The risk of occurrence is associated with various factors such as the type and condition of the feed, as well as storage methods (Makau *et al.*, 2016). Despite this transition, pastoralists have yet to fully adopt optimal technologies for handling these commercial feeds, thereby increasing the risk of mold development. This situation raises concerns about the dietary exposure of pregnant mothers and children who rely on milk from supplemented animals, potentially contributing to undernutrition among children (Gong *et al.*, 2016).

Dietary intake of contaminated cereals, water and animal-derived products serves as the primary route of aflatoxin and fumonisin exposure, particularly affecting children under five through ingestion of complementary foods (IARC, 2015; Wangia-Dixon *et al.*, 2022). Additionally, intoxication of aflatoxin —AFM_1 and AFM_2, can occur in children through

breast milk from mothers consuming contaminated foods and from animal-derived foods due to contaminated feed materials (Gong *et al.*, 2016).

The most common route of entry of AFs into human body is through ingestion of contaminated food (Lesuuda *et al.*, 2021; Paudyal *et al.*, 2017). Once in the liver the AFB1 is metabolized into other intermediate reactive, AFB1–8, 9-epoxide (AFBO) ―which has two isomers (*endo*-8, 9-epoxide and *exo*-8, 9-epoxide). If not detoxified, the exo-AFB1 8, 9-epoxide can interact with double-stranded DNA, leading to the formation of the promutagenic AFB1-N7-guanine adduct. Additionally, upon hydrolysis to AFB1-dihydrodiol, it can bind with proteins such as albumin (Rasheed *et al.*, 2021). This may interfere with DNA differentiation and intestinal integrity resulting into growth retardation in children under five years (Aroyo-Manzanares *et al.*, 2021; Rushing *et al.*, 2019).

Fumonisin toxicity in children under five primarily occurs through the inhibition of ceramide synthases, essential enzymes in sphingolipid biosynthesis and turnover (Chen, 2018). This inhibition disrupts ceramide production, reducing levels of complex sphingolipids and causing an accumulation of free sphingoid bases and sphingoid base 1-phosphates. Consequently, lipid substrates may be redirected into other pathways and products, affecting cell integrity and potentially leading to apoptosis (Chen *et al.*, 2018), thereby leading to a condition medically known as aflatoxicosis (Khlangwiset *et al.*, 2011). This disruption can clinically manifest as jaundice, bile duct proliferation, edema, and, in severe cases, acute liver failure and death. Additionally, fumonisin exposure in young children can impair growth (WHO, 2018).

Children remain vulnerable to chemical toxins exposure compared to rest of population owing to their underdeveloped immune system, lower body weight, and less acidic stomachs among other factors (Magoha*et al.*, 2014). Fumonisin exposure increases the risk of NTDs in unborn babies and a dose above the threshold level may cause fetal death (Kamle *et al*., 2019).

Worldwide, estimated 4.5 billion people are susceptible to aflatoxin and fumonisin exposures through dietary sources or in occupational settings such as grain handling and animal feed processing. Previous studies have highlighted the potential impact of aflatoxin on child growth impairment in sub-Saharan Africa and the Middle East, where maize and nuts are primary staples in complementary diets (Chen *et al.*, 2018; Gong *et al.*, 2004; Mapunga *et al.*,

2017; Raheed *et al.*, 2021). Conversely, other studies from Nepal and Tanzania have indicated no significant association between aflatoxin exposure and impaired growth in children (Mahfuz *et al.*, 2021; Mitchell *et al.*, 2017; Shirima *et al.*, 2015). The prevalence of AF in children in Tanzania range from 39-50% (Wangia-Dixon *et al.*, 2022) compared to 17% in Ethiopia (Ayelign *et al.*, 2017) respectively. However, there is limited information on occurrence of AF and FUM and their association with children nutritional status in northern Kenyan pastoralists.

Given the high rates of undernutrition, particularly stunting, in regions like northern Kenya (KNBS & ICF, 2023), understanding child exposure to aflatoxin and fumonisin in complementary foods becomes crucial. This study aims to assess the presence and levels of these toxins within households in transitional pastoral communities, examining their potential link to stunting wasting and underweight among children aged 6-59 months. The findings could inform policies promoting safer food and feed practices, crucial for child health and development.

5.2. Materials and Methods

Population sampling, social and demographic data collection, nutritional status assessment and dietary diversity methods are captured in chapters three and four of this report.

5.2.1 Food sample collection

A representative sample of about 300g-500g were drawn from a food sample (according to the willingness of the households) after thorough mixing of the content in a bag as described by Whitaker *et al.* (2011) and AOAC (1990), procedure No. 965.16. The initial food sample from which it was drawn was not measured but the household member was asked to mix it thoroughly before we the sample was picked according to the preparation method. Then placed in a sterile airtight sampling bag, coded with corresponding respondent identification before being transported for preparation and analysis for presence of molds and yeast at the Kenya Agricultural Livestock Research Organization in Marsabit County (KALRO) Marsabit laboratory.

The cereal grain samples were ground to pass through no. 20 sieve and thoroughly mixed before taking portion to be analyzed. For processed uncooked products such as maize, sorghum and wheat flour, approximately 500g of sample per household separately put into sampling bag with rubber seal or in airtight tins. Ready to Eat (RTE) complementary foods

samples were collected immediately after the food had been prepared. Randomly selected sample of about 250 g per household were aseptically collected into a sterile plastic bag, and transported, as soon as possible, on dry ice to the microbiological laboratory at the KALRO in Marsabit. The samples were then transferred under cold condition to animal science laboratory at Egerton University for analysis of aflatoxin and fumonisin.

Locally produced bovine, goat, camel, sheep and ultra-heat treated (UHT) milk sample per household were collected separately in sterile 50 ml screw cup falcon bottles after thorough mixing and immediately put in cool box with icepacks maintained at 8 - 10°C. The sample were then transported within 6 hours to KALRO Marsabit laboratory before transfer under chilled condition to animal science laboratory, Egerton University for analysis of aflatoxin M_1 and M_2.

Analysis of Aflatoxins and Fumonisin in Complementary Foods Consumed by Children in Marsabit County

A total of 136 food samples were collected from households with children aged 6-59 months in Marsabit County to assess the overall occurrence of aflatoxins and total fumonisin in complementary foods. The food samples included milk (n=53), cereal-based foods (n=68), legume-based recipes (n=11), and tuber-based recipes (n=4). Among the milk samples, 53 were analyzed for aflatoxin M1 (AFM1) and aflatoxin M2 (AFM2) levels.

In addition, 84 solid and semi-solid food samples were analyzed for aflatoxins and fumonisin contamination. Specifically, 43 samples were tested for total fumonisin, while 40 samples were tested for total aflatoxins using the lateral flow method. All 83 solid and semi-solid food samples were further analyzed for specific aflatoxin compounds, including AFB1, AFB2, AFG1, and AFG2, using high-performance liquid chromatography with fluorescence detection (HPLC-FLD).

The collected solid and semi-solid food samples comprised a variety of food types, including cereal-based foods such as maize flour, ugali, porridge, *qita*, githeri, and *fiqe*. Legume-based foods were mainly represented by beans, and tuber-based recipes consisted of Irish potatoes. Mixed recipes included meat and vegetables like cabbage, as well as local dishes.

Lateral flow method and HPLC-FLD were employed to detect and quantify aflatoxins and fumonisin levels in the food samples. The study's findings on median fumonisin and aflatoxin levels are summarized in Tables 5.2 and 5.3. Fumonisin concentrations ranged from 300

µg/kg to 7000 µg/kg, with the highest concentrations found in cereal-based foods, while total aflatoxin levels ranged from 2.0 µg/kg to 92.0 µg/kg, predominantly in cereal-based foods. The regional prevalence of these contaminants was also assessed, with Karare exhibiting the highest fumonisin and aflatoxin levels, followed by other regions in Marsabit County.

5.2.2. Detection of Total Aflatoxin and Total Fumonisin Using Lateral Flow Immunoaffinity Assay

Sample Preparation and Extraction

Lateral flow test for fumonisin (lot no. 294505) and aflatoxin (lot no.8085) was conducted according Reveal®Q+ instructions, also validated in previous studies (Katengesya, 2018; Le *et al.*, 2019; Niyibituronsa *et al.*, 2020). All procedures were done according to the manufacturer's instructions. Briefly, approximately 10 g of ground sample was weighed into a 250 ml round bottomed flask using a top loading pan balance (VIBRA serial No 0721, Shinko Denshi, Japan). Approximately, 50 ml of 65% ethanol was added to the flask, covered and then vortexed for 3 minutes using a laboratory shaker. The extracts were left to settle and were subsequently filtered using Whatman No. 1 filter paper (Cat. No. 1001 110, Whatman International Ltd., Maidstone, UK). For each sample, 100 µl of the filtered extract was transferred to a red cup containing either 500 µl of sample diluent for aflatoxins or 200 µl for fumonisins. The solution was then mixed by pipetting five times. A 100 µl aliquot of the resulting mixture was transferred to a white cup in preparation for quantifying total aflatoxins or fumonisins. Fresh Reveal Q+ strips for aflatoxins or fumonisins were placed into the white cup with the diluted sample and allowed to develop for six minutes. Afterward, the strip was removed and inserted into the black AccuScan III cartridge adapter (AS 5130, Neogen® Corporation, Lansing, MI, USA) for measurement.

The reading for each sample was taken at six minutes. Total aflatoxin and fumonisin levels were quantified according to the instructions and procedures provided by the test kit manufacturer, using Neogen's AccuScan Pro® III reader (Neogen, USA). The detection range for aflatoxins was 2–150 ppb, while for fumonisins it was 0.3–6 ppm. Samples exceeding these detection limits, primarily for aflatoxins, were diluted accordingly: for aflatoxin levels above 150 ppb, a dilution factor of either 1:5 (100 µl sample extract to 400 µl ethanol, v/v) or 1:10 (100 µl sample extract to 900 µl ethanol, v/v) was applied. Readings were recorded both as printed outputs and digitally downloaded into Microsoft Excel for further analysis.

5.2.3. Determination of AFB_1, AFB_2, AFG_1, AFG_2 using High Performance Liquid Chromatography with Florescent Light Detector (HPLC-FLD)

1 Preparation of standards Avoid section numbering beyond level 3

All the standards were received as dry crystals from Sigma Aldrich and preparations conducted according to AOAC official methods of analysis of aflatoxin **no**. **990.33** (AOAC, 2005). Briefly, approximately 2 mg of AFB_1 and AFG_1 were weighed using analytical balance and dissolved into 100 ml of methanol (HPLC grade) to give 20 ppm. Similarly, 1mg of AFB_2 and G_2 were dissolved into 100 ml of methanol. The standards for AFM_1 (code: A-9026, lot no. 73H4027) and AFM_2 (Code: A-9401, lot no. 73H4026) were prepared following the methods of AOAC no. 986.16 (AOAC, 2005). Similarly, procedure was used for AFM_1 and M_2 except for diluent which used acetonitrile: water. From the stock solution, 5ml of each standard was carefully pipetted to make 15 ml combined standard. The solution was evaporated to dryness under a gentle stream of nitrogen, facilitated by water bath warming at 40°C). Using Eppendorf pipette, 200µL hexane and 50µL of trifluoroacetic acid (TFA) was added to each vial, capped and vortex for 30 seconds. The solutions were let to stand for 5 minutes, then 10 mL water: acetonitrile (9+1) added and vortexed for 30 seconds. The layers were let to separate for 5 -10 min or centrifuge at 1000 rpm for 30 seconds. Final concentration curves of individual aflatoxin for all the standards are presented in figures 1to 6.

2 Extraction

Analytical procedures were carried out according to the method reported by FAO (2011). For extraction of solid and semi-solid food samples, approximately 50g finely ground test samples material were each weighed into 500 ml Erlenmeyer flask and mixed to 200ml, 80% HPLC grade methanol: water (80:20 v/v). The solution was blended vigorously for the first 15 to 30 seconds using commercial kitchen blender (Elekta®, EKM-1610, and Japan) and then vortexed for 30 min with a shaker (Thermofisher) before filtration using a pre folded whatman filter paper no. 4. A 5ml of the clear filtrate was pipetted into a 100ml volumetric flask and made up to the mark with Phosphate buffered saline (PBS) or double distilled water as per the manufacturer's instructions. Milk samples were defatted by first warming at 37°C and then centrifuged at 2000×*g*. The fat layer was carefully removed, and the milk was filtered through Whatman paper. A 50 ml aliquot of the filtered sample was transferred to a syringe barrel attached to an Aflatest column, with the sample passing through at a rate of 2–

3 ml per minute. The column was subsequently rinsed with 20 ml of water, which was then discarded. After drying the sorbent bed, AFM1 was eluted from the samples using 4 ml of acetonitrile. This eluent was then evaporated under nitrogen gas, and the remaining residue was reconstituted in 1 ml of the mobile phase.

Detection and Quantification

he determination of specific aflatoxins (AFB1, AFB2, AFG1, and AFG2) was conducted using the Agilent 1200 Series HPLC System (Agilent, Waldbronn, Germany), which included components such as the G1322A degasser, G129A autosampler, G1330B thermostat, CY1311A quaternary pump, G1316A temperature controller, and G1321A fluorescence detector (FLD). Reverse-phase chromatographic separation was performed on a ZORBAX Eclipse® XDB-C18 column (150 mm x 4.6 mm I.D., 5 μm particle size) safeguarded by a C18 security guard cartridge (4.3 mm I.D.), both supplied by Agilent Technologies. The mobile phase used for isocratic elution consisted of water, acetonitrile, and methanol in a 60/20/20 (v/v/v) ratio, with a flow rate of 1.0 μl/min. The column oven temperature was set to 30 °C, and the injection volume was 20 μl for standards and samples. Post-column derivatization was accomplished using a photochemical reactor (LCTech UVE, Dorfen, Germany). The fluorescence detector was set to excitation and emission wavelengths of 360 nm and 455 nm, respectively. The retention times (RT) for AFG2, AFG1, AFB2, and AFB1 were observed at 2.4, 2.9, 3.2, and 3.5 minutes, with corresponding regression equations. Additionally, the RT for AFM2 and AFM1 were noted at 1.5 and 0.3 minutes, respectively.

Data acquisition and processing were conducted using ChemStation® chromatographic software. Aflatoxin levels in the samples were quantified based on a five-point external standard calibration curve (as illustrated in Figures 1 through 6), created with a mixture of aflatoxin standards. Specifically, standards for AFB1 and AFG1 ranged from 0.3 to 1.8 ng/mL, while AFB2 and AFG2 ranged from 0.2 to 1.8 ng/mL, and AFM1 and AFM2 ranged from 0.1 to 0.6 ng/mL. The calibration curves demonstrated strong linear regression, with R^2 values ranging from 0.974 to 0.9989. The strong R^2 in the concentration gradients were considered as having better predictive power, reliant and robust for determination of aflatoxin concentration in the food samples (figures 5.1 to 5.6). Limit of detection (LoD) and limit of quantitation (LoQ) was determined using the formula by FAO (2011). Table 5.1 gives the

limits of detection (LOD) and quantification (LOQ) of the aflatoxin analogues. The limit of detection (LOD) and limit of quantification (LOQ) were determined by progressively injecting more diluted standard solutions, following the guidelines set by the International Union of Pure and Applied Chemistry (IUPAC). This method relied on a signal-to-noise ratio (S/N) of 3.3 for the LOD and 10 for the LOQ (FAO, 2011). Aflatoxin quantification was carried out using the regression equations derived from the calibration curves (Figures 5.1 to 5.6). Given the potential variability in aflatoxin distribution within sample matrices, the standard uncertainty for all aflatoxin analogues was also calculated. The uncertainty of the average was computed using the formula $\mu = s/\sqrt{n}$, where n represents the number of measurements in the set and s denotes the standard deviation of the n ratios.

Table 5.1 Limit of Detection and Quantification for aflatoxin

Compound	LOD (ppm)	LOQ (ppm)
AFB_1	0.2	0.5
AFB_2	0.1	0.2
AFG_1	0.4	1.3
AFG_2	0.4	1.3
AFM_1	0.1	0.3
AFM_2	0.1	0.3

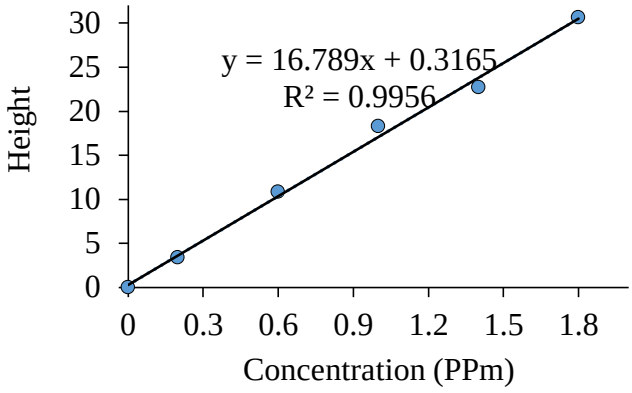

Figure 5.1 *AFB_1 Standard curve*

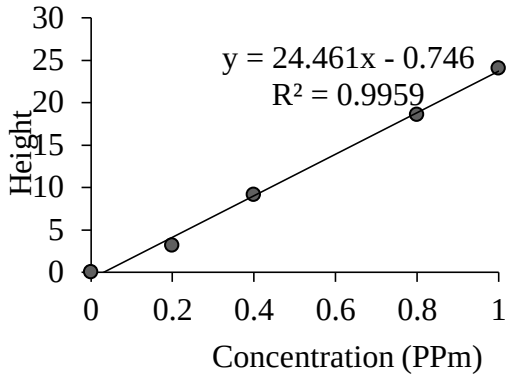

Figure 5.2 *AFB_2 Standard curve*

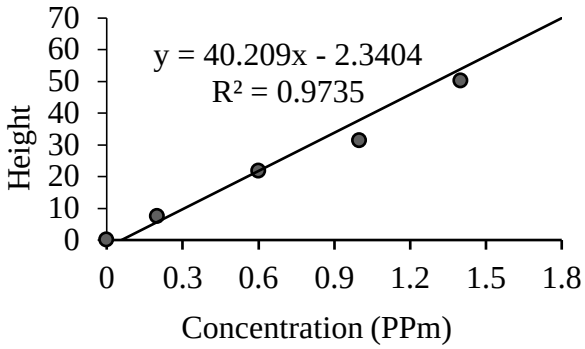

Figure 5.3 *AFG_1 Standard curve*

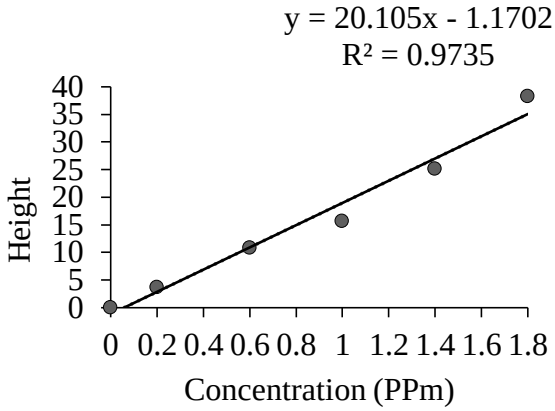

Figure 5.4 *AFG_2 Standard curve*

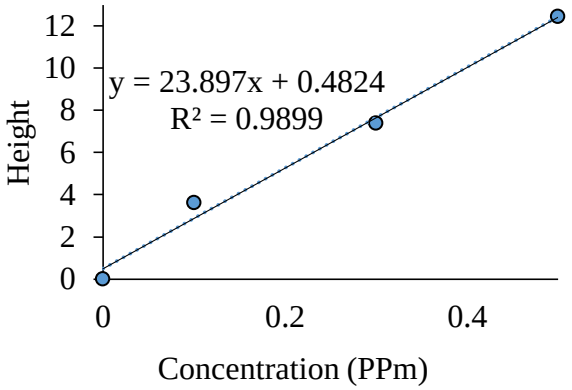

Figure 5.5 *AFM_1 Standard curve*

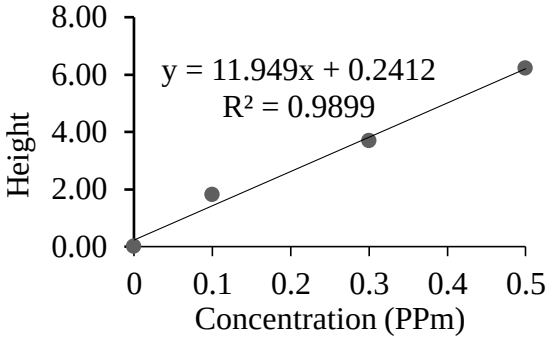

Figure 5.6 *AFM_2 Standard curve*

5.2.4. Data Analysis

Social, economic, demographic, dietary diversity, and nutritional status data were collected using KOBBO collect, then imported into Microsoft Excel 2013 for cleansing. Pre-coded data

were subsequently imported into SPSS version 26 for thorough analysis. For detailed statistical methodologies, chapters three and four provide comprehensive insights. Due to non-normal distributions, total aflatoxin, total fumonisin, AFM_1, and AFM_2 values underwent nonparametric analysis. Descriptive statistics were presented as median, minimum, and maximum values. Analysis of variance employed the Kruskal-Wallis Rank test to assess median total aflatoxin and fumonisin levels across different study sites. The AFB_1, AFG_1, AFB_2, and AFG_2 values were natural log transformed regressed regression against social and demographic. Additionally, binary logistic regression, adjusted for the age and sex of the child, aimed to predict associations between stunting and underweight among children aged 6-59 months. All analyses were conducted at a significance level of 95% confidence interval (C.I.).

5.3. Results

5.3.1 Overall occurrence of aflatoxin and fumonisin in Marsabit County

Table 5.2 presents a summary of the overall occurrence of aflatoxins and total fumonisin in complementary foods consumed by children in Marsabit County. A total of 136 food samples were collected from households with children aged 6-59 months. These samples included milk (n=53), cereal-based foods (n=68), legume-based recipes (n=11), and tuber-based recipes (n=4). Among these, 53 milk samples were tested for AFM_1 and AFM_2, respectively. Additionally, 84 solid and semi-solid food samples were analyzed for aflatoxins and fumonisin, with 43 samples tested for total fumonisin and 40 for total aflatoxin using the lateral flow method. Moreover, all 83 solid and semi-solid food samples underwent analysis for specific aflatoxin compounds (AFB_1, AFG_1, AFB_2, and AFG_2) levels using high-performance liquid chromatography (HPLC-FLD).

In terms of the distribution of solid and semi-solid foods, over 50% of the samples consisted of cereal-based foods, primarily maize flour, *ugali* (stiff porridge), porridge, *qita* (a mix of boiled dehusked maize, rice, and wheat flour), *githeri* (boiled maize mixed with beans), and *fiqe* (a local recipe). Legume-based foods predominantly featured beans, while tubers were mainly represented by Irish potatoes. Other mixed recipes included meat, vegetables such as cabbage, and local dishes (table 5.2). The findings of the present study revealed that the median occurrence of fumonisin was 300 µg/kg, with minimum and maximum levels of 300 µg/kg and 7000 µg/kg, respectively (table 5.2). High concentrations of total fumonisin were

detected in cereal-based recipes, ranging from 300 µg/kg to 7000 µg/kg, followed by legume-based recipes (300 µg/kg to 5000 µg/kg), tuber-based and meat-containing foods (300 µg/kg), respectively (Table 5.2).

In terms of the regional prevalence of total fumonisin, Karare ranked the highest, followed by Bubisa, Laisamis, Logologo, and Marsabit central, respectively (Appendix H). Overall, the median detectable concentration of total aflatoxin was 4 µg/kg, with a minimum detectable total aflatoxin level of 2.0 µg/kg, while the maximum median level was 92.0 µg/kg in cereal based food. Karare exhibited the highest levels of total detectable aflatoxin, reaching a maximum of 92.0 µg/kg, followed by Laisamis, Logologo, Marsabit central, and Bubisa regions, respectively (Appendix H).

Table 5.2 Overall Occurrence of Aflatoxin and Fumonisin (µg/Kg) in commonly consumed complementary foods in Marsabit County

		Food type						
Mycotoxin	Statistics	Milk (n=53)	Legume based (n=11)	Cereal based (n=68)	Tuber based (n=4)	Meat based (n=1)	Other foods (n=1)	Total
Total Fumonisin	Median		300	300	300	300	0.0	300
	Minimum		300	300	300	300	0.0	300
	Maximum		5000	7000	300	300	0.0	7000
Total Aflatoxin (n=38)	Median		3.0	4.0	4.0	3.0	0.0	4.0
	Minimum		3.0	2.0	2.0	3.0	0.0	2.0
	Maximum		3.0	78	92	3.0	0.0	92.0
AFB_1 (n=84)	Median		.42	.53	.70	.42	.28	0.5
	Minimum		.25	.08	.23	.42	.11	0.1
	Maximum		1.22	3.70	.97	.42	.46	3.7
AFB_2 (n=84)	Median		.36	.43	.54	.36	.27	0.4
	Minimum		.24	.14	.23	.36	.16	0.14
	Maximum		.88	2.49	.72	.36	.38	2.49
AFG_1 (n=84)	Median		.28	.33	.40	.28	.23	0.31
	Minimum		.21	.15	.21	.28	.16	0.15

Mycotoxin	Statistics	Food type						
		Milk (n=53)	Legume based (n=11)	Cereal based (n=68)	Tuber based (n=4)	Meat based (n=1)	Other foods (n=1)	Total
	Maximum		.60	1.59	.50	.28	.30	1.6
AFG_2	Median		.46	.55	.69	.46	.36	0.51
(n=84)	Minimum		.33	.19	.31	.46	.22	0.15
	Maximum		1.10	3.08	.91	.46	.50	1.6
AFM_1	Median	.31						.31
(n=84)	Minimum	.10						.10
	Maximum	25.5						25.5
AFM_2	Median	.67						.67
(n=84)	Minimum	.20						.20
	Maximum	51.1						51.1

Trend: Fumonisin was common in cereal foods while AFB1 was mainly prevalent in cereal based foods followed by legume-based food. Concentration of AFM2 was high compared to AFM1 in locally produced milk in northern Kenya

In terms of occurrence of total aflatoxin in complementary foods, a high median concentration of total aflatoxin was observed in tuber-based foods (92.0 µg/kg) and cereal-based complementary foods (4.0 µg/kg), with maximum levels reaching 19 µg/kg. Cereal-based foods such as *Ugali*, porridge and rice were the main sources of detectable levels of total aflatoxin in Logologo (4 µg/kg), Bubisa (2 µg/kg) Marsabit central, which had aflatoxin occurrence in cereals (2 µg/kg, and Laisamis at 4 µg/kg.

Table 5.2 provides an overall summary of the specific concentrations of aflatoxins in various foods. The median concentrations of AFB_1, AFB_2, AFG_1, AFG_2, AFM_1, and AFM_2 were 0.5, 0.4, 0.31, 0.51, 0.31, and 0.67 µg/kg respectively. The maximum concentration of AFB_1 was observed in cereals in Logologo (3.7 µg/kg), followed by Central (1.62 µg/kg), Bubisa (1.61 µg/kg), Karare (1.1 µg/kg) and Laisamis regions at 0.9 µg/kg respectively (Table 5.3.3). The elevated concentration of AFB_1 was also observed in tuber-based foods, reaching a maximum concentration of 0.72 µg/kg in the Sagante/Jaldesa region, followed by Logologo (0.67 µg/kg) and Marsabit Central regions, respectively. Mixed foods which comprised rice, potatoes, and occasionally mixed with beans or meat. In this category, a high concentration of AFB1 was observed in Marsabit Central region at a median concentration of 0.66 µg/kg, followed by Sagante/Jaldesa (0.56 µg/kg), Laisamis (0.47 µg/kg), Bubisa (0.36 µg/kg), and Logologo (0.29 µg/kg) respectively (Table 5.3.3). Regarding AFG1, high media concentrations were detected in cereals in Logologo region (0.44 µg/kg) reaching maximum detected levels of 1.59 µg/kg. The current study also observed high median concentration of AFG_1 in tuber-based foods in Sagante/Jaldesa at 0.50 µg/kg, followed by Logologo with 0.47 µg/kg, Karare (0.31 µg/kg) and Marsabit central at 0.21 µg/kg respectively. Mixed food recipes showed elevated detectable concentration of AFG1 in Marsabit central at 0.47 µg/kg, Sagante/Jaldesa (0.41 µg/kg), Laisamis (0.36 µg/kg), Bubisa (0.28 µg/kg) and Logologo (0.24 µg/kg) respectively (Table 5.3).

Higher median concentrations of AFB_2 were detected in tuber-based foods in the Sagante/Jaldesa regions at 0.72 µg/kg, followed by mixed foods in Marsabit Central (0.66 µg/kg), and cereal-based complementary foods in both Logologo and Marsabit Central at 0.61 µg/kg. Also, the median concentration of AFB_2 in cereals observed in Bubisa and Sagante/Jaldesa was 0.51 µg/kg and 0.50 µg/kg, reaching maximum concentrations of 1.13 and 1.84 µg/kg respectively. Regarding AFG_2, high concentrations were mainly found in tuber-based foods in Logologo (0.84 µg/kg), Sagante/Jaldesa (0.72 µg/kg), Karare (0.53 µg/kg), and Marsabit Central (0.31 µg/kg) respectively (Table 5.3). Additionally, the study showed elevated concentrations of AFG_2 in cereal-based foods in Logologo (0.78 µg/kg), Marsabit Central (0.77 µg/kg), and Bubisa (0.51 µg/kg). Furthermore, Laisamis and Sagante/Jaldesa showed low concentration of AFG_2 in cereal-based foods, indicating median concentrations of 0.38 and 0.25 µg/kg respectively. The Karare region recorded a high median concentration of AFG_2 in meat-based foods (0.46 µg/kg), followed by Marsabit

Central at 0.36 µg/kg respectively. The figures reported in the current study were higher than the thresholds set by FAO/WHO, Codex Alimentarius, and the East African Community standards for AFB1, AFG1, AFB2, and AFG2, which use 0.005 µg/kg as cutoff values for children's food. They were also higher than the standards set by the E.U. for baby foods (<0.1 µg/kg).

Overall, the median levels of AFM_1 and AFM_2 were 0.31 and 0.67 µg/kg respectively, which surpasses the East African Community standards for AFM_1 (0.05 µg/kg). However, based on the Kruskal-Wallis test for variance, the differences were not significant (p=0.063) (Table 5.3.2). Regarding regions, Laisamis ranked highest in aflatoxin contamination in milk, with minimum and maximum contamination levels of 22.6 and 45.3 µg/kg respectively (Appendix x). Bubisa followed with the second-highest levels of both AFM_1 and AFM_2 contamination in milk, with medians of 0.3 and 0.67 µg/kg, and minimum and maximum levels at 25.5 and 51.1 µg/kg respectively. Additionally, the Sagante/Jaldesa ward exhibited higher levels of AFM_1 and AFM_2 compared to Marsabit Central and Karare respectively (Appendix x).

5.3.2. Social economic and demographic factors influencing occurrence of aflatoxin

Table 5.4 gives summary of backward linear regression results of social, economic and demographic factors influencing natural logs of AFB_1. AFG_1, AFB_2 and AFG_2 respectively. The predictor variables included; household head highest level of education completed, sex of index child, marital status of care giver, distance to nearest trading centre in (Km), Age of Care Giver, Age of household head (years), If household grows crops, If household owns livestock, caregiver average monthly income (KES), care giver higher education level completed, ward, If household received food aid, household head main occupation, If household is either in settled pastoralists or agro-pastoralist (General livelihood).

The overall model showed that regions, if household practiced crop farming, caregiver highest level of education and caregiver marital status significantly accounted for the variance in four aflatoxin compounds in detected in food. Hence $LnAFB_1$ showed [F (4, 41.462) = 5.792; $p < 0.001$) with R^2 of 0.227, accounting for 22.7% of the overall variance. The model for $LnAFG_1$ indicated [(F (4, 14.959) = 1.110; $p < 0.001$ and R^2 of 0.229 accounting for 22.9% of variance in the model. $LnAFB_2$ (F (4, 23.462) = 5.842); $p < 0.001$) with R^2 of 0.228 explaining 22.8% of total variation in model. Lastly, LnAFG2 had [F (4, 21.154) = 1.566; $p < 0.001$) and R^2 of 0.228) accounting for 22.8% of variance in the model.

In terms of specific factors, the findings indicate that region of residence had a significant effect on LnAFB1 occurrence (p = 0.002), LnAFG1 (p = 0.004), LnAFB2 (p = 0.003) and LnAFG2 (p = 0.003) respectively (table 5.3.4). Growing of crops by households showed significant effect on LnAFG1 (p = 0.043) LnAFB2 (p = 0.05) and AFG2 (p = 0.048) and marginally in AFB1 (p = 0.058). Care giver marital status also had a positive and significant effect on LnAFB1 (p = 0.011), LnAFG1 (p = 0.006), LnAFB2 (p= 0.008) and LnAFG2 (p = 0.007). There was no significant relationship between caregiver education and aflatoxin occurrence in the complementary foods in the study area.

Table 5.3 Backward linear regression of social, economic and demographic factors Influencing Aflatoxin levels (in µg/Kg) in complementary foods

	[1]$LnAFB_1$		$LnAFG_1$		$LnAFB_2$		$LnAFG_2$	
Predictors	β (SE)	Sig	β (SE)	Sig	β (SE)	Sig	β (SE)	Sig
(Constant)	-.807 (0.436)	.068	-1.113 (0.262)	<0.001	-.899 (0.328)	.008	-.632 (0.311)	.046
Wards	.156 (0.048)**	.002	.087 (0.029)**	.004	.113 (0.036)**	.003	.106 (0.034)**	.003
Do you grow crops?	-.389 (0.202)	.058	-.249 (0.121)*	.043	-.302 (0.0152)*	.05	-.289 (0.144)*	.048
Caregiver education	-.061 (0.035)	.084	-.038 (0.021)	.075	-.047 (0.026)	.075	-.045 (0.025)	.075
Caregiver marital status	.248 (0.095)*	.011	.161 (0.057)**	.006	.196 (0.071)**	.008	.187 (0.068)**	.007

*P < 0.05; **P < 0.01 [1] Ln - Natural log;

Trend: Growing of crops was strong associated with AFG_1 and AFB_2

5.3.3 Association between mycotoxins and Children Nutritional status

Table 5.4 displays the regression coefficients between fumonisin and aflatoxin occurrence and the nutritional status among children. Total fumonisin and total aflatoxin concentrations were regressed against stunting (HAZ > -2 SD z-score) and underweight (WAZ > -2 SD score) as outcome variables. The findings of this study indicated that fumonisin had an increasing effect on stunting and underweight. Conversely, total aflatoxin showed increased risks of stunting but lower odds of a child becoming underweight. However, the observed effects were not significant ($p < 0.05$). On the other hand, the study did not find any significant association between AFB_1, AFG_1, AFB_2, AFG_2, AFM_1 and AFM_2 stunting and underweight (Table 5.5).

Table 5.4 Logistic regression (OR at 95% C.I) analysis of association between aflatoxin, fumonisin and nutritional status of children

	Stunting				Underweight			
	COR	Sig	*AOR	Sig	COR	Sig.	AOR	Sig.
AFB_1	0.881 (0.369, 2.103)	0.776	0.629 (0.212, 1.805)	0.379	1.397 (0.272- 7.167)	0.689	1.927 (0.326 - 11.394)	0.469
AFG_1	0.726 (0.082, 6.457)	0.774	0.299 (0.020, 4.399)	0.379	2.31 (0.038 - 140.522)	0.689	5.185 (0.60 - 450.03)	0.47
AFB_2	0.823 (0.215, 3.145)	0.775	0.477 (0.092, 2.484)	0.379	1.676 (0.135 - 20.825)	0.688	2.751 (0.178 - 42.561)	0.469
AFG_2	0.853 (0.286)	0.775	0.547 (0.143- 2.098)	0.379	1.523 (0.196 - 11.855)	0.688	2.282 (0.245 - 21.228	0.469
AFM_1	1.015 (0.901, 1.142)	0.812	1.02 (0.901-1.14)	0.812	1.06 (0.940 - 1.199)	0.336		0.336
AFM_2	1.007 (0.949, 1.069)	0.812			1.03 (0.969, 1.095)	0.336		
Total AF	1.01 (.974, 1.04)	0.651			0.659 (0.282-1.54)	0.335		
Total FUM	1.00 (1.00, 1.00)	0.671			1.280 (0.948-1.728)	0.107		

*Adjusted for child age and sex; AF=aflatoxin; FUM=Fumonisin; C.I= 95% Confidence Interval; **Trend**: no significant association between mycotoxins tested and child nutritional status outcome

5.4. Discussion

In the present study, more than 50% of complementary foods and food ingredients were from cereals, tubers and root-based sources. The findings of contaminated complementary foods reflect the dietary diversity results that showed 97% of the children's staple diets were mainly from cereals, tubers and roots (Chapter 4) attesting to dietary changes among pastoralists from predominantly milk based to cereal based diets. Similar patterns have been reported in previous studies in Malawi (Matumba *et al.*, 2014), Tanzania (Mollay *et al.*, 2020). The common cereal and tubers used were maize flour and its derivative foods such as porridge and *ugali.* Rice and Irish potatoes, wheat-based recipes such as *fiqe*, *anjera* were other sources of the staple complementary diets among children. Cereals and tubers are also excellent substrates for molds and if consumed exclusively on regular basis may lead to malnutrition among children.

The current study revealed that the detectable minimum total fumonisin in the complementary foods was 300 µg/kg, with maximum levels reaching 7000 µg/kg. Consequently, 100% of the food samples analyzed surpassed the maximum limits of 200 µg/kg recommended by European Union (EU) Regulation No. 1126/2007, East Africa Community (EAC) Standards No. DEAS; 768, 2023, and the Codex Alimentarius of FAO/WHO Regulation No. CF/14 INF/1 for processed maize-based foods and baby foods for infants and young children (EAS, 2023; EU, 2023; FAO/WHO, 2017). Approximately 33.3% of the foods analyzed exceeded the 200 µg/kg cutoff limits for fumonisin levels in complementary foods intended for infants (appendix 5.2). The percentage of positive samples surpassing the regulatory limits in this study was lower than that reported by Magoha *et al.* (2016) in Tanzania, which found that 47.62% of the samples exceeded the limits for children under five years old.

This study found no association between dietary fumonisin and indicators of child undernutrition, including stunting and underweight. Consistent with these findings, previous studies also failed to establish a link between total dietary fumonisin and child nutritional status (Magoha *et al.*, 2016; Tessema *et al.*, 2021). Although this study did not identify any significant association between fumonisin and child nutritional status, research by Chen *et al.* (2018) noted a negative relationship between fumonisin levels and underweight among 6-month-old children in rural Tanzania. Additionally, other studies revealed that infants in Tanzania with relatively higher fumonisin intake, exceeding permitted levels of 2 µg/kg

bw/day, were notably shorter and lighter than those whose fumonisin intake remained within the permitted limits (IARC, 2015; Kimanya, 2014). Furthermore, Shirima *et al.* (2015) reported an association between the co-occurrence of aflatoxin and fumonisin and stunting among children under five years old.

Fumonisin is a secondary metabolite mycotoxin produced by the fungi Fusarium verticillioides and F. proliferatum species. These toxins are common in maize-based products in warm climates globally, with fumonisin B_1 (FB_1) being the most potent and prevalent form, classified by IARC as a Group 2B possible human carcinogen (IARC, 2002). Long-term exposure of pregnant women to maize-based diets during their first trimester to dietary fumonisin may also cause neural tube defects (NTDs) in human babies, primarily attributed to the blockage of folate transport by fumonisin B1 (Wilde *et al.*, 2014).

The current study also analyzed food samples for total aflatoxin and its conjugate compounds (AFB1, AFG1, AFB2, AFG2, AFM1, and AFM2). The results from this study showed that total aflatoxin levels ranged from 2.0 to 92 µg/kg with a median of 4 µg/kg. The high concentration of aflatoxins in this study may be attributed to the reliance on purchased foods from nearby markets, whose shelf life is not guaranteed. Furthermore, poor storage of cereal-based foods can lead to degradation by molds, especially when exposed to moisture. A majority of pastoralists store foods in non-hermetic sacks or bags, which are susceptible to moisture. The median of total aflatoxin found in the current study were higher than the 0.1µg/Kg E.U limit for foods meant for infant foods but lower than 5-10 µg/Kg limit for EAC standards for infant foods. The findings of total aflatoxin levels reported here were lower than those reported among toddlers in Turkey which showed mean total AF values of 16.3 (range of 2.9–29.7) µg/Kg (Kirimker *et al.,* 2020), Singida District, Tanzania with total aflatoxin range of 0.47 to 289.28 µg/kg (Fredrick, 2021), Nigerian children with a median total aflatoxin of 2.2 µg/Kg (Ezekiel *et al.*, 2020) and 2.3 µg/Kg (Ojuri *et al.*, 2018) respectively.

In terms of specific aflatoxin conjugates, the current study reveals that the overall median of AFB_1 was 0.5 µg/kg, compared to AFG_1 (0.31 µg/kg), AFB_2 (0.4 µg/kg), AFG_2 (0.51 µg/kg), AFM_1 (0.31 µg/kg), and AFM_2 (0.67 µg/kg), respectively. The occurrence of AF conjugates in complementary foods may still be explained by the use of poor food storage facilities, which in turn expose the foods to mold growth and the concentration of mycotoxins. The median AFB_1 findings here were above the regulatory limits for AFB_1 for children (E.U Regulation, 2023; EAS, 2023). The AFB_1 was the only conjugate aflatoxin higher than the

regulatory limits of 5-15 µg/Kg for East Africa Standards (EAS, 2023), CODEX (FAO/WHO, 2017.

The figures for AFB_1 reported here were lower than other studies in Nigeria (Ojuri *et al.*, 2019) and Tanzania (Boni *et al.*, 2021), but higher than those reported by Carballo *et al.* (2019). The median of AFM_1 and AFM_2 were 0.31 µg/Kg and 0.67 µg/Kg respectively. The presence of AFM_1 and AFM_2 in milk from range animals can further be attributed to the current adoption of livestock supplementary feeds purchased from shops. This study was also conducted during the dry season when most home-based lactating animals were being supplemented with dry maize and other commercial feed supplements whose quality and safety are unknown. Poor storage of these feed supplements could contribute to the prevalence of aflatoxin in milk fed to children in the study areas. This figures here are higher than E.U, EAS and FAO/WHO regulatory limits of 0.05 µg/Kg for aflatoxin in dairy products (FAO/WHO, 2017, EAS, 2023, E.U, 2023). The findings in this study for M_1 and M_2 were higher compared to those reported by Senerwa *et al.* (2016) in pastoral households in Isiolo, northern Kenya during the dry season. Moreover, previous studies have reported lower values of AFM_1 in urban and peri urban areas in Nairobi (Kageria *et al.*, 2018) and in Nakuru (Makau *et al.*, 2016) respectively.

The most common route of entry for AFs into the human body is through the ingestion of contaminated food. Once in the liver, AFB_1 is metabolized into another intermediate, reactive compound known as AFB1–8, 9-epoxide (AFBO), which has two isomers (endo-8, 9-epoxide and exo-8, 9-epoxide). If not detoxified, exo-AFB_1 8, 9-epoxide can bind to double-stranded DNA to form the promutagenic AFB1-N7-guanine adduct or, following hydrolysis to the AFB1-dihydrodiol, it can bind with proteins such as albumin (Rasheed *et al.*, 2021). This interference with DNA differentiation and intestinal integrity may result in growth retardation in children under five years old (Aroyo-Manzanares *et al.*, 2021; Rushing *et al.*, 2019).

The current study has also shown that the regional location of households and the marital status of caregivers were positively associated with aflatoxin levels, while crop production negatively influenced aflatoxin levels in the study areas. Regions in this study depicted distinct ethnic and socio-cultural practices. For example, Laisamis, Logologo and Karare were mainly inhabited by the ethnic Rendille community whereas Bubisa was mainly inhabited by the ethnic Gabra community. Sagante/Jaldesa was mainly occupied by Borana and partly the Burji tribes. Marsabit central is mainly located with the county headquarters

hence was more urban and cosmopolitan in nature. Secondly the regions served as proxy indicators for the distance to food market centers. Households that were far from the nearest market centers, such as Karare, Logologo, and Bubisa, showed higher levels of aflatoxin. Secondly, because the long distance traveled to get to the market may contribute to longer storage times for purchased cereal and tuber-based complementary foods used by households. Poor storage at the household level could also contribute to the occurrence of aflatoxin in food in the arid and semi-arid areas of the county. This study was conducted at the tail end of a long drought season in 2020 when most pastoral livestock herds depended on poor dry feed materials from the rangelands (Lengarite *et al.*, 2014), which may be prone to mold growth, thus posing a risk of lactating animals consuming contaminated feedstuff. Pastoral feed supplementation is also an emerging practice. Currently, pastoral households retain few lactating animals, mostly goats, which are supplemented with purchased cereal-based feed supplements such as maize. In most cases, the animals are supplemented with rotten maize. Feed supplements from local stockists may also be a source of aflatoxin contamination.

This study did not establish any association between occurrence of aflatoxin and child nutritional status (stunting, underweight and wasting) also observed by Mahfuz *et al.* (2021) in Bangladesh. However other studies have reported some associations. For instance, a study by Watson *et al.* (2018) conducted in Gambia identified significant inverse correlations between LnAF-alb and length-for-age (LAZ), weight-for-age (WAZ), and weight-for-length (WLZ) z-scores among children aged 6 to 18 months. Additionally, the research indicated an inverse relationship between LnAF-alb at 6 months and the changes in WLZ from 6 to 12 months. Furthermore, LnAF-alb at 12 months was linked to alterations in LAZ and infant length during the period from 12 to 18 months. However, those reported studies that showed association with nutritional status used markers of aflatoxin from human tissues (blood and urine) and not dietary aflatoxin used in this study.

5.5. Conclusion and Recommendation

5.5.1. Conclusion

The high occurrence of mycotoxins (fumonisin and aflatoxins) is associated with shifting to cereal based complementary diets in the sedentarised households coupled with food handling practices that might have compromised food hygiene as indicated with high loads of microbial contaminants

5.5.2. Recommendation

Further research on mycotoxins should include the analysis of biosensors including blood, urine, and breast milk that may be responsible for stunting and underweight.

CHAPTER SIX

HYGIENIC HANDLING OF COMPLEMENTARY FOODS CONSUMED BY CHILDREN AGED 6-59 MONTHS IN TRANSITIONAL PASTORAL HOUSEHOLDS IN MARSABIT COUNTY

Abstract

Food safety is a major public health concern in sub-Saharan Africa, often due to improper handling of complementary food. This study assessed the safety and quality of complementary foods in transitional pastoral households in northern Kenya by analyzing 474 foods, water, and hand swab samples for initial load of contamination by environmental microorganisms to assess the hygiene and possible presence of pathogens. Enumerations through total viable counts (TVC) and total coliforms (TCC) were carried out and the determination of *Escherichia coli*, and *Salmonella* spp. using standard microbiological procedures were carried out. Data were log10 transformed and analyzed using regression methods to evaluate the effects of household characteristics on microbial loads and their association with children's nutritional status. The overall mean microbial loads (± SE) were 7.7 ± 0.02, 7.5 ± 0.03, 7.5 ± 0.36, and 1.32 ± 0.11 $\log_{10}$ CFU/ml for TVC, TCC, yeast, and molds, respectively, exceeding KEBs and EU recommended values. *Salmonella* spp. prevalence was highest in Bubisa (57%) and was notably high in camel milk (100%), processed and opened/used UHT milk (61.5%), and rice-based foods (52%). *E. coli* was prevalent in 100% of foods tested. Factors such as distance to market, education, and water treatment significantly predicted *Salmonella* spp. prevalence, while livestock ownership, faecal waste disposal, diarrheal episodes, and water source was significantly associated with *E. coli* prevalence. *E. coli* and mold contamination increased the likelihood of stunting while TVC increased the likelihood of children underweight. In conclusion, the study confirmed a high prevalence of *E. coli* and *Salmonella* Spp in complementary foods due to improper handling practices, highlighting a strong association between food safety and child undernutrition. Further research on should include the identification of strains of *E. coli* and *Salmonella* spp that may be responsible for stunting and underweight

6.1 Introduction

The transition from nomadic to sedentary lifestyles among sub-Saharan African pastoralists has brought about dietary changes, impacting health and nutrition. Lind *et al.* (2020) shed light on broader transformations of pastoralism across East Africa. Reduced livestock

ownership per capita, exacerbated by climate change events like the 2011 drought and the COVID-19 pandemic, and highlights the challenges faced by pastoralist communities (Ayele *et al.*, 2021; Coppock *et al.*, 2018; Kirui *et al.*, 2020).

Local or traditional knowledge of food hygiene and safety among pastoralist communities is deeply rooted in their unique cultural, environmental, and economic contexts. Pastoralists, such as the Maasai, Samburu, and Borana in East Africa, live in regions where food security is often precarious, and access to modern food safety technologies is limited. Over centuries, these communities have developed practices aimed at preserving food, ensuring hygiene, and mitigating contamination risks. However, while these methods have served them well in many respects, they also have certain limitations when compared to contemporary food safety standards (Galvin *et al.*, 2020).

One of the most common traditional practices among pastoralists involves the handling and preservation of milk, a central component of their diet. Milk fermentation is a key preservation technique that lowers the pH of milk, inhibiting the growth of harmful microorganisms. Additionally, pastoralists often smoke milk containers, a practice believed to enhance preservation by introducing antimicrobial properties. Herbs are sometimes used in this process, further reinforcing the milk's resistance to contamination. Such methods have been effective in extending the shelf life of milk in environments where refrigeration is unavailable (Mutungi *et al.*, 2015). Similarly, meat, another dietary staple, is preserved through sun drying, smoking, and salting, all of which reduce water activity, thus limiting microbial growth (Nyaoke *et al.*, 2017).

Water safety is another area where traditional knowledge plays a critical role. Pastoralist communities often identify safe water sources using indigenous knowledge. In some cases, they filter water using cloth or add herbs believed to purify it. However, these methods, while useful, are not always sufficient to ensure the safety of drinking water, especially as environmental conditions change (Kariuki *et al.*, 2019).

Despite the ingenuity and effectiveness of some traditional food safety practices, they are not without limitations. One of the key issues is the lack of standardization. Practices like milk fermentation or smoking vary greatly between communities, and there is no guarantee that these methods are always applied consistently or effectively. This inconsistency can result in uneven levels of hygiene and safety. For instance, while smoking milk containers can reduce

contamination, improper hygiene practices during the milking or handling process can still introduce harmful bacteria, such as *Escherichia coli* or *Staphylococcus aureus* (Mutungi *et al.*, 2015).

Additionally, traditional preservation methods may not always be effective against modern foodborne pathogens. While fermentation and smoking inhibit certain types of microbial growth, they do not eliminate all harmful organisms, especially those that pastoralist communities may not be familiar with. As climate change exacerbates the scarcity of resources, pastoralists are increasingly forced to rely on compromised water sources and to engage in unsafe food handling practices, further increasing the risk of foodborne diseases (Galvin *et al.*, 2020).

One of the most significant challenges for pastoralist communities is the limited access to modern food safety knowledge and technologies. Their remote locations often prevent them from receiving up-to-date information on contemporary food safety practices. This gap makes it difficult for these communities to incorporate modern scientific knowledge into their traditional practices. Furthermore, the harsh environmental conditions and the unpredictable availability of resources, such as water and grazing land, complicate the adoption of newer methods that could complement traditional knowledge (Kariuki *et al.*, 2019).

Pastoralist communities have developed effective traditional methods for ensuring food hygiene and safety in their challenging environments, these practices have limitations when compared to modern food safety standards. The lack of standardization, vulnerability to environmental changes, and limited access to contemporary knowledge highlight the need for greater integration of modern food safety practices. By introducing education on food safety, improving access to clean water, and adapting preservation techniques, pastoralists can enhance their food security without abandoning their cultural heritage.

Eastern African pastoralists are increasingly settling in urban areas due to factors like state control and infrastructure development (Davies & Moore, 2016; Greiner, 2020). Furthermore, Kirui *et al.* (2020) posit that only 12% of pastoralists are holding onto pastoralism, while 32% of pastoralists are dropping out and another 32% are moving out of pastoralism as a livelihood practice. This shift redefines rangeland livelihoods, with increased local capital and non-mobile livestock ownership. In attempt to ameliorate the impact of drought on livestock assets loss, sedenteral pastoralists adopt new practices, such as supplementing free

range feeding system with commercial feeds, children's diets are also changing, with a shift towards cereals, root-based foods, and locally produced milk (Oniang'o *et al.*, 2003). However, the adoption of commercial food ingredients in homemade infant foods may pose safety risks for under-five children, leading to nutritionally inadequate and microbiologically unsafe diets (Achaglinkame *et al.*, 2017; WHO, 2015b).

Children aged 6-59 months are particularly vulnerable to foodborne infections, contributing to high rates of stunting in Sub-Saharan Africa (UNICEF/WHO/WORLD BANK, 2023). Previous studies highlight varying levels of food hygiene knowledge among pastoral and sedentary communities in northern Kenya (de Leeuw *et al.*, 2019). In northern Kenya, pastoralists are known to feed children raw milk (Wayua, 2027) which plays a critical role in complementary feeding among under five children. However, there is limited information on the effect of these emerging pastoral practices on the safety of complementary foods and their association with stunting and underweight among children under five years.

The current study aimed to determine the occurrence of *Salmonella* spp and *E. coli* whose common route of entry is through ingestion of contaminated food and water during food handling and feeding. This study therefore, addresses gaps in understanding the impact of feed supplementation on livestock product quality and the safety of complementary foods for children under five. It also assesses the link between the microbial safety of complementary foods and nutritional outcomes among pastoralist children in northern Kenya. The findings will inform food safety policies and improve nutrition outcomes for these children.

6.2 Materials and Methods

6.2.1 Study site

The study was conducted in Marsabit County in months of October and November 2020. Marsabit County was purposively selected because sedentarization is currently an ongoing process and peri urban pastoral production system is emerging alongside nomadic pastoralism (Noor, 2013). Marsabit hosts a population totaling 459,785, with a density of 7 individuals per square kilometer (KNBS, 2019). In households still engaged in pastoralism, common livestock species kept comprise camels, sheep, goats, and cattle. The current study was conducted in Laisamis, Logologo, Karare, Central, Sagante/Jaldesa and Bubisa regions respectively representing the different agro-ecological zones, social, cultural and livelihoods changes. Central ward is within county headquarters and more cosmopolitan with trade in

goods and service being the main economic practice in addition to limited urban agriculture. Karare and Sagante/Jaldesa constitute agro pastoral livelihood zones while Laisamis, Logologo and Bubisa are located in the lowlands where livestock keeping is the main economic mainstay.

6.2.2 Food and water sampling

In the second phase of the survey, a subsample of 128 households, representing 32% of the total households sampled for the nutrition survey, was randomly selected using Excel tool and visited. Different samples were picked to represent the diversity of complementary food products consumed by the index child, hand swabs of caregivers, and water in the six wards, respectively. Visits to selected households were done without prior notice to capture the typical form in which complementary foods were presented to the index child by caregivers. The food samples were collected just before feeding the child, using the same feeding utensils normally used for feeding. The food samples were collected within 2-4 hours of preparation.

About 100g of solid and semi-solid food samples, 50 ml of milk samples and hand swabs were aseptically collected into a sterile airtight plastic sampling bags with zip lock. Water samples were collected from the pots in the households, nearby wells and boreholes used as source of water for domestic use. In this study, 50 ml samples were collected and directly transferred from the water collection container into sterile Falcon tubes. To ensure aseptic conditions, the lid and neck of each tube were wiped with a paper towel moistened with 70% ethanol (ET00052500, Batch No. 19680210, Scharlau, Spain). Each sample was labeled and placed in a cool box maintained at 8-10°C using dry ice packs. The samples were transported to the Kenya Agricultural and Livestock Research Organisation (KALRO) laboratory in Marsabit within 3-4 hours and stored under refrigeration at 4°C prior to analysis. To ensure ethical consideration, the food samples collected from each household was replaced with 500 ml of fresh pasteurized packaged UHT milk purchased from shops in Marsabit town.

6.2.3 Microbial Analysis

1 Sample processing

All samples were given laboratory codes that represented location, sample class (type), and household identifier. From each solid and semi-solid food sample, 25g was weighed, suspended and homogenized using a blender using in 225ml sterile peptone water at 10^{-1}

dilution. Following the homogenization process, 10 ml of the homogenate was transferred into 90 ml of buffered saline to create a 10^{-2} dilution. This mixture was thoroughly mixed, and then 1 ml was aseptically transferred serially into a series of tubes, each containing 9 ml of buffered saline to achieve dilutions of 10^{-3}, 10^{-4}, 10^{-5}, and 10^{-6}.

2 Enumeration and Isolation of microbial contaminants

Isolation of Yeast and Mod

One gram of food sample was serially diluted six-fold with distilled water. Approximately 0.1 ml of each dilution was cultured using the pour plate technique onto Potato Dextrose Agar (PDA) and incubated for 5 to 14 days at room temperature (20 - 30°C). Pure cultures of the various colonies, distinguished by their morphology, were obtained through sub-culturing the isolates onto fresh PDA plates. The fungal isolates were identified to the genus and species levels based on their macroscopic, microscopic, and biochemical characteristics observed in the pure cultures (Issaka *et al.*, 2017). Results were then reported as yeast and mold per gram or milliliter.

Total Viable Counts (TVC)

The analysis of total viable counts in food samples was conducted in accordance with the AOAC (1990) method, procedure no. 966.24. In brief, 1 ml of the sample was serially diluted six-fold using 9 ml of buffered peptone water. One milliliter (1 ml) of the homogenized sample was transferred into sterile, labeled petri dishes using a sterile pipette. Approximately 20 ml of plate count agar, tempered in a water bath at 45°C after autoclaving, was aseptically poured into each petri dish. The media and sample were mixed gently by swirling in a figure-eight motion. The petri dishes were then inverted, allowed to solidify at room temperature, and incubated at 37°C for 48 hours. Control plates containing diluents (buffered saline) and agar (PCA) were also included and incubated under the same conditions for a maximum of 48 hours. Plates that contained between 30 and 300 colonies were selected for counting. The average count from duplicate plates was calculated and converted to logarithmic values for recording and analysis. Discrete colonies that developed on the plate count agar were purified through repeated plating on the same agar and subjected to Gram staining for morphological identification, followed by biochemical tests for further identification.

Coliform Count (CC)

The procedure employed was similar to the total viable counts outlined by AOAC (1990), procedure no. 966.23. MacConkey agar with 0.15% bile salt or Violet Red Bile Agar was

utilized to select for lactose fermenters. A dilution of 1 ml of food in 9 ml of peptone water was performed (1:10 ratio) up to six dilutions. Sterile duplicate glass petri dishes were labeled according to the dilution index. Using a sterile 1 ml pipette, 1 ml of each dilution was aseptically transferred into an open sterile petri dish, which was then closed. This process was repeated for a duplicate petri dish. The procedure continued until all dilutions were pipetted into their respective plates, up to 10^{-6}. Following this, approximately 15 ml of Violet Red Bile Agar or MacConkey Agar, autoclaved at 121°C for 15 minutes and then cooled and tempered in a water bath at 45°C, was poured into the dishes. The agar and sample were gently mixed by alternating clockwise and counterclockwise rotations for about three minutes, then allowed to solidify on the bench for approximately 30 minutes. The plates were inverted and incubated at 37°C for 48 hours. Since the initial dilutions were anticipated to have more substantial growth, they were not counted; instead, the last three dilutions (10^{-4}, 10^{-5}, and 10^{-6}) were utilized for coliform counts.

To enumerate Total Fecal Coliforms in water for domestic use collected from the various water points and household containers in the study sites, this study adopted Most Probable Number (MPN) method as described by. The analysis of coliforms in the water samples was conducted using the three-tube Most Probable Number (MPN) method. For this analysis, the water samples were examined for the presence of coliforms in Lauryl Tryptose Broth (REF M080, Lot No. 0000375783, and Himedia, India), using presumptive test specific for coliforms. Approximately 10 mL of either single-strength or double-strength Lauryl Tryptose Broth was prepared in test tubes, each containing an inverted Durham tube, and sterilized at 121°C for 15 minutes. The broth was then aseptically inoculated with 0.1 mL of water for the double-strength broth and with 1 mL or 10 mL of bore well water for the single-strength Lauryl Tryptose Broth. The inoculated tubes were incubated at 35°C for 24 hours. Presence of gas indicated by a bubble in Durham s tube were indicative of presence of coliforms. Those without bubble were considered as negative for coliforms. To confirm the positive water samples, a test was conducted using brilliant green 2% bile broth. One loopful of inoculum from the positive tubes of Lauryl Tryptose Broth was transferred into sterile tubes of brilliant green 2% bile broth and incubated at 37°C for 24 hours. After incubation, the tubes were examined for gas production. The number of positive tubes was counted, and the Most Probable Number (MPN) per 100 mL was calculated according to Table No. 966.24 of A.O.A.C. (1990). The test was completed by identification of coliforms in colony forming

units per ml (CFU/ml). A loopful of the confirmed positive colonies was streaked on sterile EMBA plate and incubated at 37 °C for 24 hrs. Nucleated colonies with or without metallic sheen colonies were marked as typical.

6.3.4 Water analysis

Firstly, the original sample underwent serial dilution using sterile diluents to obtain a range of dilutions covering several orders of magnitude. Each dilution was meticulously mixed to ensure uniform dispersion of microorganisms throughout. Subsequently, aliquots from each dilution were inoculated into multiple replicate tubes or wells containing growth media specific for the target microorganism. Careful attention was paid to maintain sterile conditions during inoculation to prevent contamination. The inoculated tubes or wells were then securely sealed to minimize the risk of external contamination and incubated under optimal conditions conducive to microbial growth. Incubation periods varied depending on the microbial species being targeted and their growth characteristics. Following the designated incubation period, the tubes or wells were carefully examined for the presence of microbial growth. Positive growth indicators such as turbidity, gas production, or visible colonies were noted. The number of positive tubes or wells at each dilution level was recorded and entered into a statistical table or software program. Statistical analysis was performed to determine the Most Probable Number (MPN) of microorganisms present in the original sample. This calculation took into account the dilution factors and the probability of microbial growth at each dilution level. Finally, the MPN value was calculated based on the observed pattern of positive and negative results across the dilution series, providing an estimation of the microbial concentration in the original sample.

6.3.5 Isolation of pathogens

1 Escherichia coli

One milliliter (1 ml) of the sample was pour-plated onto approximately 15 ml of Violet Red Brilliant Agar (VRBA) and mixed gently in a figure-eight motion to ensure even distribution. The plates were then incubated at 37°C for 24 hours. After incubation, distinct colonies were selected from the VRBA plates and streaked onto Endo Methyl Blue Agar, followed by a second incubation at 37°C for 24 hours. The presence of colonies exhibiting a green metallic sheen was identified as positive for *E. coli*. The confirmation of indole production in Escherichia coli (E. coli) was conducted following established microbiological protocols. A bacterial isolate suspected to be E. coli was inoculated into tryptone broth, a medium

containing tryptophan as a substrate for indole production. After overnight incubation at 37°C, bacterial growth was observed, indicating successful cultivation of the isolate. The indole test was performed by adding Kovac's reagent directly to the bacterial culture in the test tube. The reagent, containing p-dimethylaminobenzaldehyde, was gently mixed with the culture and allowed to stand for several minutes. Subsequently, the tube was observed for any color changes in the medium. A positive reaction, indicative of indole production by E. coli, was characterized by the formation of a cherry-red color in the upper layer of the medium. Conversely, a negative reaction was noted by the absence of a color change or the presence of a yellow color in the upper layer of the medium.

***2 Salmonella* Spp**

One milliliter (1 ml) of the sample was taken from the buffered peptone water (BPW) pre-enrichment medium and transferred to a selective pre-enrichment medium of Rappaport-Vassiliadis media (RVM) broth. This mixture was then incubated at 42°C for a duration of 18 to 24 hours. About 10 µl loop full was then transferred from incubated RVM broth (II) and spread onto Xylose-Lysine Deoxycholate (XLD, and on Brilliant Green Bile Broth 2% plates and incubated at 37°C for 18-24 hours. Black colonies from XLD and colonies from BGBB were inoculated by stubbing into Triple Sugar Iron (TSI) slants with a butt of about 1 inch (2.5-3.5cm) and incubated overnight at 37°C. Production of acid (yellow) slant and acid (yellow) butt, without production of H_2S (blackening of agar) was considered positive for *E. coli*. While an alkaline (pink/red) slant and yellow butt (acid), gas, with or without H_2S gas (blackening of tubes) were considered positive for *Salmonella* spp.

6.3.6 Biochemical characterization of pathogens

The suspected colonies were picked and identified by Gram stain and biochemical tests. Definitive phenotypic characterization was done using Analytical Profile Index (API) 20 E systems (REF No. 20 100/20 160, BioMérieux SA, Marcy-1 Etoile France). Using the, biochemical confirmatory tests of E. *coli* and *Salmonella* isolates were performed using Sugar fermentation tests, Catalase, Methyl Red test (MR), Voges-Proskauer test (V-P) and indole test. Pure isolates of the target microorganisms were preserved in analytical sucrose solution (REF 11746SG500, batch No. 789860203CT, FINAR Chemicals, India) and stored under -20°C for further analysis.

6.3.7 Pathogenicity determination of *Salmonella spp* and *E. coli* isolates

The pure colonies of presumptive colonies of *Salmonella spp* and *E. coli* isolate were for the haemolytic properties following the method of Nato *et al.* (2018). Briefly, test for haemolytic properties of the single colony of each pathogenic microorganism was done by culturing the isolates on Blood agar (BA) (Oxoid, REF No. CM0055, Hampshire, UK) with 7% defibrinated sheep blood at 37°C for 24 h.

6.3.8 Antimicrobial Sensitivity Test of *Salmonella* spp and *E. coli* isolates

Antimicrobial sensitivity test for *E. coli* and *Salmonella* spp was done using Kirby-Bauer diffusion disk methods as described by CLSI (2018) with modification. In summary, 1 ml of colony-forming units (CFUs) from each microorganism was inoculated onto solidified Nutrient agar plates (REF M001-500G, lot No. 0000252887, Himedia, India) in replicates and spread evenly. After allowing the plates to dry, antibiotic sensitivity discs from Octave were placed on the surface of the petri dishes. The plates were then incubated at 37°C for 24 hours. The zone of inhibition surrounding each antibiotic was measured to assess susceptibility (Penicillin G-1 unit, Minocycline-30 µg, Erythromycin -15 µg, Methicilin-5µg, Co-Trimoxazole (sulpha/Trimethopin)-25µg (23.76/125 µg), chloramphenicol -30 µg, Ampicilin-10 µg and Lincomycin -2µg) indicated sensitivity of the organism present in the culture to that antibiotic. The drug sensitivity was then calculated based on zone inhibition breaking point reference table 6.1 below (CSLI, 2018) Strains that were resistant to three or more classes of antimicrobials were considered multidrug resistant (Iovine *et al.*, 2015).

Table 6.1 Reference for breaking point zone diameter for *Enterobacteriales*

			Category of inhibition zone diameter (in mm)		
Drug	Symbol	Concentration	Susceptible (S)	Intermediate (I)	Resistant (R)
Penicillin G	P	1 unit	26	-	26
Minocycline	MI	30µg	≥16	13-15	<12
Erythromycin	E	15µg	≥23	14-22	≤13
Methicillin	MET	5µg	≥29	-	≤28
Co-Trimethoxazole (Sulpha/Trimethoprin)	COT	25 (23.75/1.25)µg	≥16	11-15	<10

Chloramphenicol	C	30µg	≥18	13-17	≤12
Ampicillin	AMP	10µg	≥17	14-16	≤13
Lincomycin	L	2µg	≥21	15-20	≤14

Source: CLSI (2022) with modification

6.3.9 Data Analysis

The data were analyzed using SAS version 8.1 and SPSS version 25. Mean values for different regions were computed, and percentages and frequencies were determined to understand the distribution of various foods and microorganisms within them. A nested design was employed, where different foods and preparation methods were nested within distinct regions studied in Marsabit County. Mean values were discerned using the Studentized Tukey method for mean separation, with a significance level set at 95% ($p < 0.05$). Comparisons were made among means for various microorganisms across food samples and different regions. A linear regression model was used to evaluate social, economic, demographic and environmental factors influencing microbial loads in the food samples. Binary logistic regression was used to assess the effect of microorganisms on stunting and underweight among children aged 6-59 months.

6.4 Results

6.4.1 General environmental hygiene in different in Marsabit County

Analysis of variance was conducted using a nested model to examine the effect of different factors on microbial load in the food products. As summarized in Appendix 6.1, the model was significant at $p < 0.001$ with R^2 values for TVC (0.685), TCC (0.732), *E. coli* (0.425), molds (0.747), yeast (0.927), *Staphylococcus* Spp. (0.61), and *Salmonella* spp. (0.537), respectively. The effect of region and location on the occurrence of TVC, TCC, *E. coli*, molds, yeast, and *Staphylococcus* spp. was significant at $p < 0.001$. On the other hand, region had a significant effect on *Salmonella* Spp. occurrence, but not at the location level. The interaction and nesting effects of the microbial contaminants were also significant at $p < 0.001$ for all the microorganisms (Appendix 1).

Table 6.2 presents the overall summary of mean ± SE microbial loads across the six study sites. Accordingly, the overall mean microbial load was 7.7 ± 0.02, 7.5 ± 0.03, 7.5 ± 0.36, and 1.32 ± 0.11 $\log_{10}$ CFU/ml for TVC, TCC, yeast, and molds, respectively. The mean loads were significantly different across the study sites ($p < 0.001$). Additionally, results from the

current study showed that Bubisa had significantly higher load of TVC (7.86 log_{10} CFU/ml, $p < 0.001$), followed by Karare (7.80 log_{10} CFU/ml), Sagante/Jaldesa (7.76 log_{10} CFU/ml), Marsabit Central (7.67 log_{10} CFU/ml), Logologo (7.53 log_{10} CFU/ml), and Laisamis (7.52 log_{10} CFU/ml).

Similarly, the overall mean load of TCC was 7.5 ± 0.03 log_{10} CFU/ml and was significantly ($p < 0.001$) higher in Marsabit central, Sagante/Jaldesa (7.80 ± 0.03 log_{10} CFU/ml), Karare (7.79± 0.03 log_{10} CFU/ml) followed by Bubisa, Logologo and Laisamis respectively (table 6.2). The overall mean microbial load of molds was 1.32 ± 0.11 log_{10} CFU/ml with significant ($p<0.001$) differences being observed. There was significantly higher mold growth in the samples obtained from Laisamis (4.31 ± 0.20 log_{10} CFU/ml), followed by Logologo, Bubisa, and Karare, respectively (table 6.2). The study found no mold colonies in the Marsabit Central and Sagante/Jaldesa areas. The mean microbial load for yeast was 7.5 ± 0.36 log_{10} CFU/ml. The means were significantly different across the study sites ($p = 0.004$). Bubisa, Karare, and Laisamis regions had significantly higher loads of yeast ($p < 0.01$) — 7.56 and 7.54 log_{10} CFU/ml, followed closely by Sagante/Jaldesa and Marsabit Central. Laisamis had the lowest microbial loads of yeast (Table 6.2).

Table 6.2 Overall mean± SE log10 CFU/ml of environmental microbial contaminants by site

Region		TVC	TCC	Mold	Yeast
Lowlands	Bubisa (n=84)	7.86^{c} ± 0.02	7.66^{bc} ± 0.03	0.73^{ab} ± 0.20	7.56^{b} ± 0.02
	Laisamis (n=107)	7.52^{a} ± 0.05	7.22^{a} ± 0.06	4.31^{c} ± 0.20	7.53^{b} ± 0.05
	Logologo (n=46)	7.53^{a} ± 0.04	7.47^{b} ± 0.05	1.1^{b} ± 0.32	6.86^{a} ± 0.27
Highlands	Central (n=97)	7.67^{b} ± 0.02	7.80^{a} ± 0.03	0.00^{a} ± 0.00	7.48^{ab} ± 0.03
	Karare (n=72)	7.80^{c} ± 0.03	7.79^{c} ± 0.03	0.70^{ab} ± 0.22	7.54^{b} ± 0.03
	Sagante (n=65)	7.76^{bc} ± 0.02	7.80^{c} ± 0.03	0.00^{a} ± 0.00	7.48^{ab} ± 0.03
	Total (N=474)	7.7 ± 0.02	7.5 ± 0.03	1.32 ± 0.11	7.5 ± 0.36
	Sig ($p < 0.05$)	0.000	0.000	0.000	0.004

Key: Means with the same superscript letter along the column are not significantly different at $p < 0.05$.

Table 6.3 gives summary of the hygienic standard of the water and hand swab samples in the six study sites. Generally, the water samples were significantly contaminated across the six sites presenting a hazard to the children. The mean of TVC and TCC of collected water

samples were significantly higher in Karare ($P < 0.001$) compared to other sites. The study also indicated high level of pathogenic microbial (E. *coli*, *S aureus*, and *Salmonella spp*) contamination of water collected for domestic use in all the wards. Bubisa had higher TVC compared to rest of the wards. There were high but insignificant differences in TCC across the five wards. Although elevated levels of *E. coli*, *S. aureus* were observed, lower levels of *Salmonella* spp was reported in hand swab samples.

Table 6.3 gives summary of the mean microbial load for hand swab and water samples from care givers in different sites. From the results, it can be deduced that the hygienic standards of the caregivers were worrying and contributed to contamination of the foods. Apart from molds, the result show that all other indicators of contamination may have passed through the caregivers to children.

Table 6.3 Mean± SE of log10 CFU/ml of microbial contaminant of water samples by region

	Ward	Central	Karare	Laisamis	Sagante/ Jaldesa	Bubisa
Hand swabs	TVC	7.52 ± 0.09^{ab}	7.55 ± 0.01^{ab}	7.29 ± 0.10^{b}	7.59 ± 0.05^{ab}	7.79 ± 0.05^{a}
	TCC	7.01 ± 0.31^{a}	7.48 ± 0.01^{a}	7.09 ± 0.11^{a}	7.48 ± 0.06^{a}	7.71 ± 0.11^{a}
	Yeasts	7.09 ± 0.13^{b}	7.35 ± 0.01^{ab}	7.69 ± 0.10^{a}	7.42 ± 0.05^{ab}	7.48 ± 0.07^{ab}
	Molds	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	5.57 ± 0.10^{a}	0.00 ± 0.00^{c}	1.60 ± 0.80^{b}
Water samples	TVC	$7.92^{b} \pm 0.00$	$7.41^{a} \pm 0.73$	$7.4^{a} \pm 0.04$	$7.26^{a} \pm 0.11$	$7.6^{a} \pm 0.026$
	TCC	$7.9^{b} \pm 0.00$	$6.64^{a} \pm 0.16$	$7.05^{a} \pm 0.10$	$7.37^{ab} \pm 0.01$	$7.36^{ab} \pm 0.01$
	Yeast	$0.00^{a} \pm 0.00$	$1.41^{a} \pm 0.74$	$0.00^{a} \pm 0.00$	$0.00^{a} \pm 0.00$	$0.00^{a} \pm 0.00$
	Molds	$7.68^{b} \pm 0.00$	$1.9^{a} \pm 0.99$	$7.48^{b} \pm 0.01$	$7.6^{b} \pm 0.02$	$7.47^{b} \pm 0.01$

Key: Numbers with the same superscript letter along the column are not significantly different at $p < 0.05$; **Trend:** There is high environmental contamination of food consumed by children as reflected in high TVC, TCC in both water and hand swabs.

6.4.2 General Status of contamination of Complementary Foods in Marsabit

Table 6.5 gives summary of microbial loads for the various complementary foods in Marsabit County. Most of the foods were heavily contaminated as indicated by the higher total viable counts (TVC), the total coliforms (TCC) and yeast. Molds were not a major threat in most of the products although elevated loads were observed in potato, maize based foods, goat milk and tea with milk. Pathogens such as *E. coli*, *Salmonella* and *Staphylococcus aureus* were a

major a source of threat to human health as they were isolated in majority of the food samples collected.

Table 6.4 Mean ± SE of microbial contamination of different food types from all study areas

	LogTVC	Log TCC	LogYeasts	Log Molds
Anjera	$7.75^{b} \pm 0.07$	$7.81^{ab} \pm 0.07$	$7.67^{a} \pm 0.02$	$0.00^{d} \pm 0.00$
Githeri	$7.68^{bc} \pm 0.07$	$7.86^{a} \pm 0.05$	$7.61^{ab} \pm 0.07$	$0.00^{d} \pm 0.00$
Milk tea	$7.70^{bc} \pm 0.04$	$7.11^{c} \pm 0.19$	$7.39^{c} \pm 0.06$	$1.69^{d} \pm 0.37$
Others	$7.67^{bc} \pm 0.05$	$7.53^{b} \pm 0.07$	$7.47^{bc} \pm 0.04$	$0.58^{d} \pm 0.32$
Water	$7.41^{d} \pm 0.01$	$7.27^{ab} \pm 0.02$	$7.49^{bc} \pm 0.02$	$0.00^{d} \pm 0.00$
Porridge	$7.55^{cd} \pm 0.07$	$7.39^{bc} \pm 0.05$	$7.49^{bc} \pm 0.08$	$1.87^{b} \pm 0.51$
Qita	$7.56^{c} \pm 0.03$	$7.25^{bc} \pm 0.10$	$7.47^{bc} \pm 0.07$	$0.00^{d} \pm 0.00$
UHT milk	$7.69^{bc} \pm 0.08$	$7.72^{ab} \pm 0.07$	$7.52^{bc} \pm 0.03$	$0.00^{d} \pm 0.01$
cams	$7.91^{a} \pm 0.06$	$7.40^{bc} \pm 0.02$	$7.35^{c} \pm 0.07$	$0.00^{d} \pm 0.00$
cms	$7.77^{b} \pm 0.03$	$7.83^{ab} \pm 0.03$	$7.57^{ab} \pm 0.03$	$0.41^{d} \pm 0.16$
gms	$7.92^{a} \pm 0.04$	$7.62^{ab} \pm 0.05$	$7.59^{ab} \pm 0.07$	$1.89^{b} \pm 0.40$
mpv	$7.78^{ab} \pm 0.04$	$7.18^{c} \pm 0.18$	$7.42^{bc} \pm 0.04$	$1.17^{c} \pm 0.62$
rmpcb	$7.71^{bc} \pm 0.03$	$7.64^{ab} \pm 0.04$	$7.51^{bc} \pm 0.04$	$1.34^{bc} \pm 0.28$
USP	$7.59^{c} \pm 0.05$	$7.22^{bc} \pm 0.08$	$7.14^{d} \pm 0.17$	$2.68^{a} \pm 0.31$

Key: cms = cattle milk (smoked), gms= goat milk (smoked), USP= *Ugali* (stiff porridge), cams= camel milk (smoked), mpv= mixed potatoes and vegetables, rmpcb= rice, mixed with potatoes, cabbages and beans. Means with the same letter along the column are not significantly different at $p<0.05$. **Trend**: General hygienic condition of foods consumed by children across the wards were poor as reflected by TVC, TCC, yeast and molds

6.4.3 Microbial contamination of complementary Foods in agro-pastoral and urban wards of Marsabit

Table 6.6 provides summary of microbial loads in highland areas which are characterized by the urban lifestyle in the cosmopolitan ward (Marsabit Central) and peri-urban agro-pastoral highland areas (Sagante/Jaldesa and Karare wards). Most of the people in the urban areas of Marsabit central ward have adopted some of the processed foods such as cerelac (others), UHT milk, *ugali* from processed flour and *chapatis* among other foods in feeding their children.

However, the foods are heavily contaminated as shown by table 5 below. Moreover, a majority of households still rely on the traditionally known pastoral foods such as smoked

cattle milk from local production. However, use of processed milk purchased from shops was also recorded. In terms of quality and safety of sampled food in this ward, result from the current study show that nearly all types of food had loads above 10^7 CFU/ml, which is classified as unsatisfactory for human consumption. Locally produced raw cattle milk and boiled rice, *kurkufa, ashir* had higher microbial loads compared to other food types in the same area. Additionally, these foods were heavily contaminated with pathogenic microorganisms such as *Escherichia coli, Staphylococcus aureus* and *Salmonella* spp (Table 6.6).

Table 6.4 indicate the various foods consumed by the children in the agro-pastoral wards (Karare and Sagante/Jaldesa) and levels of contamination. As observed from the urban region represented by Marsabit central ward, the agro-pastoral wards also considered as peri-urban areas have a variety of complementary foods. However, the contamination levels in the food is high with all the candidate pathogenic microorganism being isolated in all the foods posing health risks to the children. In these wards, milk products and rice showed the greatest risk with unsatisfactory quality levels recommended for healthy and safe complementary foods.

Table 6.5 Food samples distribution and microbial load for food samples collected in the Highland regions of Marsabit

Ward	Food type	LogTVC	Log TCC	LogMoulds	LogYeasts
Central	Milk tea (n = 18)	7.68cd ± 0.02	6.58e ± 0.35	0.00c ± 0.00	7.29de ± 0.08
	Others (n = 9)	7.74b ± 0.01	7.62bc ± 0.14	0.00c ± 0.00	7.54cd ± 0.02
	Qita (n = 11)	7.56d ± 0.03	7.25cd ± 0.10	0.00c ± 0.00	7.47cd ± 0.07
	UHT milk (n = 4)	7.54d ± 0.01	7.77ab ± 0.12	0.00c ± 0.00	7.44cd ± 0.07
	Cms (n = 9)	7.91ab ± 0.07	7.68b ± 0.05	0.00c ± 0.00	7.72a ± 0.05
	Mpv (n = 9)	7.77b ± 0.07	6.70de ± 0.22	0.00c ± 0.00	7.44cd ± 0.07
	Rmpcb (n = 3)	8.05a ± 0.01	8.05a ± 0.01	0.00c ± 0.00	6.42f ± 0.06
	USP (n = 13)	7.66cd ± 0.03	7.30cd ± 0.13	0.00c ± 0.00	7.72a ± 0.02
Sagante	Anjera (n = 3)	7.87b ± 0.01	8.05a ± 0.01	0.00c ± 0.00	7.64bc ± 0.01
	Githeri (n = 3)	7.84b ± 0.01	7.90ab ± 0.01	0.00c ± 0.00	7.54cd ± 0.01
	Milk tea (n = 9)	7.79b ± 0.03	7.92ab ± 0.04	0.00c ± 0.00	7.26de ± 0.09
	Others (n = 6)	7.57cd ± 0.05	7.67bc ± 0.02	0.00c ± 0.00	7.41cd ± 0.03
	Cms (n = 15)	7.71c ± 0.03	7.95ab ± 0.03	0.00c ± 0.00	7.50cd ± 0.09
	Gms (n = 6)	8.05a ± 0.01	7.56bc ± 0.13	0.00c ± 0.00	7.67b ± 0.01
	Mpv (n = 3)	7.87b ± 0.01	7.65bc ± 0.02	0.00c ± 0.00	7.67b ± 0.01
	Rmpcb (n = 9)	7.78b ± 0.07	7.94ab ± 0.05	0.00c ± 0.00	7.60bc ± 0.05
	USP (n = 2)	7.77b ± 0.01	7.72b ± 0.01	0.00c ± 0.00	7.65bc ± 0.01
Karare	Githeri (n = 1)	7.77b ± 0.01	8.05a ± 0.01	0.00c ± 0.00	7.40d ± 0.01
	Porridge (n = 3)	7.82b ± 0.01	7.72b ± 0.01	0.00c ± 0.00	7.70ab ± 0.01
	Cms (n = 38)	7.82b ± 0.04	7.85bc ± 0.05	0.45c ± 0.25	7.61bc ± 0.04
	Gms (n = 6)	8.01ab ± 0.02	7.81ab ± 0.11	0.00c ± 0.00	7.02e ± 0.19
	Mpv (n = 3)	7.75b ± 0.01	7.75ab ± 0.01	5.83a ± 0.06	7.43cd ± 0.01
	Rmpcb (n=9)	7.84b ± 0.03	7.79ab ± 0.07	0.00c ± 0.00	7.65bc ± 0.03
	USP (n = 9)	7.62cd ± 0.09	7.60bc ± 0.11	1.99b ± 0.04	7.52cd ± 0.04

Key: cms = cattle milk (smoked), gms= goat milk (smoked), USP= Ugali (stiff porridge), cams= camel milk (smoked), mpv= mixed potatoes and vegetables, rmpcb= rice, mixed with potatoes, cabbages and beans. Means with the same letter along the column is not significantly different at $p<0.05$. **Trend**: Microbial contamination of the foods consumed by children in agro-pastoral and urban were above the KEBs recommended limits.

6.4.4 Microbial Quality of Complementary Foods in Pastoral Areas

Table 6.8 present the types of sampled foods and the levels of contamination of the various foods in wards from the pastoral lowland regions. The pastoral children in Bubisa, Laisamis and Logologo were seen to consume different varieties of foods as sampled during the study. Similar to urban and agro-pastoral wards, foods in these lowland pastoral wards were highly contaminated. The TVC and TCC were above 10^7 CFU/ml, higher than recommended limits for ready to eat foods. Likewise, candidate pathogenic microorganisms were present in all the foods at quantities above 10^6 CFU/ml which is considered potential hazard for children and general human health. Goat milk which was the main complementary food had the highest level of contamination (10^8 CFU/ml) in terms of TVC, TCC in Bubisa compared to other food types.

Table 6.6 Food samples distribution and microbial load for food samples collected in lowland region of Marsabit

Region	Food type	LogTVC	Log TCC	LogMolds	LogYeasts
Bubisa	Anjera (n = 6)	7.73^{b} ±0.14	7.84^{ab}±0.08	0.00^{f}±0.00	7.65^{bc}±0.04
	Githeri (n = 3)	7.63^{cd}±0.01	7.85^{ab}±0.01	0.00^{f}±0.00	7.82^{ab}±0.01
	Milk tea (n = 3)	8.05^{a}±0.01	7.48^{bc}±0.01	0.00^{f}±0.00	7.60^{bc}±0.01
	Others (n = 3)	8.03^{a}±0.01	7.18^{cd}±0.04	0.00^{f}±0.00	7.51^{cd}±0.01
	UHT milk (n = 6)	7.98^{ab}±0.03	7.84^{cd}±0.08	0.00^{f}±0.00	7.57^{bc}±0.02
	Cams (n = 3)	8.05^{a}±0.01	7.36^{c}±0.02	0.00^{f}±0.00	7.50^{cd}±0.00
	Gms (n = 9)	8.02^{a}±0.01	7.56^{bc}±0.01	0.00^{f}±0.00	7.44^{cd}±0.02
	Rmpcb (n = 33)	7.75^{b}±0.04	7.64^{bc}±0.04	1.42^{e}±0.42	7.60^{bc}±0.02
	USP (n = 9)	8.05^{a}±0.01	7.82^{ab}±0.06	0.00±0.00	7.46^{cd}±0.02
Laisamis	Milk tea (n = 9)	7.52^{de}±0.16	7.23^{cd}±0.20	5.33^{b}±0.12	7.71^{ab}±0.16
	Porridge (n = 15)	7.50^{de}±0.10	7.31^{cd}±0.06	2.99^{d}±0.66	7.55^{c}±0.11
	Cms (n = 6)	7.78^{b}±0.04	7.96^{ab}±0.04	6.90^{a}±0.02	2.36^{i}±1.06
	Gms (n = 20)	7.81^{b}±0.07	7.59^{bc}±0.08	3.98c±0.53	7.85^{a}±0.10
	Rmpcb (n = 3)	$7.51\pm^{de}$0.01	6.88^{de}±0.06	5.51^{b}±0.02	7.49^{cd}±0.01
	USP (n = 42)	7.42^{de}±0.09	6.96^{d}±0.12	4.55^{c}±0.30	7.29^{de}±0.09
Logologo	Githeri (n = 1)	7.23^{f}±0.01	7.56^{bc}±0.01	0.00^{f}±0.00	7.40^{d}±0.01
	Others (n = 3)	7.33^{ef}±0.02	7.33^{c}±0.01	4.09^{c}±0.32	7.01^{f}±0.04
	Porridge (n = 6)	7.53^{de}±0.03	7.45^{bc}±0.10	0.00^{f}±0.00	7.51^{cd}±0.01
	UHT milk (n = 3)	7.32^{ef}±0.01	7.40^{bc}±0.01	0.00^{f}±0.00	7.51^{cd}±0.01
	Cms (n = 8)	7.45^{de}±0.06	7.54^{bc}±0.03	0.00^{f}±0.00	7.43^{cd}±0.03
	Cams (n = 3)	7.78^{b}±0.01	7.44^{bc}±0.01	0.00^{f}±0.00	7.20^{e}±0.03
	Gms (n= 1)	8.05^{a}±0.01	8.05^{a}±0.01	0.00^{f}±0.00	6.83^{g}±0.01
	Rmpcb (n = 18)	7.53^{de}±0.08	7.49^{bc}±0.11	2.04^{e}±0.70	7.40^{d}±0.09
	USP (n = 3)	7.92^{ab}±0.01	7.16^{cd}±0.02	0.00^{f}±0.00	0.00^{j}±0.00

Key: cms = cattle milk (smoked), gms= goat milk (smoked), USP= Ugali (stiff porridge), cams= camel milk (smoked), mpv= mixed potatoes and vegetables, rmpcb= rice, mixed with potatoes, cabbages and beans. Means with the same letter along the column are not significantly different at $p<0.05$. **Trend**: Microbial contamination of the foods consumed by children in pastoral wards were above the KEBs recommended limits.

6.4.5 Prevalence of *E. coli* and *Salmonella* spp in complementary foods in Marsabit

In terms of the enumeration of enteric coliforms, the overall microbial load of *E. coli* and *Salmonella* spp. was 7.24 ± 0.03 and 7.34 ± 0.04 log10 CFU/ml, respectively (Table 6.7). *E. coli* loads were significantly higher ($p < 0.001$) in Sagante/Jaldesa (7.56 ± 0.03 log10 CFU/ml), followed by the regions of Marsabit Central, Karare, Bubisa, Laisamis, and Logologo in that order (Table 6.7).

Table 6.7*:* Overall mean± SE of log_{10}CFU/ml of microbial pathogenic contaminant by ward

Region	*E. coli*	*Salmonella* spp	*Staphylococcus* Spp.
Karare (n=72)	$7.31^{c} \pm .0.03$	$7.36^{ab} \pm 0.06$	$7.39^{c} \pm 0.02$
Laisamis (n=107)	$6.95^{b} \pm 0.05$	$7.1^{a} \pm 0.17$	$6.91^{a} \pm 0.05$
Logologo (n=46)	$6.68^{a} \pm 0.01$	$7.45^{ab} \pm 0.06$	$7.19^{b} \pm 0.05$
Marsabit Central (n=97)	$7.53^{d} \pm 0.13$	$7.26^{ab} \pm 0.05$	$7.29^{bc} \pm 0.02$
Sagante/J (n=65)	$7.56^{d} \pm 0.03$	$7.33^{ab} \pm 0.06$	$7.25^{b} \pm 0.02$
Bubisa (n=84)	$7.24^{c} \pm 0.02$	$7.66^{b} \pm 0.02$	$7.17^{b} \pm 0.03$
Total (N=474)	7.24 ± 0.03	7.34 ± 0.04	7.18 ± 0.02
Sig	< 0.001	< 0.001	0.001

Numbers with different superscripts are significantly different at 95% Confidence interval.
Trend: Microbial pathogenic contaminants of the foods consumed by children in all the wards were above the KEBs recommended limits.

In terms of prevalence of pathogenicity, results of the current study showed *E. coli* was detected in 100% of all food samples tested in the six study sites (figure 6.1). There were significantly higher microbial counts of *Salmonella* spp. in Bubisa, followed by Logologo, Karare, Sagante, Marsabit Central, and Laisamis, respectively (Table 6.7). Moreover, the study shows that the prevalence of *Salmonella* spp was significantly high in samples collected in Bubisa at 57% followed by Karare (501%), Sagante/Jaldesa (34%), Laisamis (35.5%), Logologo (32%) and Marsabit central (31%) respectively (Figure 6.1).

Although not part of the study objective, the overall mean microbial count of *Staphylococcus* spp. was 7.18 ± 0.02 log10 CFU/ml, with higher occurrences observed in the agro-pastoral regions of Karare, Marsabit Central, and Sagante compared to the lowland regions of Logologo, Bubisa, and Laisamis (Table 6.7). *Staphylococcus* spp. was detected in 100% of samples collected in all regions except Karare, where the prevalence was 81% (Figure 6.1).

In terms of pathogenicity in complementary foods, *Qita* (a local composite recipe made of maize and wheat flour) and camel milk posed the highest health risk, with a 100% prevalence of *Salmonella* spp. followed by opened ultra-heat treated (UHT) milk at 61.5%, rice-based recipes at 52%, *githeri* (a mix of boiled maize and beans, sometimes mixed with potatoes and vegetables) at 50%, porridge at 45.8%, smoked cattle milk at 42.1%, *anjera* (a local pancake prepared from wheat flour) at 41.7%, and smoked goat milk at 38.6%. Milk tea, which was highly consumed, showed a 28% prevalence of *Salmonella* spp., in addition to a 38% prevalence contributed by other minor foods (Figure 6.2). The graph illustrates the prevalence of *Salmonella* spp., *E. coli*, and Staphylococcus spp. across various wards, with corresponding error bars indicating the variability in these estimates. *Salmonella* spp. generally shows more variability in its prevalence, as seen through the larger error bars in most wards, particularly in Bubisa and Karare, suggesting greater uncertainty in these measurements. In contrast, E. coli and *Staphylococcus* spp. consistently display smaller error bars across all wards, indicating more precise and reliable prevalence data. For example, in Bubisa, while the prevalence of *Salmonella* spp. varies significantly, the prevalence of *E. coli* and Staphylococcus spp. is recorded with higher precision. Similarly, in Karare and Logologo, the error bars for E. coli and *Staphylococcus* spp. are minimal, reflecting consistent data. Overall, *E. coli* and *Staphylococcus* spp. exhibit a high prevalence with smaller margins of error, while *Salmonella* spp. shows both lower prevalence and greater variability in the measurements across the wards (Figure 6.1).

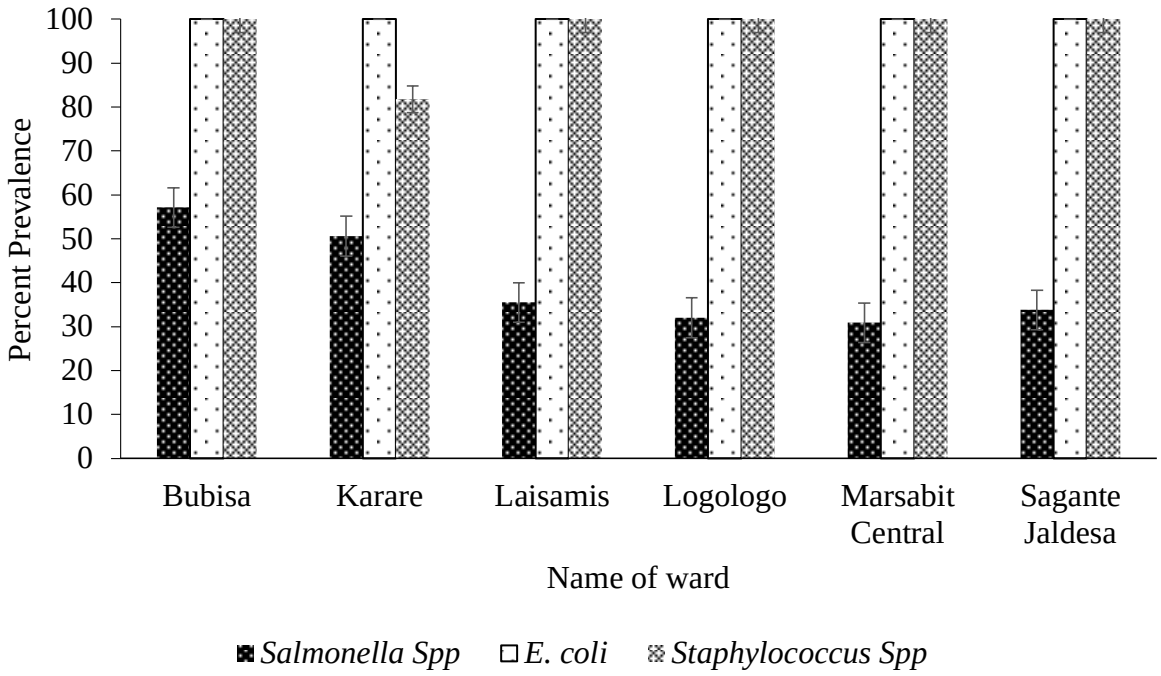

Figure 6.1 *Figure showing the percentage prevalence of potential food pathogens in food samples collected from different wards*

Trend: *E. coli* and *Staphylococcus* spp are more prevalent

(Bubisa, *N=84*, Karare, *N=77*, Laisamis *N=107*, Logologo, *N=50*, Marsabit Central, *N= 97*, and Sagante Jaldesa, *N=65*)

The prevalence of *Salmonella* spp., *Staphylococcus* spp., and *E. coli* in various food types, with error bars indicating variability in the estimates. Across all food types, Staphylococcus spp. shows consistently high prevalence, close to or at 100%, with minimal error bars, indicating precise measurements. *E. coli* also demonstrates high prevalence across most food types, although with slightly more variation in foods such as Githeri, Milk tea, and opened UHT milk, where error bars are slightly larger. *Salmonella* spp., on the other hand, has a lower prevalence compared to the other two pathogens, with more noticeable variability, as shown by the larger error bars in foods like Cams, Githeri, Milk tea, and UHT milk. These differences in prevalence and error bar sizes suggest that *Salmonella* spp. is less prevalent but shows more variability in its detection, while *Staphylococcus* spp. and *E. coli* are more prevalent and measured with greater precision across the different food types (Figure 6.2).

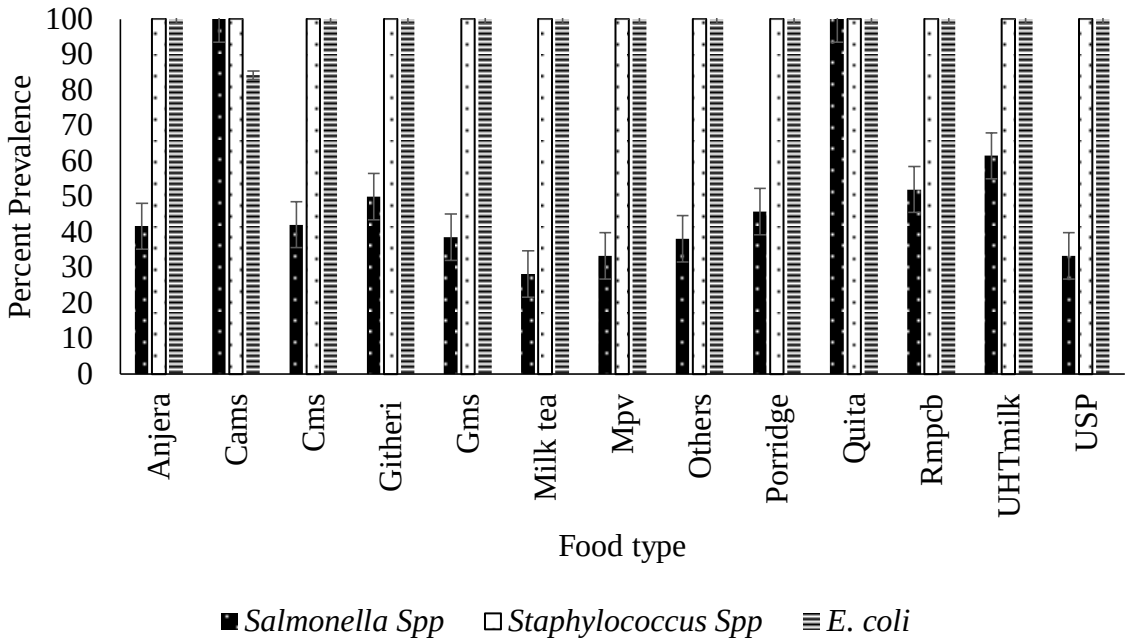

Figure 6.2 *The percentage prevalence of potential food pathogens in food samples collected from Marsabit County*

Trend: Prevalence of in foods *Salmonella* spp was dwarfed by *E. coli* and Staphylococcus spp in most complementary foods except in camel milk and *qita*

Key: (Anjera, n=12, cams, n=6, cms, n=76, githeri, n=12, gms, n= 44, Milk tea, n=39; mpv, n=15 others, n=21, porridge, n=24, Qita, n=11, rmpcb n=39, UHT milk, n= 75, and USP, n=78); cms = cattle milk (smoked), gms= goat milk (smoked), USP= Ugali (stiff porridge), cams= camel milk (smoked), mpv= mixed potatoes and vegetables, rmpcb= rice, mixed with potatoes, cabbages and beans

6.4.6. Analytical profile of phenotypic (API) Isolates

Table 6.8 provides a summary of the analytical profile index of phenotypic isolates from the samples collected in the six regions. In addition to the candidate bacteria (*E. coli* and *Salmonella spp. arizonae*), about eight other opportunistic bacterial phenotypes were identified. These included *Cronobacter* spp., *Klebsiella pneumoniae spp. pneumoniae*, and various *Enterobacter* spp. such as *E. aerogenes*, *E. cloacae*, *E. serratia* and *E. odorifera1*, which showed a higher prevalence compared to *E. coli* and *Salmonella enterica spp. arizonae*.

Other environmental microbial phenotypes identified included *K. pneumoniae spp. ozonae*, *Providencia rettgeri*, and *Roultella ornithinolytica*. *E. coli* was isolated in goat milk from

Bubisa, while *Salmonella enterica spp. arizonae* was isolated in cattle milk from Karare. *Cronobacter spp*. were mainly prevalent in foods such as *qita* mixed with beans, and porridge ingredients such as flour and water collected from the urban regions in Marsabit Central and Laisamis, respectively. *Klebsiella pneumoniae* spp. *pneumoniae* was isolated in *Ashir* (Marsabit central), maize flour (Laisamis), and *githeri* (Sagante/Jaldesa). *Enterobacter cloacae* occurred mainly in pooled water, hand swabs from Laisamis ward, and foods such as *fiqe* from Marsabit Central ward. *Enterobacter aerogenes* was isolated in cattle milk from Karare. *P. rettgeri* was found in tea with milk, while *Roultella ornithinolytica* was isolated in cattle milk from Laisamis. *E. serratia* and *E. odorifera* were more prevalent in cooked rice, hand swabs, and tea with milk.

The isolated microorganisms were tested for hemolysis of blood cells and drug resistance. An example of the hemolytic effect of *Salmonella* spp. for sample 15b sal (*Salmonella* Spp. plate) is shown in Figure 6.3.

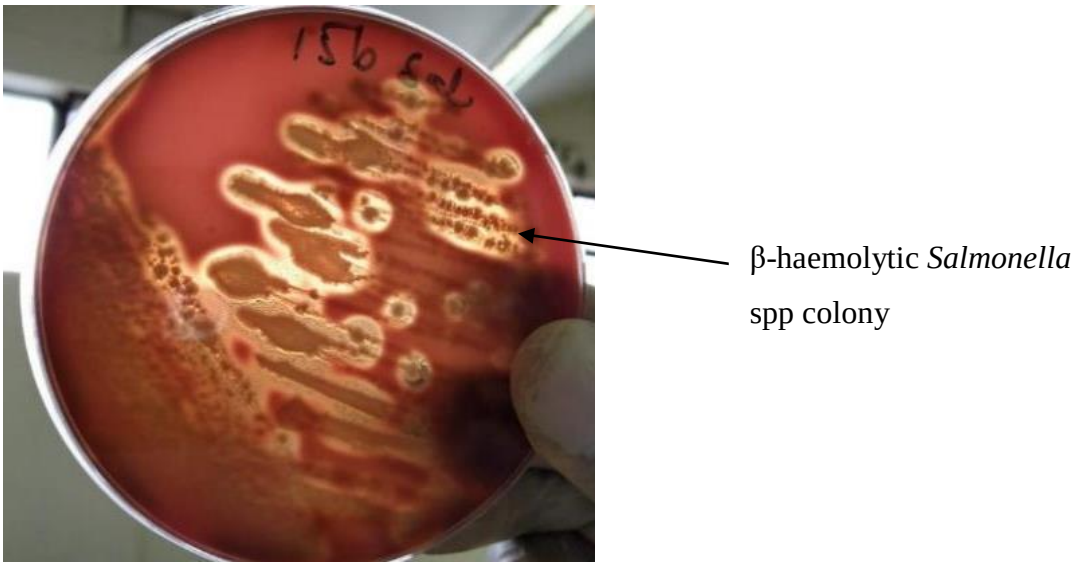

Figure 6.3*: Photo of β-haemolytic Salmonella spp colony*

Table 6.8 Phenotypic isolates from Analytical Profile Index (API) Kit

	Wards						
Phenotypic isolates	Karare (n = 2)	Laisamis (n = 11)	Logologo (n = 1)	Marsabit Central (n = 7)	Sagante/Jaldesa (n = 2)	Bubisa (n=2)	Total (N=25)
Cronobacter spp	0 (0.0)	1 (9.1)	0 (0.0)	3 (42.9)	0 (0.0)	1 (50.0)	5 (20.0)
Enterobacter aerogenes	1 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (4.0)
Enterobacter cloacae	0 (0.0)	0 (0.0)	0 (0.0)	1 (14.3)	0 (0.0)	0 (0.0)	1 (4.0)
Enterrobacter cloacae	0 (0.0)	1 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (4.0)
Entrobacter cloacae	0 (0.0)	0	0 (0.0)	0 (0.0)	1 (50.0)	0 (0.0)	1 (4.0)
Escherichia coli	0 (0.0)	1 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (4.0)
Klebsiella pneumoniae spp ozaenae	0 (0.0)	1 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (4.0)
Klebsiella pneumoniae spp pneumoniae	0 (0.0)	2 (18.2)	0 (0.0)	2 (28.6)	1 (50.0)	0 (0.0)	5 (20.0)
Providencia rettgeri	0 (0.0)	1 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (4.0)
Raoultella ornithinoltic	0 (0.0)	1 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (4.0)
Salmonella enterica spp arizonae	1 (50.0)	0	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (4.0)
Serratia odorifera	0 (0.0)	1 (9.1)	0 (0.0)	1 (14.3)	0 (0.0)	1 (50.0)	3 (12.0)
Unknown	0 (0.0)	2 (18.2)	1 (100)	0 (0.0)	0 (0.0)	0 (0.0)	3 (12.0)

Trend: *Salmonella* spp was isolated in Karare region mainly in cattle milk while *E. coli* was mainly Laisamis

6.4.7 Antibiotic Sensitivity of phenotypic isolates

Table 6.9 provides a summary of antibiotic sensitivity results based on mean (SE) inhibition zones in millimeters (mm). These inhibition zones were compared with the Clinical Laboratory Standards Institute (CLSI) breakpoints for each antibiotic against the bacterial isolates tested (CLSI, 2018). The results of the current study have shown that *E. coli* from northern Kenya was sensitive and resistant to more than 3 out of the eight antibiotics tested. *Escherichia coli* was resistant to penicillin, methicillin, ampicillin and lincomycin (50%). Additionally, *E. coli* was sensitive to Erythromycin, Co-trimoxazole and chloramphenicol (37%). *Salmonella enterica* spp *arizonae* was sensitive to minocycline, Co-trimoxazole, chloramphenicol and ampicillin (50%) and resistant to penicillin, Erythromycin, Methicillin and Lincomycin (37.5%).

As summarized in Table 6.10, the study findings showed that *E. coli* from northern Kenya was resistant to penicillin (G), methicillin (MET), ampicillin (AMP), and lincomycin (L). Additionally, *E. coli* was sensitive to erythromycin (E), co-trimoxazole (CoT), and chloramphenicol (C). The result of the current study also indicate *Salmonella enterica spp. arizonae* was sensitive to minocycline (MI), co-trimoxazole (CoT), chloramphenicol, and ampicillin, but resistant to penicillin (G), erythromycin (E), methicillin (MET), and lincomycin (L).

The other opportunistic bacterial isolates reported in this study showed multidrug resistance against the eight antibiotics tested. Most of the bacteria were resistant to penicillin (G) except *E. serratia odorifera*. *Cronobacter* spp. were resistant to penicillin (G), erythromycin (E), methicillin (MET), ampicillin (AMP), and lincomycin (L), and sensitive to minocycline (MI), co-trimoxazole (CoT), and chloramphenicol (C), with two subspecies being in the intermediate zone. Klebsiella pneumoniae spp. pneumoniae was sensitive to penicillin (G), minocycline (MI), erythromycin (E), methicillin (MET), co-trimoxazole (CoT), ampicillin (AMP), and lincomycin (L), but tended to be more sensitive to co-trimoxazole (CoT) and chloramphenicol (C).

Another significant bacterial isolate, E. cloacae, was resistant to penicillin (G), erythromycin (E), methicillin (MET), ampicillin (AMP), and lincomycin (L), with some subspecies showing sensitivity towards penicillin (G), co-trimoxazole (CoT), and chloramphenicol (C). E. aerogenes was resistant to penicillin (G), co-trimoxazole (CoT), and lincomycin (L), while

E. odorifera was resistant to all eight antibiotics tested. K. pneumoniae spp. ozaenae was resistant to penicillin (G), methicillin (MET), and lincomycin (L), while P. rettgeri showed varying sensitivity and resistance to penicillin (G), methicillin (MET), ampicillin (AMP), and lincomycin (L). R. ornithinolytica was sensitive to penicillin (G), erythromycin (E), methicillin (MET), co-trimoxazole (CoT), ampicillin (AMP), and lincomycin (L). The results demonstrated a high level of multidrug resistance among the bacterial phenotypic isolates tested.

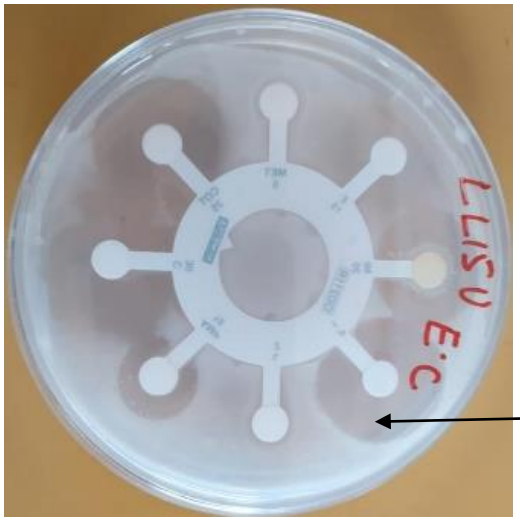

***Figure 6.4**: photo of Inhibition zone of E. coli colony*

Table 6.9 Mean (SE) inhibition zone in mm for the various antibiotic drugs

Antibiotic	*Cronobacter spp (n=5)*	*Enterobacter aerogenes (n=2)*	*Enterobacter cloacae (n=1)*	*Enterobacter serratia, odorifera1 (n=4)*	*K. pneumoniae, spp pneumoniae (n=5)*	*K. pneumoniae, spp ozaenae (n=1)*	*Providencia rettgeri (n=1)*	*Roultella ornithinolitic (n=1)*	***Salmonella enterica, arizonae (n=1)***	*Unknown (n=3)*	***E. coli (n=1)***
P	21.6 (0.25)	24.5 (1.50)	20.00	18.5 (1.90)	18.4 (0.25)	19.00	22.00	0.00	**0.00**	20 (2.50)	**22.00**
MI	15.6 (0.25)	20.5 (2.50)	15.00	9 (3.50)	10.8 (3.70)	19.00	15.00	20.00	**28.00**	16.67 (3.50)	**20.00**
E	10.6 (4.45)	19 (0.00)	0.00	11.75 (4.40	17.8 (1.72)	27.00	18.00	0.00	**0.00**	17 (2.00)	**23.00**
MET	4.6 (1.90)	4 (4.00)	0.00	1.75 (1.75)	5.2 (1.32)	7.00	7.00	0.00	**0.00**	2.67 (2.67)	**7.00**
CoT	25.2 (0.37)	12.5 (12.50)	26.00	17.25 (5.7)	17.2 (4.30)	23.00	26.00	0.00	**28.00**	16.67 (8.40)	**26.00**
C	25.6 (0.68)	27.5 (3.50)	25.00	23.75 (2.18)	24.2 (0.74)	22.00	24.00	27.00	**28.00**	27 (2.08)	**23.00**
A	0 (0.00)	0 (0.00)	0.00	0 (0.00)	6.4 (1.60)	16.00	0.00	0.00	**20.00**	0 (0.00)	**0.00**
L	0 (0.00)	0 (0.00)	0.00	0 (0.00)	0.0 (0.00)	8.00	0.00	0.00	**0.00**	0 (0.00)	**0 (0.00)**

Key: penicillin (G), methicillin (MET), ampicillin (AMP), and lincomycin (L), Erythromycin (E), Co-trimoxazole (CoT) and chloramphenicol (C), and minocycline (MI).**Trend**: *Salmonellaenterica* and *E. coli* were resistant to multiple drugs

Table 6.10 Antimicrobial sensitivity profile of phenotypic isolates according to heamolytic classes

		Antibiotic Drugs Tested																% MDR Index		
		PR		MI			E			MET	CoT		C	AMP			L	Mean		
Phenotypic isolate	Blood Agar	R	S	I	R	S	I	R	S	R	R	S	S	I	R	S	R	S	I	R
Cronobacter spp	Beta	3	0	0	0	2	2	1	0	3	0	3	3	0	3	0	3	37.5	0	62.5
	Gamma	2	0	1	0	1	1	1	0	2	0	2	2	0	2	0	2	32	12	56
Enterobacter aerogenes	Beta	1	0	0	0	1	1	0	0	1	1	0	1	0	1	0	1	25	12	62
	Gamma	0	1	0	0	1	1	0	0	1	0	1	1	0	1	0	1	50	12	38
Enterobacter cloacae	Beta	1	0	1	0	0	0	1	0	1	0	1	1	0	1	0	1	25	12	62.5
K. pneumoniae, spp pneumoniae	Beta	5	0	0	5	0	4	1	0	5	1	4	5	0	5	0	5	25	10	67
K. pneumoniae, spp ozaenae	Gamma	1	0	0	0	1	0	0	1	1	0	1	1	1	0	0	1	50	12	38
Providencia rettgeri	Alpha	1	0	1	0	0	1	0	0	1	0	1	1	0	1	0	1	25	25	50
Roultella ornithinolitic	Alpha	1	0	0	0	1	0	1	0	1	1	0	1	0	1	0	1	25	0	75
Salmonella enterica	Beta	**1**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**	**1**	**0**	**0**	**1**	**1**	**50**	**0**	**50**
Unknown	Alpha	2	0	0	1	1	1	1	0	2	1	1	2	0	2	0	2	25	6	69
E. coli	Beta	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**1**	**1**	**0**	**1**	**0**	**1**	**50**	**0**	**50**

[1] R means Resistance, S- Sensitive, I- intermediate; MDRI- Multiple Drug Resistance Index

Trend: *Salmonella*enterica and *E. coli* showed higher sensitivity and resistance to multiple antibiotic drugs

6.4.8 Factors influencing occurrence of *TVC, TCC, E. coli, Yeast and mold, Staphylococcus spp., Salmonella* loads in complementary foods in Marsabit

Table 6.11 provides summary of linear regression factors influencing microbial loads (TVC, TCC, *E. coli*, yeast, molds, *staphylococcus* spp and *Salmonella* spp in the food, water and hand swabs in the study area. Significant factors influencing occurrence of TVC loads included distance to the nearest market ($p< 0.001$), primary occupation of both household head ($p< 0.05$) and caregiver ($p< 0.05$), number of children under five years in a household ($p< 0.001$). Total coliforms counts were influenced by distance to nearest market ($p< 0.05$), if household practiced crop farming ($p< 0.001$), if household treated water before drinking ($p< 0.001$) and if index child experienced diarrheal episodes a fortnight preceding the survey time (Table 6.11)

Prevalence of *Escherichia coli* in the samples was found to be significantly influenced by factors such as; distance to the nearest market ($p< 0.001$), livestock keeping by household head ($p< 0.001$). Other significant factors influencing occurrence of *E. coli* included source of water for drinking ($p< 0.001$), time taken to water source and back ($p< 0.001$), quantity of water utilized by household per day ($p< 0.05$), faeces disposal methods ($p< 0.05$) and diarrheal episodes among children two weeks to survey time ($p< 0.001$) (Table 6.11).

Significant factors influencing occurrence of molds in the study areas encompassed distance to the nearest market ($p< 0.001$), family size ($p< 0.01$), crop farming ($p< 0.001$), care giver marital status ($p< 0.001$), occupation ($p< 0.01$), income ($p< 0.05$), gender of index child ($p< 0.05$), source of water for drinking ($p < 0.001$), quantity of water consumed by households per day ($p < 0.05$), diarrheal episodes ($p< 0.01$) and disposal of fecal material ($p< 0.001$). Furthermore, yeast prevalence was significantly influenced by livestock keeping, ($p< 0.01$), caregiver level of education completed ($p< 0.01$), income ($p< 0.05$), time taken to water source and back ($p< 0.001$), quantity of water used by u=household per day ($p< 0.01$) and cleanliness of household compound ($p < 0.01$). Occurrence of *Salmonella* Spp was significantly influenced by; distance to nearest market, negatively associated with household head level of education ($p< 0.001$) and age ($p< 0.001$). Additionally, care education level ($p< 0.001$) and water treatment practices ($p< 0.001$) significantly influence occurrence of *Salmonella* in the samples analyzed. Family size ($p< 0.001$), caregiver occupation, source of drinking water, disposal of fecal materials and reported cases of diarrheal episodes among

children ($p< 0.05$) were the significant predictors of *Staphylococcus* Spp occurrence in the study area (Table 6.11).

The age of the household head had a significant positive association with the presence of total coliform counts (TCC) and E. coli, suggesting that older heads of households may have practices or conditions contributing to contamination. However, it had a negative association with *Salmonella* spp., indicating that older heads might be more cautious in practices reducing Salmonella risks. Marital status of the caregiver did not significantly affect most pathogens, though it was negatively associated with mold contamination, suggesting a potential role in food preparation. Regarding gender of the child, no significant effect was found for most contaminants, except a negative association with molds, which might suggest gender-related caregiving practices that influence exposure to certain types of contamination. The findings suggest that while age and marital status of caregivers and household heads may have some impact on food safety, gender of the child has a minimal influence overall. Other factors, like education and water quality, played a more prominent role in contamination levels.

Table 6.11: Effect of Demographic and Environmental (WASH) Factors on the Quality and Safety of Complementary Foods

Predictor variables	TVC	TCC	*E. coli*	molds	Yeasts	*Staph*.spp	*Salmonella* spp
Bo	7.515	6.836	6.043	4.545	7.586	6.624	7.732
Distance to nearest market (in Km)	0.209^{***}	0.122^{*}	0.180^{***}	-0.221^{***}	-0.048^{ns}	0.090^{ns}	0.178^{***}
Family size	0.115^{ns}	0.018^{ns}	-0.010^{ns}	-0.135^{*}	0.018^{ns}	0.160^{***}	0.105^{ns}
Age of Household Head (years)	0.044^{ns}	0.110^{*}	0.124^{*}	-0.095^{ns}	0.069^{ns}	0.054^{ns}	-0.168^{***}
Household head highest level of education	0.006^{ns}	-0.070^{ns}	0.099^{ns}	0.031^{ns}	0.105^{ns}	0.076^{ns}	-0.221^{***}
Primary occupation of household head	-0.138^{*}	0.088^{ns}	-0.121^{ns}	-0.090^{ns}	0.049^{ns}	-0.037^{ns}	-0.147^{*}
If household head keeps livestock	0.062^{ns}	0.046^{ns}	0.131^{***}	-0.014^{ns}	-0.100^{*}	-0.030^{ns}	0.045^{ns}
If household head grows crops	-0.044^{ns}	-0.157^{***}	-0.002^{ns}	0.124^{***}	0.044^{ns}	-0.053^{ns}	-0.073^{ns}
Marital status of care giver	0.016^{ns}	0.044^{ns}	0.042	-0.206^{***}	-0.002^{ns}	0.038^{ns}	-0.056^{ns}
Caregiver highest level of education	0.060^{ns}	0.094^{ns}	0.047^{ns}	0.006^{ns}	-0.128^{*}	0.052^{ns}	0.249^{***}
Caregiver primary occupation	0.126^{*}	0.016^{ns}	0.043^{ns}	-0.103^{*}	0.017^{ns}	0.109^{*}	-0.070^{ns}
Caregiver grouped Income	0.020^{ns}	0.053^{ns}	0.025^{ns}	0.094^{*}	0.156^{***}	-0.032^{ns}	-0.022^{ns}
Number of children under five years of age	-0.156^{***}	0.054^{ns}	0.037^{ns}	0.010^{ns}	-0.029^{ns}	-0.016^{ns}	-0.037^{ns}
Gender of index child	0.033^{ns}	0.007^{ns}	0.011^{ns}	-0.085^{*}	-0.021^{ns}	0.012^{ns}	-0.051^{ns}
Source of drinking	0.080^{ns}	0.029^{ns}	0.189^{***}	-0.132^{***}	-0.016^{ns}	0.122^{*}	0.062^{ns}
Return Time to water source,	0.013^{ns}	0.157^{ns}	0.135^{***}	-0.120^{***}	0.167^{**}	0.044^{ns}	-0.009^{ns}
Daily Quantity of water used by household	0.053^{ns}	0.013^{ns}	-0.116^{*}	0.100^{*}	-0.121^{*}	-0.030^{ns}	0.088^{ns}
If household treats water before drinking	0.027^{ns}	0.248^{***}	-0.058^{ns}	0.018^{ns}	0.036^{ns}	-0.032^{ns}	0.165^{***}

Predictor variables	TVC	TCC	*E. coli*	molds	Yeasts	*Staph*.spp	*Salmonella* spp
Disposal of child waste/faeces	-0.006^{ns}	-0.074^{ns}	0.092*	-0.150***	-0.032^{ns}	0.122*	0.057^{ns}
If household compound is clean	-0.057^{ns}	-0.040^{ns}	0.020^{ns}	0.085^{ns}	-0.259***	0.063^{ns}	-0.061^{ns}
If child experienced diarrhoea past 2 weeks	-0.009^{ns}	-0.133*	0.174***	-0.121*	-0.011^{ns}	0.111*	-0.008^{ns}

ns means Not Significant at (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$)

Trend: *E. coli* was positively associated with child diarrhoea, poor disposal of child faecal waste, source of drinking water, livestock ownership and distance to nearest market while *Salmonella* spp was mainly associated with source of drinking water and level of education of both household head and caregiver/mother .

6.4.9 Association between microbial contaminants and nutritional status of children

Nutritional status results are presented in Chapter 4 of this report. This section assesses the relationship between microbial factors and nutritional status (stunting and underweight) among children. Table 6.12 summarizes the univariate and multivariate results of the binary logistic regression of TVC (Total Viable Count), TCC (Total Coliform Count), yeasts, molds, and pathogens (*E. coli*, *Salmonella* spp., and *Staphylococcus* spp.) regressed against stunting and underweight respectively.

The results of the current study show that children who consumed foods with high total viable counts were four times more likely to be underweight (AOR = 4.304, 95% CI: 0.29 - 0.92, p = 0.004). However, the prevalence of *Salmonella* spp. was less likely to result in underweight among children in the study area (AOR = 0.499, 95% CI: 0.33 - 0.75, p = 0.001).

Children who consumed foods with elevated mold contamination were more likely to be stunted (AOR = 1.314, 95% CI: 1.19 - 1.46, p< 0.001). Additionally, children fed on foods contaminated with *E. coli* were 1.9 times more likely (AOR = 1.88, 95% C.I: 1.18 – 3.01, p = 0.008) to be stunted (table 6.4.12). However, exposure to *Salmonella* spp. reduced the likelihood (AOR = 0.572, 95% CI: 0.39 - 0.82, p = 0.003) of a child being stunted in Marsabit County. Similarly, the occurrence of Staphylococcus spp. in complementary foods was less likely (COR = 0.367, 95% CI: 0.21 - 0.64, p< 0.001) to result in stunting among children.

Table 6.12: Binary logistic regression of association between microbial contaminants and child nutritional status

	Stunting				Underweight			
	COR	Sig	AOR	Sig	COR	Sig	AOR	Sig
TVC	1.30 (0.70, 2.42)	0.408	2.37 (0.95, 5.88)	0.064	2.29 (1.07, 4.88)	0.033	4.304 (1.57, 11, 76)	.004
TCC	1.21 (0.86, 1.69)	0.277	1.41(0.87, 2.27)	0.163	1.29 (0.87, 1.93)	0.206	1.13 (0.71, 1.79)	.603
Yeast	0.91 (0.53, 1.55)	0.715	0.544(0.29, 1.01)	0.054	1.47 (0.79, 2.73)	0.227	0.921 (0.465, 1.82)	.812
Mold	1.23 (1.13, 1.33)	<0.001)	1.314 (1.19, 1.46)	<0.001)	1.02 (0.93, 1.11)	0.731	1.077(0.97, 1.20)	.175
E. coli	1.99(0.84, 1.72)	0.324	1.88 (1.18, 3.01)	0.008	0.991(0.68, 1.45)	0.962	0.834 (0.22, 3.16)	.790
Salmonella Spp.	0.732 (0.58, 0.93)	0.009	0.572(0.398, 0.82)	0.003	0.651 (0.50, 0.85)	0.001	0.499(0.33, 0.75)	.001
Staphylococcus Spp.	0.367 (0.21, 0.64)	<0.001	0.550 (0.27, 1.12)	0.101	1.132 (0.60, 2.13)	0.701	1.446 (0.66, 3.19)	.361

COR means Crude Odds Ratio; AOR means Adjusted Odds Ratio; Sig means significant at 96% Confidence interval

Trend. *Salmonella* spp and *E. coli* spp were strongly associated with stunting while *E. coli* was associated with underweight

6.5 Discussion

This study focused on assessing the microbial safety of complementary foods given to children aged 6-59 months in settled pastoral households in northern Kenya. The analysis of microbial contamination across six regions, covering both the lowlands and highlands of Marsabit County, revealed substantial differences in contamination levels across various food products. Utilizing a nested model in the analysis of variance, significant factors contributing to microbial contamination were identified, supported by significant p-values ($p < 0.001$) for Total Viable Counts (TVC), Total Coliform Counts (TCC), *E. coli*, molds, yeasts, *Staphylococcus spp.*, and *Salmonella spp.* The R^2 values, ranging from 0.425 to 0.927, highlighted the strong influence of these factors on microbial contamination (Appendix **G**).

The differences in food handling practices among caregivers at the various study sites, alongside environmental factors such as sanitation and water access, played a pivotal role in the observed disparities in microbial contamination. Significant effects of wards and locations were seen regarding the presence of TVC, TCC, *E. coli*, molds, yeasts, and *Staphylococcus spp.* ($p < 0.001$), underscoring the variation in food handling practices among caregivers. The improper storage of food, the use of unsafe water sources, and the inconsistent application of hygienic practices likely contributed to these findings. Furthermore, the lack of refrigeration in many households would have accelerated the proliferation of microbes, particularly in foods that are prone to spoilage such as milk and meat.

Region-level influences were also noted for *Salmonella spp.*, though this effect was less pronounced at the location level (Table Appendix vii). The interaction and nesting effects of microbial contaminants consistently showed significant relationships ($p < 0.001$) across all microorganisms tested, illustrating the complex and interconnected factors that contribute to contamination in complementary foods.

The analysis of mean microbial loads in different wards (Table 6.2) revealed significant contamination across all regions, with Bubisa exhibiting higher Total Viable Counts (TVC) compared to other regions. In terms of pathogenic microorganisms, Sagante/Jaldesa and Marsabit Central exhibited elevated levels of *E. coli*, while Bubisa had a higher prevalence of *Salmonella spp.* These findings highlight the potential health risks associated with the

consumption of contaminated foods, particularly in young children, who are more susceptible to foodborne diseases.

The mean TVC in food samples ranged from 7.86 log10 CFU/ml in Bubisa to 7.52 log10 CFU/ml in Laisamis, with all samples exceeding the recommended quality limit for bacterial loads in ready-to-eat food, which is set at 10^3 to 10^5 CFU/ml for microbiological quality standards (KEBS, 2022). This alarming result suggests widespread food safety issues in these regions, potentially driven by improper food handling, unsafe water usage, and environmental sanitation challenges.

Caregivers' practices during food preparation, such as the improper storage of food, limited access to clean water, and insufficient cooking, likely played a crucial role in the observed microbial contamination levels. These practices, compounded by environmental factors like inadequate sanitation facilities and poor personal hygiene, demonstrate the urgent need for targeted interventions to improve food safety practices in these households. Implementing educational programs focused on proper food handling, storage, and hygiene practices, as well as increasing access to clean water and sanitation, could mitigate these risks and improve the safety of complementary foods for children in the region.

Comparisons with related studies revealed that the TVC load in this research aligns with findings in milk at the farm level in Rwanda, where total bacterial counts ranged from 10^6 CFU/ml at the farm level to 10^8 CFU/ml at milk collection centers (Ndahetuye*et al.*, 2020). Despite pastoralists favoring raw smoked milk over boiled milk (Wayua, 2017), the TVC loads reported here were lower than those documented for complementary food and drinking water among children in Zanzibar, Tanzania (Kung'u *et al.*, 2009; Miller, 2020). Conversely, a study conducted among bottle-fed babies in an outpatient facility in Arba Minch, southern Ethiopia, reported higher TVC in CFU/ml for ready-to-eat complementary food compared to the levels reported in this study (Marege *et al.*, 2023).

Reliance on perishable foods like cabbages, tomatoes, onions, and Irish potatoes sourced from other counties, such as Isiolo (288 km) and parts of Meru County (approximately 400 km away), could potentially impact the microbial integrity of consumed food in the study areas. Figure 6.2 displays the different foods consumed among them being mixture of foods having vegetables rice beans. As noted by Grace (2015), the elongation of food value chains,

leading to bulking at distribution points like markets, may foster the proliferation of foodborne pathogens, potentially contributing to the elevated TVC observed in this study. A study by Nato *et al.* (2018) reported a change in microbial load in pastoral milk in northern regions, from a mean ± SD 10 4.91±1.04 $\log_{10}$ CFU/ml at production to 7.52±1.32 $\log_{10}$ CFU/ml at the terminal market in Nairobi, illustrating the impact of transportation on the quality of milk products. As heating of the foods follows log reduction in the destruction of the microbes, the higher the numbers the higher the load in the final products.

The detailed breakdown of microbial loads in various complementary foods across the county revealed extensive contamination, with higher total viable counts, total coliforms, and yeast observed as observed in tables 6.5 and 6.6. Notably, pathogens such as *E. coli*, *Salmonella* Spp, and *Staphylococcus* Spp posed significant threats to human health, being isolated in the majority of the collected food samples. Camel milk and *qita* generally indicated highly contaminated food with *Samolnella* Spp and *E. coli*. The detection of Total Coliform Counts (TCC) in a sample serves as a proxy indicator of unsanitary environmental coliform conditions during food preparation. In the current study, the mean TCC across the wards ranged from $\log_{10}$ 6.74± 0.024 CFU/ml in rice, mixed potatoes cabbages and beans mixture to $\log_{10}$ 7.86 ± 0.03 CFU/ml in *githeri* (table 6.5). These findings were twice as high as the recommended limit of $\log_{10}$ 3.0 CFU/ml, resulting in a prevalence rate of 100% (KEBs, 2022). Despite some pastoralists transitioning to a more sedentary lifestyle, they still maintain a few home-based lactating herds to supply milk to the family. This interaction with livestock may present challenges related to environmental sanitation, especially as most households live in close proximity to home-based lactating animals, particularly goats and camels. Additionally, the responsibility of milking goats generally falls on caregivers, with the majority being mothers in this case. Unsanitary milking of the goats, poor storage conditions and post-cooking contamination by the caregivers due to poor sanitation are major factors contributing to the cross contamination.

The occurrence of microbial contamination in different wards of Marsabit County varied significantly. In Bubisa, the microbial contamination, particularly Total Viable Counts (TVC) and Total Coliform Counts (TCC), were notably higher than in other wards. The predominant consumption of smoked goat milk in Bubisa, which exhibited the highest TVC (10^8 CFU/g), may explain this elevated contamination. Bubisa's pastoral lifestyle, reliance on traditional

food processing methods, and limited access to refrigeration or sanitation infrastructure contribute to these findings. Studies in other rural African settings have similarly reported higher contamination levels in areas with traditional food handling and preservation methods, especially in milk products (Ayele *et al.*, 2021). In comparison, wards like Laisamis and Logologo, while still showing high microbial contamination, exhibited slightly lower TVC levels in foods such as porridge and rice, likely due to their proximity to peri-urban centers, where food handling practices might be relatively improved (Abebe & Kifle, 2019).

In contrast, urban and agro-pastoral areas like Marsabit Central, Karare, and Sagante/Jaldesa also exhibited high microbial loads in complementary foods, but different foods posed greater risks in these regions. For example, in Marsabit Central, raw cattle milk, boiled rice, and local dishes like kurkufa had unsatisfactory levels of microbial contamination, often exceeding the recommended limits for TVC (7.91 log10 CFU/ml). The use of processed foods, though present, did not mitigate contamination, likely due to improper storage and handling post-purchase. Similar trends of foodborne pathogens, such as *E. coli* and *Salmonella*, being prevalent in urban settings have been observed in other studies, particularly in sub-Saharan Africa (Lassi *et al.*, 2020). These findings suggest that both environmental factors and cultural food practices play crucial roles in determining microbial safety, necessitating tailored interventions to reduce contamination risks in both rural and urban settings.

The handling practices of complementary foods are crucial for ensuring their safety by preventing spoilage and the presence of pathogenic microorganisms. Employing appropriate methods, such as thermal treatment at the correct temperature, is vital to maintain food integrity in terms of safety and nutritional quality. However, the risk of post-processing contamination by spoilage and pathogenic bacteria exists due to contact with unsanitary environments, unhygienic conditions of the food handlers, dirty equipment or equipment cleaned with untreated water (microbial load for water from the different regions given in table 6.3) and improper cooking practices, allowing the survival of thermo-tolerant microbes. Figure 1 indicates the prevalence of potential pathogens in different regions. *E. coli* recorded prevalence of 100%, *S. aureus* approximately 90% and *Salmonella* spp approximately 41% in all the areas. This can be attributed to the handling by the caregivers causing post-cooking or handling contamination. As indicted in table 6.5 for highland regions and table 6.6 for lowland region, the foods were highly contaminated with TVC, TCC, *E. coli* and *S. aureus.*

Inadequate preservation and storage facilities may further contribute to the proliferation of spoilage and pathogenic microorganisms in the food matrix, making it unsafe for consumption. The occupation of the household head and caregiver significantly influences the quality of purchased food, particularly in rural settings where certain occupations may adversely impact food quality. In rural pastoral livelihoods, where livestock management, such as milking and food handling, remains pivotal, interactions between these practices and caregivers' responsibilities, including cleaning parlors and tending to young stock, may pose risks of food contamination. Caregivers, often responsible for household sanitation, can inadvertently become vectors of the pathogens and spoilage microbes in food if not handling practices are inadequate. Previous studies have highlighted the potential link between livestock keeping and the spread of foodborne microbial pathogens (Chen *et al.*, 2022; Ngure *et al.*, 2019).

Water remains crucial for food safety, and contaminated water can compromise both food safety and quality. Table 6.3 indicate the microbial contamination of pooled water collected from different regions. The water was highly contaminated due to lack of treatment, and being borehole, water mostly contaminated by the running water from the fields that animals defecate most especially in the lowlands and occasional floods. It may also serve as a direct source of diarrheic pathogens if consumed by a child in its raw form. In this study, the time taken to reach the water source and return, the quantity of water consumed by the household per day, and the lack of water treatment significantly contributed to the high prevalence of *E. coli* in complementary foods, water, and hand swabs. However, yeast was the only microbial contaminant that showed an effect on the cleanliness of the compound, with cleaner compounds exhibiting less yeast occurrence. Cleanliness of compounds was notably poor in the lowlands, where compounds were littered with various livestock waste materials, ranging from droppings to bones and skins of dead animals.

Upon specific regional analysis, Marsabit Central ward, representing an urban lifestyle, revealed heavily contaminated processed foods, raising concerns about their safety. In the highland regions associated with Agro-pastoral wards, such as Karare and Sagante/Jaldesa, also exhibited high contamination levels in various complementary foods, underscoring the urgency of enhanced food safety practices. In lowland pastoral areas like Bubisa, Laisamis, and Logologo, goat milk, a primary complementary food, displayed the highest

contamination levels, surpassing recommended limits for Total Viable Counts and Total Coliforms. This poses potential health hazards for children in these areas. The hygienic practices of caregivers, as assessed through hand swabs, revealed concerning behaviors contributing to food contamination. While mold levels exhibited variation, other indicators of contamination suggested potential transmission from caregivers to children.

The study confirmed the presence of pathogenic bacteria, such *as E. coli* and *Salmonella spp*, in most of the samples analyzed, aligning with findings by Smith *et al.* (2019), who observed a similar prevalence of zoonotic pathogens in beef and swine meat in Canada, including 100% prevalence of *E. coli* in meat. Additionally, spoilage and toxigenic bacteria, including Staphylococcus spp, were identified. The mean viable loads of *E. coli* were $\log_{10}$ 7.13 CFU/ml in hand swab samples, $\log_{10}$ 7.14 CFU/ml in water, and ranged between 4.0 to 8.05 CFU/ml depending on the food type and locality. For *Salmonella s*pp, prevalence of above 40% in the food samples collected in the regions was observed especially goat milk having high prevalence. These findings, while high, compared favorably with figures from some complementary foods in agro-pastoral regions in Karamoja, Uganda, but were notably higher than those in pastoral and agricultural regions (Okidi *et al.*, 2022). Figure 6.2 similarly gives a picture of seriousness in community awareness on matters concerning to food safety as the foods were contaminated with potential pathogens could lead to diarrhoea and potential food diseases such as staphylococcal food poisoning.

Most samples exceeded the recommended limits for *E. coli* contamination (>2.0 CFU/ml), with 95.7% of samples in Karare ward and 100% in the remaining five wards. However, these figures were lower than those reported in previous studies in Bangladesh (Samad *et al.*, 2021) and in water samples from rivers in South Africa (Madilonga *et al.*, 202; Potgieter *et al.*, 2020). A review of zoonoses found in milk by Mpatswenumugabo *et al.* (2023) indicated that *E. coli* and *Salmonella* spp were the most frequently reported zoonotic pathogens after *Brucella* spp in East Africa. These pathogens, including *E. coli*, *Salmonella* spp, and *Staphylococcus* spp, are recognized for their capacity to cause diarrhea, thereby compromising the nutritional status of children whose immune systems are still in the developmental stage. The prevalence of these microorganisms was alarmingly high, with 100% of loads surpassing the established limits for ready-to-eat foods (CLSI, 2018).

Regarding the occurrence of yeast and molds, 100% and 21% of samples, respectively, were affected by these contaminants, further indicating the poor quality and safety of complementary foods provided to children in the study area. Yeast and molds can disrupt the nutrient content of food through fermentation, rendering the food nutritionally compromised. Additionally, molds may introduce mycotoxins into foods.

Phenotypic isolates from the Applied Profile Index (25E) as in table 6.10 indicated the presence of *E. coli* and *Salmonella enterica spp arizonae*. Other opportunistic bacteria isolated in food, water, and hand swabs, such as *Enterobacter* spp, *Klebsiella pneumonia spp pneumonia*, *Cronobacter* spp among others, present an additional dimension in examining the ecological properties of microbial contaminants in population-based studies. Moreover, exploring cultural practices, such as the sniffing of tobacco among pastoralists, could provide further insights into any potential associations between these known nasopharyngeal bacteria and their presence in complementary foods.

The study results have also revealed that the majority of phenotypic isolates exhibited both alpha and gamma haemolysis. The most important was the beta-hemolysis which showed the effect of the pathogens in blood cell hemolysis. Figure 6 shows example of the *Salmonella* spp, depicting beta-hemolysis hence a potential health and disease-causing pathogen. From the API isolation it was noted that some of the *Salmonella* species identified originated from reptiles such as snake which are rampant in the study area as they look for water and shed in the settlement areas.

Figure 6.4 provide an example of *E. coli* isolate from sample LL15U and the resistance to the different drugs. This study revealed that most of the microorganism had resistance to multidrug (table 6.9 and table 6.10). Numerous prior studies have similarly reported multidrug resistance in *E. coli* within pastoral environments, particularly in camel and cattle milk in northern Kenya (Nato *et al.*, 2018), as well as in fresh foods sold in markets in Bangladesh (Samad *et al.*, 2023). Additionally, Bolukaoto *et al.* (2021) confirmed the presence of Hybrid Diarrheagenic *E. coli* in environmental waters in South Africa. Various factors have been identified as key facilitators of antimicrobial resistance (AMR).

The interaction between livestock, wildlife, and humans can contribute to the transfer of antimicrobial resistance genes in pathogenic microorganisms. For instance, Muloi *et al.*

(2023) observed that the carriage of antimicrobial resistance genes is significantly higher when manure is kept in close proximity to households. Factors contributing to antimicrobial resistance include, but are not limited to, easy access to antibiotics for both livestock and human treatment, lack of awareness regarding AMR, and unregulated access to pharmacies and agro-chemical suppliers in low-income settings (EFSA Panel on Biological (Hazards *et al.*, 2022; Muloi *et al.*, 2023).

The negative impact of higher TVC on food quality extends to nutritional integrity, with a significant association observed between increased TVC and underweight and wasting among children as in table 6.2. Islam *et al.* (2012) similarly reported a significant association between aerobic plate count and wasting in children in Bangladesh. Elevated TVC in food may compromise nutrient availability by altering the food product's pH, consequently contributing to undernutrition in the form of underweight and wasting. This situation may be exacerbated by poor cooking and storage practices employed by caregivers. Regarding the association with nutritional status indices, the study established a positive association between *E. coli* and stunting, while *Salmonella* spp was significantly associated with stunting, underweight, and wasting. Ingestion of *E. coli* and *Salmonella* spp is known to cause diarrhea in children. With a less developed immune system, the occurrence of these two pathogenic bacteria may compromise intestinal integrity, affecting nutrient absorption and resulting in malnutrition in a child.

6.6 Conclusions and Recommendations

The *E. coli* and *Salmonella* spp. were prevalent at rates higher KEBs recommended limits and had strong association with stunting and underweight. It is recommended that ways be put in place to raise awareness of hygienic handling practices of the introduced complementary food to caregivers in sedentarised pastoral households for effective risk communication

CHAPTER SEVEN

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

7.1. General Discussion

Communities living in the arid and semi-arid areas (ASAL) where Marsabit County is located have over the time experienced gradual but irreversible change from nomadic pastoralism to both sedenteral and semi sedentary lifestyle, evidenced by reduced frequency shifting *Manyattas* (homesteads) to far areas in search of pasture and water. The observed changes can partly be attributed to the harsh climatic changes characterized by long and frequent droughts, occasionally punctuated by short rainy season accompanied by flash floods. The two climatic dynamics have seen breakdown in known traditional pastoral livelihood systems previously dependent on livestock keeping and diets based on animal source foods (ASF).

Moreover, Government of Kenya policies tend to promote settlement of pastoralists so as to have more centralized access to social services such as health services, education and security among others. The net effect of this population dynamics is shift from pure livestock keeping to a more sedenteral type of economy in which diets are more diverse heavily dependent on cereals, tubers as staple food, supplemented with plant-based protein sources in addition to milk.

Malnutrition is a significant public health challenge in Northern Kenya, particularly among children under the age of five. The current study has confirmed prevalence of stunting, underweight and wasting among children aged 6-59 months in northern Kenya. While there has been a downward trend in undernutrition globally and in Kenya, the latest results from the 2022 Kenya Demographic and Health Survey (KDHS), the prevalence of stunting (low height for age) among children under the age of five in the northern Kenya region remains higher compared to the national average of 26%.Additionally, the prevalence of wasting and underweight among children under five in the North Eastern region is equally above the national levels and globally recommended cut off values by WHO. Furthermore, the United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) reported that in 2021, over 2.5 million people in Kenya were food insecure, with 1.2 million children and pregnant and breastfeeding women acutely malnourished and in need of nutrition assistance.

Several factors negatively impacting on nutritional status of under have been reported. As reported in the current study. Caregiver monthly income has a significant effect on wasting among children. Furthermore, caregiver occupation is strong associated with malnutrition among pastoral children in northern Kenya. With high illiteracy level and with a majority of caregivers being housewives, their capacity to practice appropriate complementary feeding may be low. Water and sanitation play a critical role in managing malnutrition among households. Poorly kept compounds, not washing hands before feeding and open defecation practices were found to significantly affect malnutrition among children I the area. This hygiene related factors compromise food safety and quality hence affecting health and nutrition of children under five in the area.

Based on this research, the prevalence of underweight, stunting, and wasting among children in northern Kenya exceeded the WHO-recommended cut-off values of <10%, <20%, and <5%, respectively (de Onis, 2019; WHO, 2006). These figures were also higher compared to the Kenya Demographic and Health Surveys (KNBS & ICF 2023), with the high undernutrition rate attributed to inadequate dietary intake, poor digestion, and child morbidity, which hinder muscle development and linear growth. Comparisons with similar studies in Uganda, Pakistan, and other regions indicated higher prevalence rates in this study, though variations were observed based on local socioeconomic factors and feeding practices (Khan *et al.*, 2019; Nankinga *et al.*, 2019; Okidi *et al.*, 2022).

The study also identified critical environmental factors influencing malnutrition, particularly in relation to water sources and sanitation. Children relying on public water pans or unprotected wells had a higher likelihood of stunting due to contamination from sandstorms and open defecation, which introduced diarrheal bacteria like *E. coli* and *Salmonella* spp. into the water and food supply. These environmental conditions, particularly in the Bubisa ward, where open defecation and sandstorms were common, exacerbated diarrheal episodes and contributed to stunting. The findings aligned with similar studies in Cambodia, Uganda, and Ethiopia that also linked stunting to poor sanitation and contaminated water sources (Blaney *et al.*, 2019; Geletaw *et al.*, 2021; Okidi *et al.*, 2022).

Additionally, the study underscored the role of caregiver income, education, and family size in influencing childhood malnutrition. In the Sagante/Jaldesa ward, younger caregivers, often

resulting from early marriages, were associated with higher undernutrition rates due to poor feeding practices. Similarly, larger family sizes in the Sagante/Jaldesa and Bubisa wards were linked to inadequate food allocation, further contributing to wasting and underweight among children. Higher caregiver income positively impacted dietary diversity and improved nutritional outcomes, highlighting the need for targeted interventions to address these socioeconomic and environmental challenges in combating malnutrition in the region (Abera *et al.*, 2021; Ahmad *et al.*, 2020).

Water Utilization, Sanitation, and Hygiene Practices (WASH) in Marsabit County reveal some intriguing trends. Boreholes are the primary source of water for 41.9% of households, followed by water bowsers (21.6%). Usage of tap water is mainly limited to urban centers such as Marsabit Central and Sagante/Jaldesa. Interestingly, borehole use is highest in Bubisa (91.8%), significantly more than in Logologo (79%), Laisamis (62.3%), and Karare (47.2%) ($\chi 2$; $p<0.001$). Boreholes are also the main source of drinking water (43.9%), followed by water bowsers (19.5%) and tap water (18.8%). Borehole reliance for drinking is most significant in Bubisa (95.9%) compared to other regions like Logologo (76.7%) and Laisamis (60.9%). Water tracking is prominent in Marsabit Central (50%) and Sagante/Jaldesa (16.1%).

Water Treatment was also observed and a significant 63.7% of households consume raw water, with Logologo leading in this practice (97.7%), followed by Laisamis (91.3%) and Bubisa (77.6%). Boiling water is practiced by 12.7% of households, and chemical treatment is used by 23.4%. Chemical treatment is more common in urban areas like Sagante/Jaldesa (38.1%) and Marsabit Central (35.5%). The average time taken to fetch water, including waiting time, is 58.37 minutes. Households in Karare spend the most time (116.79 minutes), while those in Logologo spend the least (28.02 minutes). This reflects significant regional disparities in water accessibility ($F=24.131$; $p<0.001$).

Households consume an average of 61.17 liters per day. Interestingly, households in Logologo consume the most water (79.07 liters), whereas those in Bubisa consume the least (48.57 liters). These variations may be linked to differences in water access and availability ($F=7.752$; $p<0.001$). Water is most expensive in Bubisa (KES 24.75 per 20-liter container) and cheapest in Laisamis (KES 11.70). The variability in water prices reflects the differing

availability and ease of access across the wards ($F=6.160$; $p<0.001$). The findings highlight significant regional disparities in water sources, treatment practices, and access across Marsabit County. Boreholes are the dominant water source, especially in rural areas like Bubisa, while urban areas like Marsabit Central rely more on tap water. The majority of households still consume raw water, particularly in Logologo and Laisamis. Access to water is highly variable, with some households spending considerable time fetching water, while others have better access. These factors directly influence water consumption patterns and prices across the county.

The current study has revealed a variety of composite foods (dietary diversity) preferred by settled pastoral households as complementary food. Although milk and its derivatives accounted for 42% of all complementary foods, the other 58% of foods types were from locally formulated recipes. For example, *Ashir, Kurkufa, Qita* and *anjera* was popular among the Burji tribe but has since been adopted as weaning foods among other communities within the county. Apart from *ashir* which is prepared from dehusked boiled maize and occasionally blended with milk, *qita* and *anjera* are prepared as a blend of maize flour and wheat flour with addition of yeast. Most households prefer whole wheat flour to processed wheat flour. *Kurkufa* on the other hand is prepared from using rolls from blended wheat and maize flour. The small roll (balls) is in turn cooked with a stewed meat. Some of these ready to eat foods require proper storage in order to maintain the nutrient integrity.

Locally produced milk is mainly from own production or purchased from local vendors in open air market with most supplies coming from Karare and Sagante/Jaldesa wards respectively. Additionally, consumption of processed milk was on the rise as observed in intake of UHT milk (4.6%). The study also indicated majority of ready to eat solid and semi-solid complementary foods were composited from different products. For example, rice mixed with beans, porridge mixed with milk and goat milk mixed with *ugali*, potatoes mixed with rice and cabbages, whole maize mixed with beans among others. Ceralac—a modern cereal branded food consumed in urban areas was also a part of the meals in some of the homes for the children especially urban-like areas such Marsabit central. The diversity in the food consumed in these regions indicate a shift in food consumption and efforts put in by different organizations to sensitize the communities on other alternatives of meals and not only depending on livestock products alone. On the other hand, current study highlighted that

over 50% of complementary foods and food ingredients consumed were derived from cereals, tubers, and roots. This dietary trend aligns with the findings that 97% of children's staple diets comprised these food groups, reflecting a shift among pastoralist communities from milk-based diets to cereal-based diets, similar to changes reported in Malawi and Tanzania (Matumba *et al.*, 2014; Mollay *et al.*, 2020). The main foods included maize, rice, potatoes, and wheat-based recipes. However, cereals and tubers are prone to mold contamination, raising concerns about malnutrition if consumed regularly. The study's findings showed the presence of total fumonisin in complementary foods at levels ranging from 300 µg/kg to 7000 µg/kg, with all samples surpassing the maximum limits set by the European Union and East Africa Community (FAO/WHO, 2017; EAS, 2023; EU, 2023). About 33.3% of the samples exceeded fumonisin levels recommended for infants, though this percentage was lower than previously reported in Tanzania (Magoha *et al.*, 2016).

In terms of aflatoxin contamination, the study revealed total aflatoxin levels in complementary foods ranged from 2.0 to 92 µg/kg, with a median of 4 µg/kg. Poor storage practices and reliance on purchased foods from local markets likely contributed to the high aflatoxin concentrations. The aflatoxin levels found were higher than the European Union limits for infant foods but lower than the East Africa Community standards. The study also examined specific aflatoxin conjugates, finding AFB1 levels higher than regulatory limits, while other conjugates like AFB2, AFG2, and AFM2 were within acceptable ranges (EAS, 2023; FAO/WHO, 2017). Additionally, AFM1 and AFM2 in milk from animals fed commercial maize-based supplements exceeded limits set for dairy products, likely due to poor feed storage and contamination during the dry season.

Despite the high levels of aflatoxin and fumonisin detected in food, the study did not find any significant association between these mycotoxins and indicators of child undernutrition, such as stunting, underweight, or wasting. This is consistent with earlier research in similar settings (Magoha *et al.*, 2016; Tessema *et al.*, 2021), although some studies have suggested a possible link between aflatoxin exposure and growth retardation in children (Chen *et al.*, 2018; Shirima *et al.*, 2015). The findings also indicated that certain household factors, such as location and proximity to market centers, influenced aflatoxin levels, with more distant regions showing higher contamination due to longer storage times for purchased foods. However, the study ultimately did not establish any conclusive relationship between aflatoxin

exposure and child nutritional status, mirroring results from other regions such as Bangladesh (Mahfuz *et al.*, 2021).

Food quality and safety remains critical in containing underlying factors of undernutrition among children below five years. The findings of this study has confirmed the occurrence of mycotoxins in milk and composited foods. This can be attributed to consumption of purchased cereals and tubers from the food market. Most of the foodstuff are imported from other counties especially from Meru. The long distance travelled against the high ambient temperatures in northern Kenya may contribute to proliferation of yeast and molds. Storage conditions within households also may provide conducive environment under high temperatures and humid condition. Pastoral households (*manyattas*) are generally very small in size and poorly aerated. Microbial growth in stored foods can proliferate under such condition.

Additionally, high microbial loads reported here still indicated poor state of quality and safety of complementary foods. The study showed high prevalence of *E. coli* and *Salmonella* spp in nearly all the food types and environmental samples (water and hand swabs). Contaminated foods from environmental hazards and microbial pathogens remain a grey area in handling malnutrition among children especially in northern Kenya. Most pastoralists have a long history with consumption of raw milk. Consumption of raw milk poses danger to safety and health of the growing child as most samples rated as unsatisfactory. Secondly, with poor storage facilities against lack of knowledge on food safety and hygiene, complementary foods still face challenges with microbial contamination.

Moreover, reported on the microbial safety of complementary foods given to children aged 6-59 months in pastoral households in northern Kenya, revealing significant microbial contamination across various regions. The findings indicated that different locations and wards exhibited substantial disparities in contamination levels, with Total Viable Counts (TVC), Total Coliform Counts (TCC), *E. coli*, molds, yeasts, *Staphylococcus* spp., and *Salmonella* spp. exceeding the recommended safety limits (KEBS, 2022). Factors such as food handling practices, environmental conditions, and preparation methods played a crucial role in these variations. Notably, the prevalence of *E. coli* was found to be 100%, while

Salmonella spp. had a prevalence of 41%, with regions like Bubisa showing the highest microbial loads.

The report also highlighted the role of environmental sanitation and water quality in food contamination. It was noted that unsanitary practices, such as improper milking, inadequate cooking methods, and the use of untreated water, significantly contributed to the contamination of food. Water used for food preparation, particularly in the lowlands, was found to be highly contaminated with *E. coli*, further exacerbating the risks. The proximity of livestock to households, coupled with the involvement of caregivers in milking and food handling, increased the likelihood of contamination. The study emphasized that the microbial contamination levels observed in these foods pose serious health risks to children, contributing to gastrointestinal illnesses and, consequently, malnutrition.

Furthermore, the study raised concerns about antimicrobial resistance (AMR) in the region. Many of the microbial isolates, including *E. coli* and *Salmonella* spp., exhibited multidrug resistance, with these pathogens being frequently detected in food, water, and hand swabs. The findings highlighted the role of livestock interactions, wildlife, and human practices in the transmission of antimicrobial resistance genes. Additionally, the high levels of contamination were associated with poor nutritional outcomes among children, including stunting, underweight, and wasting, as observed in similar studies in Bangladesh and East Africa (Islam *et al.*, 2012; Mpatswenumugabo *et al.*, 2023). The report called for improved food safety practices, enhanced water quality, and better regulation of antibiotics to reduce health risks in these communities.

Although this current study did not test for diarrheal disease conditions, data from the Ministry of Health in Marsabit County registered 33251 confirmed cases of diarrheal diseases, 1293 cases of dysentery and 161 cases of cholera (MoH-Marsabit, 2020) within the health facilities. Qualitative data from the current study also point at an association between water access and utilization, disposal of faecal material and reported diarrheal episodes two weeks prior to the study period. In terms of policies, available policy documents reviewed such as the Marsabit County Livestock policy, missed out on food and feed safety provisions in the implementation matrix (MoA-Marsabit, 2021).

The limitations of this study are notable and affect the generalizability and comprehensiveness of the findings. As a cross-sectional study, it only provides a snapshot of the dietary practices and microbial contamination at a single point in time, which limits the ability to observe changes over time. The use of a qualitative Dietary Diversity Score (DDS) questionnaire also poses a limitation, as it may not fully capture the quantitative aspects of dietary intake, thus affecting the accuracy of nutritional assessments. Additionally, the focus on only two foodborne pathogens, *E. coli* and *Salmonella* spp., leaves out other potential microbial contaminants that could impact food safety and health. The study also restricted its microbial safety evaluation to complementary foods from staple sources, omitting a wider range of dietary items that might also be significant. Time and resource constraints further limited the study's depth, particularly in exploring the broader range of foodborne pathogens and toxins, such as aflatoxins and fumonisins, which were detected but not comprehensively linked to undernutrition. These limitations suggest a need for further research with a more expansive scope to provide a deeper understanding of food safety and its impact on child health in northern Kenya.

7.2 Conclusions

i. In conclusion, the study showed a high prevalence of stunting, underweight and wasting due to a shift in dietary practices to a more cereal based diets.

ii. The also showed more than half of the children did not meet the recommended dietary diversity associated mainly with income of households.

iii. The high occurrence of mycotoxins (fumonisin and aflatoxins) is associated with shifting to cereal based complementary diets in the sedentarised households coupled with food handling practices that might have compromised food hygiene as indicated with high loads of microbial contaminants and presence of enteric pathogens; *E. coli* and *Salmonella* spp.

iv. The *E. coli* and *Salmonella* spp. presence had strong association with stunting and underweight. It is recommended that ways be put in place to raise awareness of hygienic handling practices of the introduced complementary food to caregivers in sedentarised pastoral households for effective risk communication

7.3. Recommendations

i. It is recommended that ways be put in place to raise awareness of hygienic handling practices of the introduced complementary food to caregivers in sedentarised pastoral households for effective risk communication.

ii. It is advisable to implement current policies focused on nutrition education regarding child feeding guidelines among settled pastoral caregivers in northern Kenya.

7.4. Area for future Research

Further longitudinal research on mycotoxins should include the analysis of biosensors including blood, urine, and breast milk, along with the identification of strains of *E. coli* and *Salmonella* spp that may be responsible for stunting and underweight.

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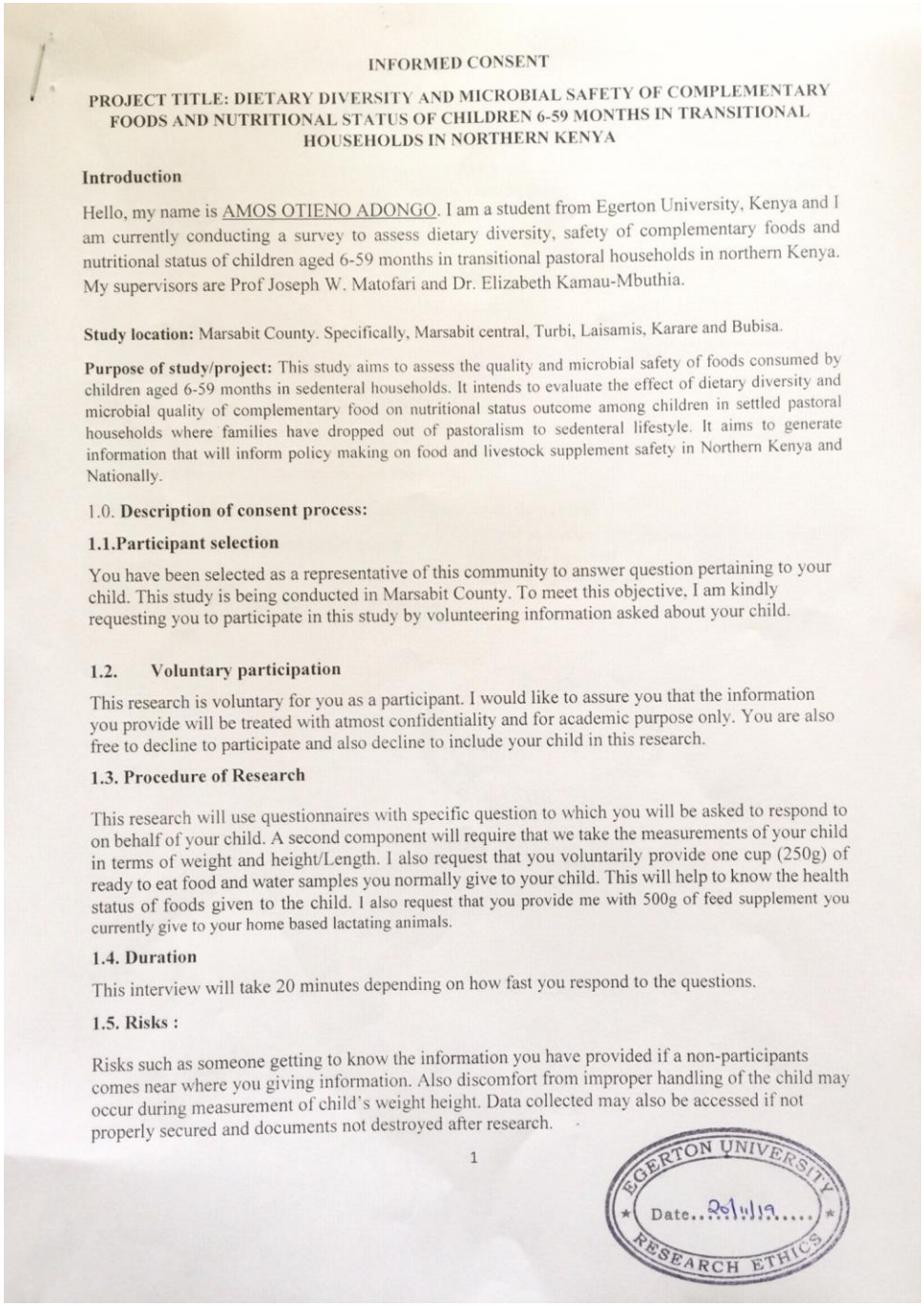
APPENDICES

Appendix A: Consent form



INFORMED CONSENT

PROJECT TITLE: DIETARY DIVERSITY AND MICROBIAL SAFETY OF COMPLEMENTARY FOODS AND NUTRITIONAL STATUS OF CHILDREN 6-59 MONTHS IN TRANSITIONAL HOUSEHOLDS IN NORTHERN KENYA

Introduction

Hello, my name is AMOS OTIENO ADONGO. I am a student from Egerton University, Kenya and I am currently conducting a survey to assess dietary diversity, safety of complementary foods and nutritional status of children aged 6-59 months in transitional pastoral households in northern Kenya. My supervisors are Prof Joseph W. Matofari and Dr. Elizabeth Kamau-Mbuthia.

Study location: Marsabit County. Specifically, Marsabit central, Turbi, Laisamis, Karare and Bubisa.

Purpose of study/project: This study aims to assess the quality and microbial safety of foods consumed by children aged 6-59 months in sedenteral households. It intends to evaluate the effect of dietary diversity and microbial quality of complementary food on nutritional status outcome among children in settled pastoral households where families have dropped out of pastoralism to sedenteral lifestyle. It aims to generate information that will inform policy making on food and livestock supplement safety in Northern Kenya and Nationally.

1.0. **Description of consent process:**

1.1.Participant selection

You have been selected as a representative of this community to answer question pertaining to your child. This study is being conducted in Marsabit County. To meet this objective, I am kindly requesting you to participate in this study by volunteering information asked about your child.

1.2. Voluntary participation

This research is voluntary for you as a participant. I would like to assure you that the information you provide will be treated with atmost confidentiality and for academic purpose only. You are also free to decline to participate and also decline to include your child in this research.

1.3. Procedure of Research

This research will use questionnaires with specific question to which you will be asked to respond to on behalf of your child. A second component will require that we take the measurements of your child in terms of weight and height/Length. I also request that you voluntarily provide one cup (250g) of ready to eat food and water samples you normally give to your child. This will help to know the health status of foods given to the child. I also request that you provide me with 500g of feed supplement you currently give to your home based lactating animals.

1.4. Duration

This interview will take 20 minutes depending on how fast you respond to the questions.

1.5. Risks :

Risks such as someone getting to know the information you have provided if a non-participants comes near where you giving information. Also discomfort from improper handling of the child may occur during measurement of child's weight height. Data collected may also be accessed if not properly secured and documents not destroyed after research.

1

EGERTON UNIVERSITY
Date..26/4/19.....
RESEARCH ETHICS

Appendix B: Data collection tool

ASSESSING THE IMPACT OF DIET AND FOOD SAFETY ON CHILD NUTRITIONAL STATUS IN PASTORAL COMMUNITIES

1. Section 1: Identifying Variables

Could you please provide the following information about you and your family?

Questionnaire number: |_____|_____|_____|	Date of survey ____/____/_____ dd/mm/yy
Name of County_____	Name of Enumerator_____
Name of Sub county_____	Mobile No._____
Name of Ward_____	GPS Points
Name of Location _____	Longitude (North / South) _____
Village (*Manyatta*)_____	Latitude (East)_____ Altitude_____(Metres)
Distance to Nearest Trading centre:_____(Km)	Start time _____End time_____

SECTION 2. HOUSEHOLD DEMOGRAPHIC AND SOCIO ECONOMIC CHARACTERISTICS

2.1 Could you please provide the demographic, social and economic characteristics of household members (Include students, but don't include employed children not residing or depending on the household)

In this context, a household is a group of people who cook together and eat together and drawing food from a common source – share resources together. Family members who work away or are not dependent on the household for at least 6 months are excluded. (For this purpose, household members are not necessarily the same as family members)

Fill the table for each column downwards before moving to the next column

ID	First Name of household / member (Start with household head) (12)	Year of birth (e.g. 1948) (13)	Gender 1=Male 2=Female (14)	Marital status *(CODE A)* (15)	Relationship to current HHH *(CODE B)* (16)	Highest level of education completed *(CODE C)* (17)	Primary occupation (only one) *(CODE D)* (18)	Average monthly income (KES) (19)

1								
2								
3								

CODES:

CODE A: (MARITAL STATUS OF RESPONDENT)	CODE B: (RELATIONSHIP TO HHH)	CODE C: (HIGHEST EDUCATION)	CODE D: (PRIMARY OCCUPATION)
1. Married 2. Single 3. Divorced 4. Widow / widower	1. Head 2. Spouse 1 3. Spouse 2 6. Parent 7. In laws 8. Child 9. Grandchild	1. None 2. Primary 3. Secondary 4. Certificate 5. Diploma 6. University	Livestock keeping Labourer (e.g. herder) Selling milk and milk products Trading in livestock and livestock products Formal salaried employment Self-employed Old/Retired /Pensioner unemployed

20	Do you own livestock? 1. Yes […….] 2. No [……..]
21	For how long have you been keeping livestock
22	If the answer to Q20 above is yes, give total number of 1. Sheep […….] 2. Cattle [……..], 3. Camel [……..], 4. Goats [……..],
23	Has the number of your livestock changed since the last rains i.e. since end of last year? [……..] Codes: (1=Increased 2=Reduced 3=Remained the same)
24	If increased/decreased what are the reason(s)? Note : Multiple réponses possible Codes : (1= Animals gave birth 2= Bought 3= Given 4= Death because of drought 5= Death because diseases 6= Sold 7= Raid 8= Other (specify)----------
25	Do you experience a shortage of feeds for your dairy cattle ____ [1=YES 2=NO]
26	If yes give 3 major strategies you apply during the period of scarce and very scarce feed shortage

SECTION 3.0. LIVESTOCK AND CROP SITUATION

CODE Strategy (multiple response)
Use conserved/stored forages 2) Feed less to animals 3) Feed less to certain categories of animal 4) Hired grazing land
5.) Reduce herd size 6) Purchase fodder 7) Purchase concentrate feed 8) Feed forages not normally used) Migrate animals to another area

If you purchase feeds during periods of scarcity, what is name and the source of livestock feed supplement you normally purchase?

	27). Name of feed	28). Source	29). Storage material used
1			
2			
3			

The enumerator to request for the respondent for sample of not more than 1 kg for the feed supplement commonly used by households

Give details for current household milk production

30). Livestock species	31). No. of animals in milk currently.	32). How many times do you milk per day.	33). Average amount of milk from all animals (L)*	34). Amount consumed at home per day (L)*	35). Amount sold per day (L)*	36). Selling Price (KES) per Litre	37).Market where sold *(CODE F)*	38). Distance from home to milk market (Km)
Camels								
Cattle								
Goat								
Sheep								

**Estimate this from local measures given then convert into litres. Enumerator can request the respondent for milk sample (500ml)*

CODE F: Market where sold:
[1] Individual consumers in the *manyatta [*2] Individual consumers in the urban centre [3] Traders (brokers, hawkers) [4] Hotels [5] Processors (e.g. women groups, etc.)

6.4. Do you grow crops, If so, how many years? (If yes, which crop in term of priority)

	39). Crop grown	Rank	40). Acreage	41). When was last harvest	42). Amount harvested (MT/acre)
1.					
2.					

3					

he enumerator should ask the respondent for a sample of up to 1 kg of food crops (such as cereals) that are produced and stored by the household.

SECTION 4.0. WATER SOURCES AND HYGIENE (WASH)

42). What is your current MAIN source of water for general household use? *Codes*: 1=River 2=Lake 3=Tap water 4=Borehole 5=protected well 6=Unprotected well 7=Public pan 8=Water bowser/tanker 9=Dam 10=Digging along the Laga 11=Rain water 12=Other _____	43). How long does it take to go to the MAIN source of water, fetch it and come back (including waiting time at the water point) in minutes?	44). On average, how many jerricans of water does the household use per day? [Enter in litres]	45). How much do you pay for a 20 litre jerrican of water currently? (enter zero if water is free)	46). What is your Current main source of DRINKING water? *Codes:* 1=River 2=Lake 3=Tap water 4=Borehole 5=Protected well 6=Unprotected well 7=Public pan 8=Water bowser 9=Dam 10=Digging along the Laga 11=Rain water 12=Other Specify_____	47). Do you do anything to the water before drinking it? *Codes:* 1=Nothing 2=Boiling 3= Add chemicals 4= Use traditional herbs 5=Filters/Sieves 6=Decant
[…]Main source	[…….]Minutes	[…….]Litres	[…] KES	[…….]	[…….]

SECTION 5.0. SANITATION – TOILET FACILITY

48). Does your household have access to a toilet facility that you use? [If NO, Skip to 3.3] 1=Yes 2=No	49). (If yes), what type of toilet facility do you have? 1=Bucket 2=Traditional pit latrines 3=Ventilated improved pit latrine 4=Flush toilet 5=Other Specify _____	50). (If No), where do you go/use? (probe further) 1= Bush 2=Open field 3.=Near a water source 4.=Behind the house 5.=Other (specify)_____	51). [OBSERVE] how does children's faeces get disposed 1= disposed of immediately and hygienically 2= Not disposed (scattered in the compound)	52). Do you wash your hands before you feed your child? 1 = Yes 2 = No	53) [OBSERVE] Is the compound clean? 1 = Yes 2 = No
[……..]	[……..]	[……..]	[……..]	[……..]	[……..]

SECTION 6.0. INFANT AND YOUNG CHILD FEEDING

This section is administered to the primary (mother or caregiver) of the eligible child.

ID	54). Full Name of eligible child care giver (pick details from household members table)	55). Year /month of birth (e.g. 1948)	56). Gender 1=Male 2=Female	57). Relationship Child *(CODE B)*	58). Caregiver highest level of education completed *(CODE C)*	59). Caregiver Primary occupation (<u>only one</u>) *(CODE D)*	60). Caregiver average monthly income (KES)
		____/_____					

CODES:

CODE A: (MARITAL STATUS OF CAREGIVER/MOTHER)	CODE B: (RELATIONSHIP TO CHILD)	CODE C: (CARE GIVER HIGHEST EDUCATION)	CODE D: (PRIMARY OCCUPATION OF CARE GIVER)

1. Married 2. Single 3. Divorced 4. Widow / widower	1 Mother 2. Aunt 3. step mother 4. House help 5. Sister	1. None 2. Primary 3. Secondary 4. Craft/vocational/ Certificate 5. Diploma 6. University	Livestock keeping Trading in livestock and livestock products Formal salaried employment (e.g. Gok, NGO, private sector) Self-employed business - trade Self-employed business – services unemployed

INFANT AND YOUNG CHILD FEEDING SECTION

This section is completed by the primary caregiver (typically the mother) of the eligible children. If the household has more than one eligible child, a separate questionnaire should be filled out for each one. (This step is done after identifying eligible children based on household information.)

61). Name of child (from column 2 of household information): 62). Gender of child (from column 3 of household information (1 = Male; 2 = Female): | |

NO.	QUESTIONS	CODING CATEGORIES	SKIP
63a).	Month and year (*NAME*) was born? (When is his/her birthday?) ***If the respondent does not know the exact birth date, ask:*** Does *(NAME*) have a health/vaccination card with the birth date recorded? ***f the health or vaccination card is provided and the respondent verifies its accuracy, record the date of birth as listed on the card.***	DAY.....| |_ | *IF DAY IS NOT KNOWN, ENTER '98'.* MM.....| |_ | YY....| | || | |	***If month and Year not known, go to q10b.***
63b).	Use calendar of events to identify the month and year of birth. ***Inquire if the date of birth is unknown or if a health/vaccination card is unavailable.***	| | |/| | | | MM / YY	

64).	How many months old is (***Name***)? ***Record age in number of completed months.*** ***Verify consistency by ensuring that the year and month recorded in Q10 align with the age in months in Q11, and resolve any discrepancies. If a birth date was documented on a health card, use the card as the reliable data source.***	| | |	
65).	***Verify question 11. Is the child Aged 6–59 months?***	YES.....[1] NO.....[2] DON'T KNOW .... [8]	End Module
66).	Has (*NAME)* ever been breastfed?	YES.....[1] NO .....[2] DON'T KNOW.... [8]	End Module

I would like to ask about what liquids (NAME) may have had yesterday during the day or at night.

67).	[Read Each Item On The List, Starting With Breast milk.]	YES	NO	
A	Breast milk	1	2	
B	Plain water	1	2	
C	Infant formula (Nan/Cerelac/AmEx) Number of times [ ]	1	2	
D	Other milks (tinned milk, powdered or fresh milk, e.g. Safari land, Halwa, Nido) Number of times [ ]	1	2	
E	Juices or juice drinks? (Quencher, Highlands, Afia, Cola, Savannah, Tamu-Tamu)	1	2	
F	Soup	1	2	
G	Fermented milk / sour milk / yoghurt Number of times [ ]	1	2	
H	Thin porridge	1	2	
I	Tea/Coffee (white)	1	2	

J	Other liquids, e.g. black tea, herbal drinks	1	2	

Please list everything that (Name) consumed yesterday, either during the day or night, both at home and outside, including items mixed with other foods.

If a food item doesn't appear in any of the listed food groups below, record its name in the box labeled "other foods." For items used in small quantities as seasonings or condiments, place them under the condiments category. Yesterday during the day or night, did (***Name)*** drink/eat any (***Food Group Items***)?

68).			YES	NO	DK
1	Grains, roots and tubers	A	1	2	8
2	Legumes and nuts	B.....	1	2	8
3	Flesh foods (meats)	C.....	1	2	8
4	Eggs	D	1	2	8
5	Vit A fruits and vegetables	E	1	2	8
6	Dairy products	F	1	2	8
7	Other fruits and vegetables	G	1	2	8

Other foods: **the enumerator canwrite down other foods in this box that the respondent mentioned but are not in the list above.**

69).	How many times did (NAME) eat solid, semi-solid, or soft foods (excluding liquids) yesterday, either during the day or at night, to satisfy their hunger?	NUMBER OF TIMES | |_____|

73). Has (Name) been sick from a diarrhoea related case in the last TWO (2) WEEKS)?

1. Yes [___] 2. No [___]

74). When (Name) was sick the LAST time did you seek assistance?

1. Yes [___] 2. No [___]

75). IF YES, where?

1= Public Clinic/Hospital

2= CHW

3= Mobile Clinic

4= Private Clinic/Pharmacy

5= Shop/Kiosk

6= Relative/Friend

7= Traditional Healer

8= No Assistance sought

SECTION 7.0. ANTHROPOMETRY

NO.	QUESTIONS	CODING CATEGORIES
76).	Weight of (NAME). Record in kg (+/-100g) (##. #)	KG |____|____|.|____|
77).	Length of (NAME)	CM

The enumerator should ask for samples of staple complementary foods provided to the eligible child and thank the respondent for their cooperation and time.

Appendix C: Research Outputs

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ORIGINAL ARTICLE

Food Science & Nutrition Open Access WILEY

Determinants of undernutrition among settled pastoralists' children aged 6–59 months in Kenya

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Abstract

The transition from nomadism to sedentary lifestyle has introduced changes in diets and undernutrition is endemic among settled pastoral households. This study aimed to investigate the underlying factors affecting stunting, underweight, and wasting of children aged 6–59 months in Marsabit County, Kenya. A cross-sectional household survey was conducted in six wards capturing pastoral, agro-pastoral, and urban livelihood practices. Using multistage sampling method, 394 children aged 6–59 months participated with written consent from the caregivers. A pretested questionnaire and anthropometric measures were used during data collection. Population characteristics were summarized into means and proportions, while chi-square and analysis of variance were used to evaluate associations between variables. Backward logistic regressions were used to explore predictors of stunting, underweight, and wasting, respectively. The results showed that the mean Height for Age Z-score, Weight for Age Z-score, and Weight for Height Z-score were −1.51, 1.54, and 1.02, respectively. The prevalence of stunting, underweight, and wasting was 38.1%, 23.0%, and 18.5%, respectively. The age of child, source of drinking water, and waste disposal were some of the main factors influencing stunting among children. In conclusion, the prevalence of undernutrition was high compared to the World Health Organization recommended cutoffs. Water sources hygiene, and caregiver's income were some of the main predictors of undernutrition among children. Development agencies need to focus on the supply of potable water, access to toilet facilities, in addition to nutrition education on hygienic complementary feeding practices among pastoral caregivers.

KEYWORDS
children, pastoralist, stunting, underweight, wasting

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DIETARY DIVERSITY AMONG CHILDREN AGED 6-59 MONTHS FROM SETTLED PASTORAL COMMUNITIES IN MARSABIT COUNTY, KENYA

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ABSTRACT

Settlement among pastoralists is expected to facilitate access to social amenities. However, information on its impact on dietary changes and undernutrition under five children is limited. This study aimed to determine dietary diversity among children aged 6-59 months in settled pastoral households. In a cross sectional survey, 394 households with index child were randomly sampled using multistage technique. A pre-tested questionnaire was used to collect information on population characteristics and dietary diversity. A dietary diversity score and minimum dietary diversity of the children were then calculated by summing the number of food groups from 0 to 7 eaten by the child 24 hours from the previous day. Categorical data was presented as proportions, while continuous variables mean ± standard error. Chi-square and analysis of variance were used to establish population differences. Linear regression was used to assess the relationship between population characteristics and dietary diversity. Logistic regression was used to assess the association between food groups and child nutritional status. Results showed that 51.5% of children never met minimum dietary diversity. Cereals, roots and tubers were the most frequently consumed food group at 97%. Distance to market (P<0.05), household head education (p<0.05), caregiver occupation (p<0.05) and income were associated with dietary diversity. Eating legumes (OR= 0.50, 95% C.I (0.30, 0.85); p = 0.010) and vitamin A rich fruits and vegetables (OR= 0.50, 95% C.I (0.30, 0.85); p = 0.010) showed reduced odds of stunting while dairy products reduced the risk of a child becoming underweight [AOR= 2.09, 95% C.I (1.16 - 3.79); p = 0.015]. Overall, the findings highlight significant gaps in meeting dietary diversity recommendations among children in settled pastoral areas. Household head and caregiver attributes were identified as key influencing factors. It is recommended that county governments in northern Kenya promote optimal complementary feeding guidelines among settled pastoral caregivers to improve child nutrition.

Key words: Pastoralists, children, under-five, dietary diversity, stunting, wasting, underweight, northern Kenya

Appendix D: Research permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 279014

Date of Issue: 07/January/2020

RESEARCH LICENSE

This is to Certify that Mr.: Amos Adongo of Egerton University, has been licensed to conduct research in Marsabit on the topic: - DIETARY DIVERSITY AND MICROBIAL SAFETY OF COMPLEMENTARY FOODS AND NUTRITIONAL STATUS OF CHILDREN 6-59 MONTHS IN TRANSITIONAL HOUSEHOLDS IN NORTHERN KENYA for the period ending : 07/January/2021.

License No: NACOSTI/P/20/2972

279014

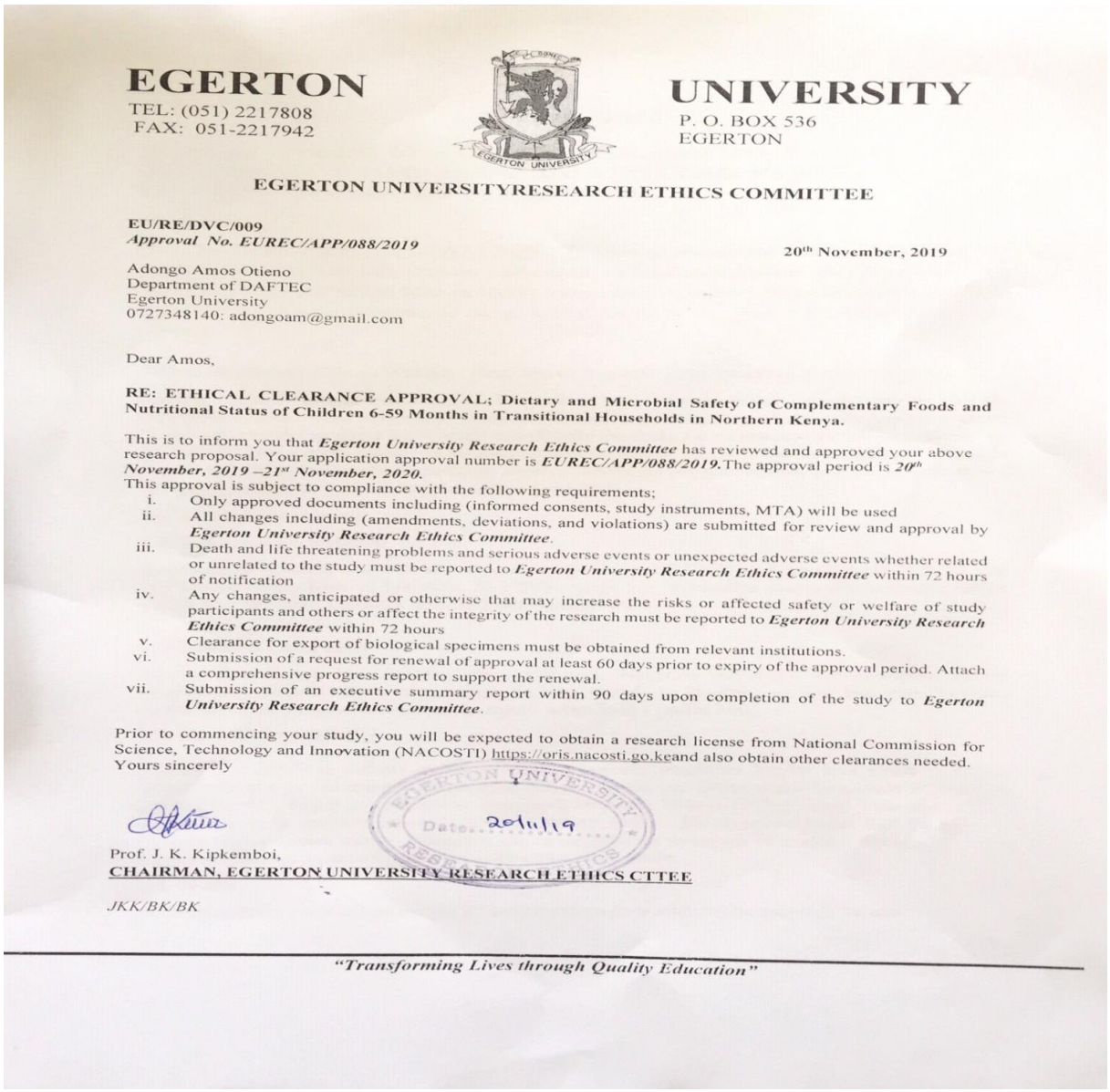
Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

Appendix E. Ethical approval



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EGERTON

EGERTON UNIVERSITYRESEARCH ETHICS COMMITTEE

EU/RE/DVC/009
Approval No. EUREC/APP/088/2019

20th November, 2019

Adongo Amos Otieno
Department of DAFTEC
Egerton University
0727348140: adongoam@gmail.com

Dear Amos,

RE: ETHICAL CLEARANCE APPROVAL; Dietary and Microbial Safety of Complementary Foods and Nutritional Status of Children 6-59 Months in Transitional Households in Northern Kenya.

This is to inform you that ***Egerton University Research Ethics Committee*** has reviewed and approved your above research proposal. Your application approval number is ***EUREC/APP/088/2019.*** The approval period is ***20th November, 2019 –21st November, 2020.***
This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***Egerton University Research Ethics Committee***.
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***Egerton University Research Ethics Committee*** within 72 hours of notification
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***Egerton University Research Ethics Committee*** within 72 hours
v. Clearance for export of biological specimens must be obtained from relevant institutions.
vi. 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.
vii. Submission of an executive summary report within 90 days upon completion of the study to ***Egerton University Research Ethics Committee***.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.keand also obtain other clearances needed.
Yours sincerely

Date 20/11/19

Prof. J. K. Kipkemboi,
CHAIRMAN, EGERTON UNIVERSITY RESEARCH ETHICS CTTEE

JKK/BK/BK

"Transforming Lives through Quality Education"

Appendix F. Food Sample Distribution

	Study site					
Food type	Karare	Laisamis	Logologo	Marsabit Central	Sagante/Jaldesa	Bubisa
Cereals (n=68)	6 (75.0)	21 (95.5)	9 (75.0)	12 (75.0)	7 (70.0)	13 (81.3)
Milk (n=53)	14 (26.4)	11 (20.8)	6 (11.3)	7 (13.2)	9 (17.0)	6 (11.3)
Mixed recipe (n= 11)	0 (0.0)	1 (4.5)	2 (16.7)	3 (8.4)	2 (20)	3 (18.3)
Tuber based (n=4)	1 (12.5)	0 (0.0)	1 (8.3)	1 (6.3)	1 (10.0)	0 (0.0)
Meat based (n=1)	1 (12.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Total (N=137)	**22**	**33**	**18**	**23**	**19**	**22**

Appendix G: Statistical outputs

Objective 5. Analysis of variance for effect of wards, location, food type and the food type nested within ward and location for different microbial quality indicators

SOV	do	TVC	TCC	*E. coli*	Molds	Yeasts	*Staph.*	SS
Ward	5	1.343^{***}	6.811^{***}	8.687^{***}	239.354^{***}	3.644^{***}	2.653^{***}	0.041^{***}
Location	8	0.505^{***}	2.106^{***}	2.016^{***}	4.701^{***}	0.876^{***}	0.274^{***}	0.004^{ns}
Food-type	34	0.096^{***}	0.575^{***}	0.875^{***}	7.945^{***}	1.154^{***}	0.147^{***}	0.007^{***}
Rep	2	0.001	0.027	0.010	0.005	0.004	0.015	0.001
Food-type (W*L)[1]	39	0.388^{***}	1.040^{***}	0.792^{***}	5.060^{***}	3.561^{***}	0.2252^{***}	0.021^{***}
Error	331	0.040	0.123	0.491	1.742	0.048	0.059	0.003
R^2	-	0.685	0.732	0.425	0.747	0.927	0.610	0.537
C.V	-	2.609	4.679	9.746	98.896	2.956	3.363	6.791

[1] Ward*location; C.V mean coefficient of variation, TVC means Total Viable Counts; TCC means Total coliforms; SS means *Salmonella/ Shigela* spp

Appendix H: Tables Showing Median and Maximum Occurrence of Aflatoxin and Fumonisin (µg/Kg) in Complementary Foods by ward

Region	Food type		Total AF[λ]	Total FUM[ɟ]	AFB_1	AFB_2	AFG_1	AFG_2	AFM_1	AFM_2
Karare	Mixed recipe	Median	3	2650						
		Min[¥]	3	300						
		Max[§]	3	5000						
	Cereals	Median	19	300	0.49	0.41	0.31	0.52		
		Min	2	300	0.08	0.14	0.15	0.19		
		Max	78	7000	1.05	0.77	0.53	0.96		
	Tuber based	Median	92	0	0.51	0.41	0.32	0.53		
		Min	92	0	0.51	0.41	0.32	0.53		
		Max	92	0	0.51	0.41	0.32	0.53		
	Meat based	Median			0.42	0.36	0.28	0.46		
		Min			0.42	0.36	0.28	0.46		
		Max			0.42	0.36	0.28	0.46		
	Milk	Median							0.22	0.50
		Min							0.08	0.21
		Max							2.63	5.31
Laisamis	Mixed recipe	Median			0.60	0.47	0.36	0.61		
		Min			0.60	0.47	0.36	0.61		
		Max			0.60	0.47	0.36	0.61		
	Cereals	Median	4.00	300.00	0.31	0.29	0.24	0.38		
		Min	2.00	300.00	0.09	0.14	0.15	0.20		

Region	Food type		Total AF[λ]	Total FUM[J]	AFB_1	AFB_2	AFG_1	AFG_2	AFM_1	AFM_2
		Max	14.00	7000.00	0.90	0.67	0.48	0.85		
	Milk	Median							0.49	1.04
		Min							0.14	0.33
		Max							22.64	45.34
Logologo	Mixed recipe	Median		300.00	0.32	0.29	0.24	0.38		
		Min		300.00	0.31	0.29	0.24	0.38		
		Max		300.00	0.32	0.29	0.24	0.38		
	Cereals	Median	4.00	300.00	0.82	0.61	0.44	0.78		
		Min	2.00	300.00	0.15	0.18	0.18	0.25		
		Max	7.00	300.00	3.70	2.49	1.59	3.08		
	Tuber based	Median			0.90	0.67	0.47	0.84		
		Min			0.90	0.67	0.47	0.84		
		Max			0.90	0.67	0.47	0.84		
	Milk	Median							0.22	0.50
		Min							0.08	0.20
		Max							0.39	0.83
Central	Mixed recipe	Median		300.00	0.88	0.66	0.47	0.83		
		Min		300.00	0.88	0.66	0.47	0.83		
		Max		300.00	0.88	0.66	0.47	0.83		
	Cereals	Median	2.00	300.00	0.80	0.61	0.44	0.77		
		Min	2.00	300.00	0.26	0.26	0.22	0.34		
		Max	13.00	300.00	1.62	1.14	0.76	1.42		

Region	Food type		Total AF[λ]	Total FUM[ɟ]	AFB_1	AFB_2	AFG_1	AFG_2	AFM_1	AFM_2
	Tuber based	Median	4.00	300.00	0.23	0.23	0.21	0.31		
		Min	2.00	300.00	0.23	0.23	0.21	0.31		
		Max	5.00	300.00	0.23	0.23	0.21	0.31		
	Meat based	Median	3.00	300.00	0.28	0.27	0.23	0.36		
		Min	3.00	300.00	0.11	0.16	0.16	0.22		
		Max	3.00	300.00	0.46	0.38	0.30	0.50		
	Milk	Median							0.24	0.53
		Min							0.11	0.28
		Max							0.70	1.45
Sagante	Mixed recipe	Median			0.73	0.56	0.41	0.71		
		Min			0.25	0.24	0.21	0.33		
		Max			1.22	0.87	0.60	1.10		
	Cereals	Median			0.64	0.50	0.37	0.64		
		Min			0.25	0.25	0.22	0.33		
		Max			2.71	1.84	1.20	2.29		
	Tuber based	Median			0.97	0.72	0.50	0.91		
		Min			0.97	0.72	0.50	0.91		
		Max			0.97	0.72	0.50	0.91		
	Milk	Median							0.35	0.76
		Min							0.08	0.22
		Max							1.52	3.09
Bubisa	Mixed recipe	Median		300.00	0.42	0.36	0.28	0.46		

Region	Food type		Total AF[λ]	Total FUM[J]	AFB_1	AFB_2	AFG_1	AFG_2	AFM_1	AFM_2
		Min		300.00	0.35	0.31	0.26	0.41		
		Max		300.00	1.22	0.88	0.60	1.10		
	Cereals	Median	2.00	300.00	0.65	0.51	0.38	0.65		
		Min	2.00	300.00	0.20	0.22	0.20	0.29		
		Max	2.00	4000.00	1.61	1.13	0.76	1.42		
	Milk	Median							0.31	0.67
		Min							0.14	0.34
		Max							25.54	51.14
		Rank			30.420	30.420				

[¥]Max means maximum; [§]Min Means minimum; [λ] AF mean Aflatoxin; [J] FUM mean Fumonisin

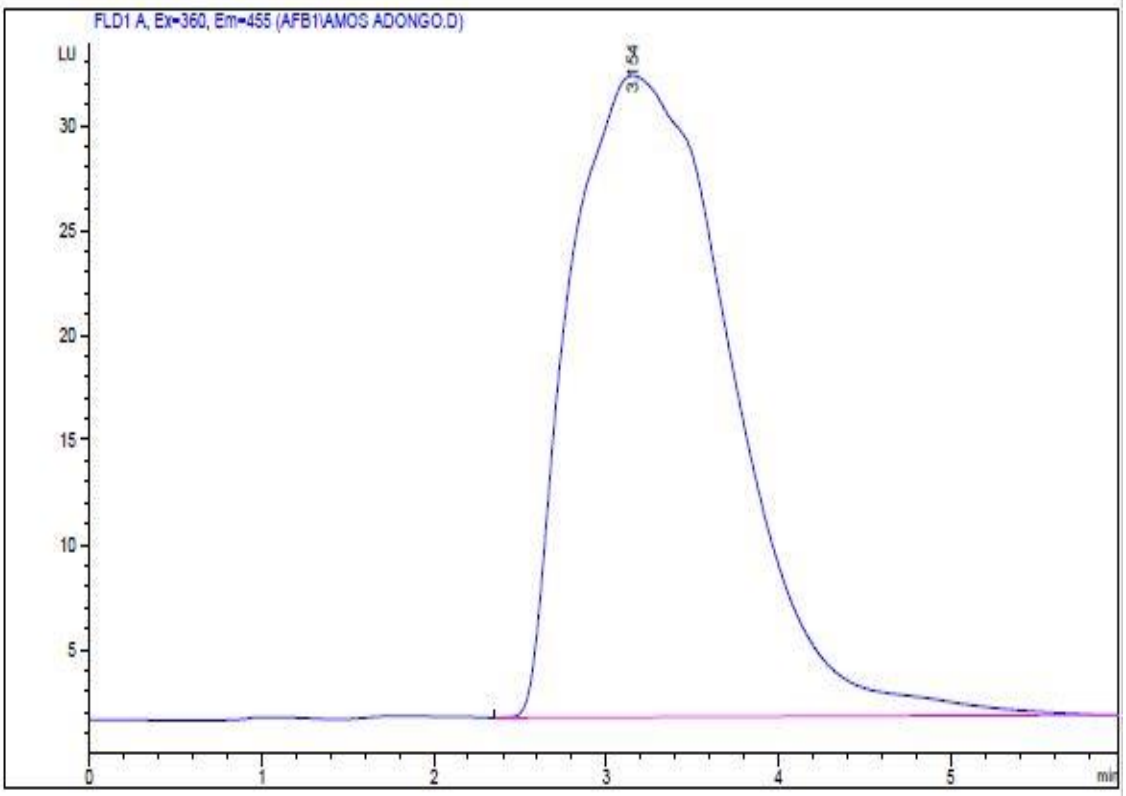
Appendix I: HPLC Analysis of AFB2 Standard Using Reverse Phase Column

Data File C:\Chem32\1\Data\AFB1\AMOS ADONGO.D
Sample Name: AFB2 STD [9 ML/50ML]

==========

Acq. Operator : SYSTEM
Sample Operator : SYSTEM
Acq. Instrument : ANIMAL SCIENCE HPLC Location : 1
Injection Date : 2020-12-23 13:24:45
Inj Volume : 20.000 µl
Method : C:\Chem32\1\Methods\AFB1.M
Last changed : 2020-12-22 09:34:00 by SYSTEM
Method Info : Always follow the extraction procedure outlined for the AFB1 METHOD

Sample Info : HPLC: ALL PARTS ARE AGILENT 1260 SERIES
Column: C18, 4.6*100mm [REVERSE PHASE]
Column Temp. : 30oC
MOBILE PHASE:WATER/ACN/METHANOL [60:20:20]



==========

Area Percent Report

Data File C:\Chem32\1\Data\AFB1\AMOS ADONGO.D
Sample Name: AF SAMPLE 02

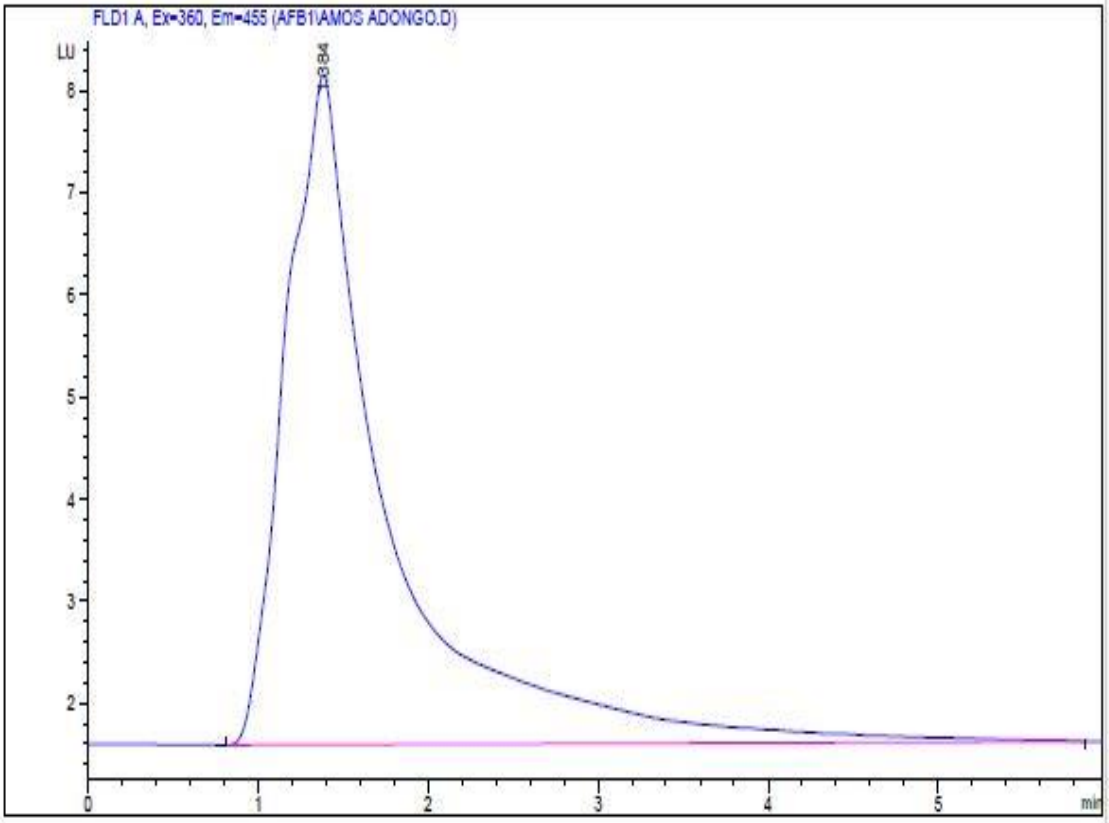
==========

Acq. Operator : SYSTEM
Sample Operator : SYSTEM
Acq. Instrument : ANIMAL SCIENCE HPLC Location : 1
Injection Date : 2021-01-08 10:22:38

Inj Volume : 20.000 µl

Method : C:\Chem32\1\Methods\AFB1.M
Last changed : 2020-12-22 09:34:00 by SYSTEM
Method Info : Always follow the extraction procedure outlined for the AFB1 METHOD

Sample Info : HPLC: ALL PARTS ARE AGILENT 1260 SERIES
Column: C18, 4.6*100mm [REVERSE PHASE]
Column Temp. : 30oC
MOBILE PHASE:WATER/ACN/METHANOL [60:20:20]



==========

Area Percent Report

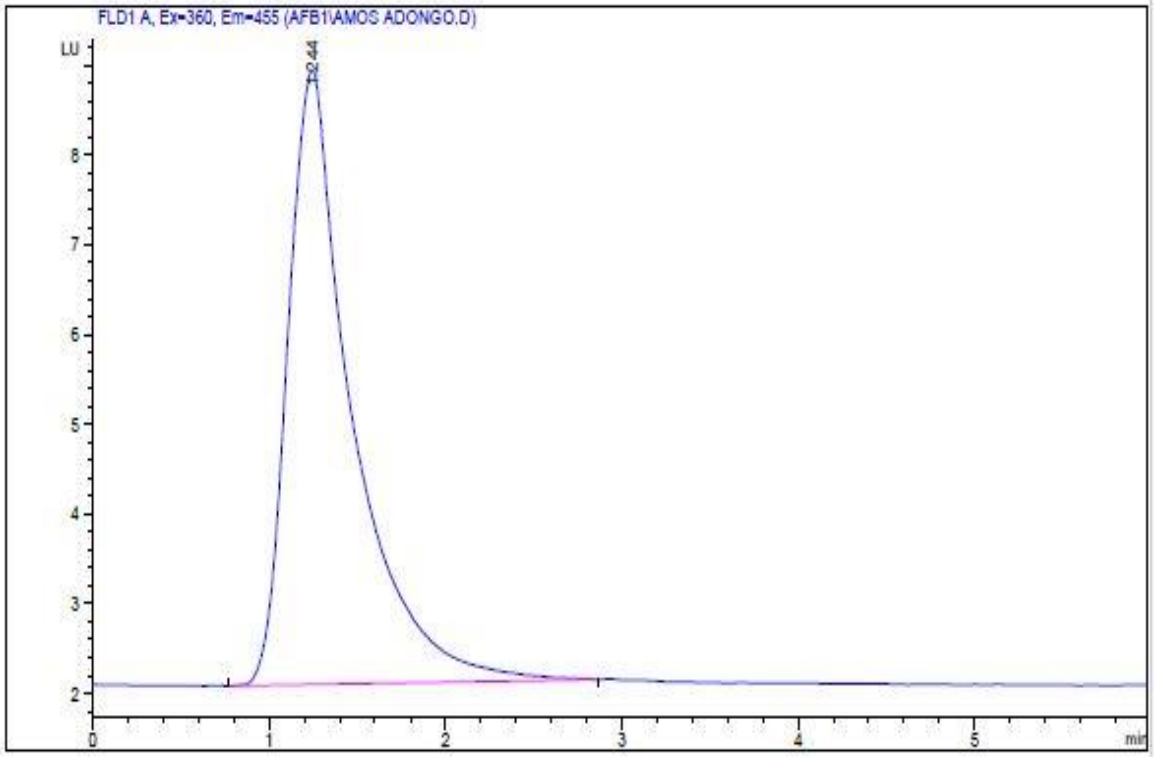
==========

Sorted By : Signal

Sample Name: AF SAMPLE 78

```
=====================================================================
Acq. Operator   : SYSTEM
Sample Operator : SYSTEM
Acq. Instrument : ANIMAL SCIENCE HPLC            Location :   1
Injection Date  : 2021-03-05 12:14:54
                                                 Inj Volume : 20.000 µl
Method          : C:\Chem32\1\Methods\AFB1.M
Last changed    : 2021-01-14 13:55:15 by SYSTEM
Method Info     : Always follow the extraction procedure outlined  for the AFB1 METHOD

Sample Info     : HPLC: ALL PARTS ARE AGILENT 1260 SERIES
                  Column: C18, 4.6*100mm [ REVERSE PHASE ]
                  Column Temp. : 30oC
                  MOBILE PHASE:WATER/ACN/METHANOL  [60:20:20]
```




```
=====================================================================
                        Area Percent Report
=====================================================================

Sorted By             :      Signal
Multiplier            :      1.0000
```

The images show a chromatogram obtained from high-performance liquid chromatography (HPLC) analysis of an AFB2 (Aflatoxin B2) standard. The HPLC system used is an Agilent 1260 series equipped with a C18 reverse-phase column (4.6 x 100 mm) operating at a temperature of 30°C. The mobile phase composition is water, acetonitrile (ACN), and methanol in a ratio of 60:20:20. The injection volume for this analysis was 20 µl. The chromatogram exhibits a clear peak with a retention time of approximately 3.5 minutes, representing the detection of the AFB2 standard, with fluorescence detection parameters set at Ex = 360 nm and Em = 455 nm. This setup provides a reliable quantification of aflatoxin B2 in a sample, following the outlined extraction procedure and method. The chromatographic method ensures precision in identifying and quantifying aflatoxins in food and feed safety testing.