EVALUATION OF DAIRY PRODUCTION, MILK PROCESSING AND MILK PRODUCTS QUALITY AMONG SMALLHODER DAIRY FARMERS IN TARABA STATE

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DECLARATION

I Ardo, Bashir Aishatu a postgraduate student in the department of Animal Science, Taraba State University, with Registration Number TSU/Ph.D/ANS/18/0002 Declare that this Thesis "**EVALUATION OF DAIRY PRODUCTION, MILK PROCESSING AND MILK PRODUCTS QUALITY AMONG SMALLHODER DAIRY FARMERS IN TARABA STATE"** was written by me and the work embodied in this thesis report is original and has not been submitted in part or in full for any diploma or degree of this or any other university. All quotations are indicated and sources of information specifically acknowledged by means of references.

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ARDO, Bashir Aishatu Date

CERTIFICATION

This is to certify that this research project report titled **EVALUATION OF DAIRY PRODUCTION, MILK PROCESSING AND MILK PRODUCTS QUALITY AMONG SMALLHODER DAIRY FARMERS IN TARABA STATE"** was carried out by Ardo, Bashir Aishatu, with matriculation number TSU/Ph.D/ ANS/ 18/ 0002 which meets the regulation governing the award of Ph.D in Reproductive Physiology (Dairy) of Faculty of Agriculture, Taraba State University, Jalingo.

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ABSTRACT

Four experiments were conducted to determine dairy production, milk processing and milk products quality among small holder dairy farmers in four Local Government Areas (Ardo-Kola, Jalingo, Bali, and Gassol) of Taraba State, Nigeria. In study one, it understudied the socio-economic characteristics of milk producer groups in the study area through qualitative research technique. Traditional dairy farming system predominantly managed by male farmers, with 95.5% of households led by men and 81% being polygamous. The majority of household heads (62%) are middle-aged, falling between 36-55 years. Milk production demonstrates significant seasonal variations, with total production decreasing from 9,625 liters in the dry season to 7,780 liters in the wet season. Marketing is primarily conducted market sales on daily/weekly/ alternate days (45%), with adult females (80%) being the primary milk sellers. Agricultural service access remains limited, with only 25% of farmers receiving livestock extension services. Credit accessibility is equally constrained, with merely 22% of farmers accessing financial support. In study two, investigated the presence and types of mastitis causing organisms in the area of the study. Analyzing 144 total samples across different sampling conditions, the research revealed significant variations in bacterial prevalence and growth rates. Bacterial growth rates varied substantially between locations, ranging from 41.67% in Bali to 61.11% in Gassol. Sampling conditions dramatically influenced bacterial presence, with unwashed teats (66.67%) and bedding/soil (69.44%) showing highest growth rates, while disinfected teats demonstrated minimal bacterial growth (5.56%). Five primary bacterial species were identified: Salmonella sp. (21 isolates), Staphylococcus sp. (18 isolates), Streptococcus sp. (13 isolates), E. coli (10 isolates), and Klebsiella sp. (7 isolates). Statistical analysis revealed significant differences between locations (p=0.027) and sampling conditions (p=0.042). Identification and classification of types of microbes present in milk and milk products was investigated in study three. Analyzing 192 samples across different milk conditions, the research investigated bacterial prevalence and distribution. Mean growth rates were relatively consistent across locations, ranging from 0.38 ± 0.15 in Jalingo to 0.42 ± 0.17 in Ardo Kola. Bacterial distribution varied across milk conditions: fresh milk (29.2-37.5%), overnight samples (41.7-45.8%), pasteurized milk (37.5-45.8%), and fermented milk (37.5-45.8%). Seven bacterial species were identified, with *E. coli* showing the highest prevalence (20.8-33.3%), followed by *Streptococcus* sp. (16.7-20.8%) and *Staphylococcus* sp. (12.5-20.8%). Statistical analysis revealed no significant differences between locations (p=0.261). Study four, investigated milk nutrient composition across four local government areas in Taraba: Ardo Kola, Jalingo, Bali, and Gassol. Analysis covered fresh, pasteurized, and overnight raw milk samples, revealing significant variations in nutrient profiles. Fresh milk showed notable differences in protein (2.25-3.50%), fat (2.51-5.75%), and lactose (3.36-5.23%) content. The results indicated that the informal dairy sector in Taraba State faces significant challenges in maintaining milk quality and safety standards.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

1.1.1 Nigeria population and demographics

Nigeria is the most populous country in Africa and the seventh in the world. At present, Nigeria's human population estimated at about 210 million. It is projected that by the year 2050, Nigerian's population will reach 400 million thus making it the third most populous country in the world after India and China (UNFPA, 2022). Issues of concern with this increase in human population has to do with food security especially in terms of animal protein where demands currently supersede domestic supply, and the deficit in domestic supply is often met by s large imports.

1.1.2 The Nigerian economy

Agriculture is an important sector of the Nigerian economy. It contributed approximately 22% to the GDP of Nigeria in the first quarter of 2020 and 26.84% in 2022 (NBS, 2022). It is heterogeneous, comprising of smallholders, medium and large scale farms with different levels of efficiency. However, the smallholder farmers dominate both the crop and livestock production landscape. The steady increase in population has necessitated calls for an effective, efficient and sustainable means of meeting the nutritional demands of her population (Mailafia, *et al*., 2010). Shortage of protein, particularly those of animal origin is prevalent in most parts of the country (Abdulraheem, *et al*., 2016). However, agricultural productivity is constrained by a variety of institutional, economic, .and agro-ecological constraints.

In order to ensure adequate supply of protein, especially from animal sources to the rapidly growing population of Nigeria, the output of animal products has to be increased especially by ruminant animals such as cattle and goat (Ogbonna, 2015). The livestock sector contributes about 6-8% to the Gross Domestic Product (GDP), 20-25% to the added value of Agriculture, and 36.5% to the aggregate protein intake of the populace (FMARD, 2017). The largest proportion of milk produced for human consumption is obtained from cattle. Dairy cows efficiently convert human-inedible food and by-products into nutrient-rich milk (van Hooijdonk and Hettinga, 2015). The National Livestock Census had cattle population at 14 million cattle with an estimated annual increase rate of 4% (RIMS, 1990). This puts the estimated current population at about 20.6 million. Of the national cattle herd, 95% is under traditional smallholder pastoral production systems and crop-livestock farmers while privately owned commercially oriented dairy farms account for remaining 5%. Despite this cattle population, the supply of dairy products has been declining over the years, while demand has continued to grow due to increases in human population and urbanization. With an estimated average annual domestic milk production of 531,587 tons (Knoema, 2022) and a demand of about Nigeria has remained a net importer of dairy products to bridge the gap between supply and demand

However, the dairy industry is second largest segment in the food industry in Nigeria. It has been growing at the rate of 8% since 2010, and generated estimated revenue of over 345 million Naira (USD 2 million) in 2013, despite being mainly subsistence oriented with low productivity: the average production is between 295 to 2585 kg per cow per year among the indigenous breeds of cattle which is less than one tenth of the global average (Olorunnisomo, 2013, Makun, 2018). The sub-sector plays an important role in contributing to the national economy thereby generating income for farmers, providing opportunities for job, ensuring food security, providing services, contributing to cultural, social, asset, environmental values, and sustaining livelihoods (Pawlak and Kołodziejczak 2020)

Reports indicate that Nigeria has the potential of being a major milk producer in Africa. Using improved methods of storing, processing, packaging, and transporting, milk output can be raised substantially for internal use and for export. Nigeria is the largest milk producer in West Africa and the third largest producer of cow milk in Africa (Aderinkola, *et al*., 2022), thanks to our nomadic and semi-nomadic Fulani. Africa contributes just over two percent of the World's milk supply. Milk accounts for twenty to twenty-five percent of the agricultural sector in Sub-Sahara, two percent of its calories, thirty-three percent of its calcium, and four percent of protein for its people.

1.2 Statement of Problem

Livestock production is confronted with a number of constraints, which leads to low productivity and reduced profitability on the long run. Problems associated with reduced livestock productivity and profitability includes; inadequate consumption of protein of animal origin, poverty, unemployment, low contribution to the Nation’s Gross Domestic Product (GDP) among others. Smallholder dairy farming has become popular in most developing countries (Banda *et al*., 2000; Ngongoni *et al*., 2006; Muchenje *et al.*, 2007).

Among the problems identified in milk production in Nigeria are low milk output of Fulani cows, poor grass quality that leads to low milk yield, and lack of storage and processing equipment. Unsanitary methods of milk handling, breakdown of processing plants, and inefficient milk collection also impede the performance of the milk industries in Nigeria. Competition between itinerant milk collectors and official milk collectors, faulty pricing and management policies, and lack of economic incentives from the government hamper the expansion of Nigeria's dairy industry.

The dairy industry in Nigeria is faced with logistical problems too. The inefficient method of collection and distribution of milk hinder dairy development. Milk producing areas are in the hinterland, where vehicles cannot reach easily. The lack of access roads and specialized vehicles necessitate the delivery of milk by foot or by donkeys. Transportation by foot or on the hooves is obvious slow, and in the milk marketing, it may spell the difference between business success and business failure. The Fulani cannot deliver the milk to the processing centers within the critical four hours after milking. More than half of the milk spoils before reaching the final consumer.

Since liquid, wholesome milk is unstable under heat, delays render it insipid and unsalable. Pastoralists do not refrigerate or preserve their milk; therefore, the shelf-life of fresh milk is short, usually less than three hours.

Rural inhabitants who do not have refrigerators ferment their milk. More than seventy percent of the milk is converted into sour milk; thirteen percent is drunk fresh; and seven percent is used to make ghee, cheese, and butter. Fresh, liquid milk can only be used by urban residents who use refrigerators. Milk producers cannot sell fresh, wholesome milk except by request. Even then, the milk must be delivered in the morning to avoid the afternoon heat that can render the milk sully.

In view of the above, this study seeks to understudy the dairy production value chain; the quality of raw milk, pasteurized and fermented milk products obtained from the small holder pastoral dairy farmer while comparing it to recommended best practice and what is commercially obtained and it will further seeks to find improved method of production that will improve the keeping quality of the products without altering its nutritional composition and quality starting from the health status of the dairy cow.

1.3 Objectives of the Study

The broad objective this study is to determine factors that influence the quality of milk and milk products under varying production, handling and processing conditions and proffer possible solutions thus promoting hygienic milk handling and production procedures that will increase shelf life and market value of dairy products. The specific objectives of the study are:

i. To determine the socio-economic characteristics of milk production and processing methods among smallholder milk production households in the study area using qualitative method of data collection.
ii. To understudy the mastitis causing organism, its highest points of infection among small holder dairy herds from the pastoral communities in the study area, e.g swap samples of teats and beddings.
iii. To identify, classify and determine the prevalence of microbes present in milk and milk products small holder dairy herds from the pastoral communities in the study area.
iv. To carry out nutrient composition analysis of milk and milk products among smallholder dairy farmers

1.4 Justification of Study

The global demand for milk and dairy products is increasing rapidly, due to the growing world population combined with urbanization, shifts in dietary patterns and income growth (IFCN, 2013; Migose *et al*., 2018; Vroegindewey *et al*., 2021). Milk and dairy products play important roles in consumer’s diet, which contributes to their healthy living (RIM, 2013). The livestock industry plays a very important role in the Nigerian agriculture accounting for 12.7% of the agricultural GDP. The National Livestock Census puts cattle population at 14 million cattle with an estimated annual increase rate of 4% (RIMS, 1990). Despite this cattle population, the supply of dairy products has been declining over the years, while demand has continued to grow due to increases in human population and urbanization. Consequently, Nigeria has remained a net importer of dairy products to bridge the gap between supply and demand. The dairy industry in Nigeria is unorganized with much of its activities: milk production, processing, marketing and consumption being in the hands of the traditional smallholder producers. Of the national cattle herd, 96% (13.5 million) is owned by traditional smallholder pastoralists and crop-livestock farmers while privately owned commercially oriented dairy farms account for remaining 4%. The traditional pastoral herd is the most important source of domestic raw milk in the Nigeria. It is evident that the traditional smallholder/ informal milk production and markets have a key role to play in the development of the domestic milk production. However, the sector is plagued by low productivity. Technical, institutional and policy-related constraints are responsible for this less than optimum performance of the traditional smallholder dairy production system. The technical constraints to improve and sustainable productivity of the traditional dairy sector revolves around three major factors namely: limited milk production potential of the indigenous cattle, Seasonal quantitative and qualitative feed shortages, and health issues especially helminthes infestation and easily treatable infectious diseases (Barje *et al.*, 1995; Smith and Olaloku, 1998). Similarly, weak infrastructural base and poor support services such as poor feeder roads, unreliable power supply, inefficient cooling and processing capacity, and have been repeatedly shown to adversely affecting output and economic returns of small holder peri-urban-dairy units (Smith and Olaloku, 1998). Despite these constraints, past and projected trends in production and consumption of dairy products in Nigeria point to the enormous opportunities for dairy sector growth with extended benefits to the producing households.

Seasonal quantitative and qualitative feed shortage is perhaps the major constraint to improved production and productivity of peri-urban dairy enterprises, and farmers usually cite it as a priority problem to be tackled by research. Appropriate feed packages suitable for urban dairy producers are available and continue to be developed. These are built around improved fodder cultivation including leguminous forages, where land is available, the improvement of poor quality forages and crop residues, including the utilization of multi-nutrient blocks, and efficient supplementation of grazed pastures. What are often lacking are policy incentives that encourage their adoption and utilization. Availability of good quality feed (forage/roughage and concentrate feed) throughout the year is a major limitation for increased milk production, especially when better breeds have been introduced (Udo *et al*., 2007). Ehoche *et al.* (2001) reported that supplementation of Bunaji cows raised under agro-pastoral management system with legume crop residues significantly increased milk offtake and that the beneficial effect of the supplementation further manifested when a strategic helminthes control programme was adopted alongside the supplementation.

1.5 Scope and Limitations

The choice of the study site will be governed by the presence of a large concentration of settled cattle owners who are involved in milk production, processing and marketing of milk and milk products in the area. The study will be carried out in four (4) Local Government Areas of Taraba State namely: Ardo-Kola and Bali Jalingo, and Gassol and Jalingo in North and Central Senatorial Districts of Taraba State respectively where there is huge concentration of the small holder dairy farmers. The study will be restricted to smallholder (agro-pastoral) households and/or pastoralists with milk producing cows who are also involved in milk processing and marketing. Within each Local Government area, three (3) districts within each district three villages will be selected for use in this study. Not less than two hundred households will be selected per Local Government Area and the household heads interviewed through the administration of a structured questionnaire instrument. Milk and products samples will be collected from the selected households at regular intervals over the study period.

CHAPTER TWO

2.0 LITERATURE REVIEW

Smallholder farmers are the cornerstone of the livestock sector and an essential element in building and developing the local dairy value chain, critical for developing its local economy. In Nigeria, despite the efforts made since the colonial period until now, farmers still face many problems that prevent them from participating effectively in developing the dairy value chain FAO, (2014). Despite the worldwide expansion of large-scale industrial dairy production, more than 80 percent of milk produced in developing countries comes from small-scale producers. Small-scale dairy farmers practice a mixture of commercial and subsistence production. They combine crops and dairy production with off-farm activities (McDermott *et al*., 2010), which contributes to higher food production and farm income (Babatunde and Qaimb, 2010).

Studies indicate that about 75% of the farms in the world are family farms, as most of them are small family farms. Despite the different development and modernization policies that each country adopts to advance the agriculture field in all its sectors, smallholder farmers face many challenges at the local and international levels FAO, (2014). Smallholders are the backbone of the economy in countries that depend heavily on agriculture. The dairy sector is one of the most important agricultural sectors for smallholder farmers, as it plays a fundamental role in their daily income and self-sufficiency as well as food security. If farmers are forced to change their behavior due to international hygiene standards without suitable governmental solutions to support them, social problems will arise, and economic issues will appear for society. Thus, this may lead to the farmers' abandoning their farms. The resulting consequences may be drastic, which may occur in fundamental changes in the landscape due to the lack of pastoralism and the inadequate supplies and nutritional status of former smallholders Jakliˇc *et al.* (2014).

Dairy production plays an important role in providing food security, essential nutrients to child growth (Bennett *et al*., 2006), and a source of income and employment to millions of smallholder families (Martínez-García *et al*., 2013). In addition, it enhances the livelihoods of smallholders, promoting regular monetary earnings to farmers; providing high profit margins, low production costs, low liabilities, limited liquidity risk, and relative resilience to rising feed prices (FAO, 2010).

The rapid economic growth and the higher consumption of dairy products in developing countries have created new opportunities for improving dairy production both quantitatively and qualitatively. This situation has also provided facilities for the possible inclusion of smallholder farmers in remunerative dairy markets. However, involving small-scale farmers in supply chains requires governments' clear understanding of supply processes in order to develop mechanisms that guarantee smallholders' access to these markets (Omore and Staal, 2009). We can delineate a dairy supply chain as a group of stakeholders linked to achieve a more effective and consumer-oriented flow of dairy products. It starts with raw milk production and ends when other processors, institutions and consumers utilize the products that were created in the value chain. Dairy supply chains comprise six core activities such as production, transportation, processing, packaging, storage and consumption (Muhammad *et al*., 2014). In developing countries, the weak coordination process between milk producers, traders and retailers (Seifu and Doluschitz, 2014) makes difficult the optimization of the delivery of goods, services and information from one supplier to another.

Different studies reported a large variation of organizations involved through dairy supply chains in developing countries, especially in contexts where various forms of organizations work simultaneously in the same area and influence the way milk is produced, processed or commercialized. Dairy supply chains may vary from dairy farmers delivering raw milk directly to consumers (Thorpe *et al*., 2000) to an industrial plant collecting milk through collecting cooperatives (Sraïri, *et al*., 2009) or cheese processors collecting milk by themselves (Brokken and Seyoum, 1990).

2.1 The Nigerian Dairy Sector

2.1.1 The nature of supply, demand, and consumption of milk

Milk is the most frequently used cattle product, however, many families cannot get enough milk for daily nourishment. Although traditional dairying in Nigeria starts centuries ago, industrial dairying is recent. In 1945, the last colonial Chief Veterinary Officer of Nigeria, Mr. H.H. Wells, reported to the Home Office in London that Her Majesty's Empire in Nigeria had developed much interest in dairying and was supplying cheese and butter to Allied Forces in Morocco (Interview with N.L.P.D. staff, July 1992).

Reports indicate that Nigeria has the potential of being a major milk producer in Africa. Using improved methods of processing, packaging, storing and transporting, milk output can be raised substantially for internal use and for export. Nigeria is the largest milk producer in West Africa and the third largest producer of cow milk in Africa, thanks to our nomadic and semi-nomadic Fulani. Africa contributes just over two percent of the World's milk supply. Milk accounts for twenty to twenty-five percent of the agricultural sector in Sub-Sahara Africa, two percent of its calories, thirty-three percent of its calcium, and four percent of protein for its people. By value, livestock products make up eleven percent of the food (Michael, *et al.*, 1991).

2.2 Raw Milk

2.2.1 Milk

Milk is defined as a fresh, clean, whole undigested and normal mammary secretion obtained by draining of the udder of healthy cows that are properly fed, kept and contains no appreciable colostrums (Ajogi *et al.*, 2005). Milk isan Important source of protein, minerals, vitamins and fat in human diet (Pirestani and Eghbalsaeed, 2011) which approximately comprises of 87% water, 3.7% protein, 4.9% lactose and 0.7% ash 3.6% fat (Ramesh *et al.*, 2008). With these constituents, milk is described as the most nearly perfect food (Barrett, 2006). This complex biochemical composition, nutritional values and high water content render milk an excellent growth medium for both pathogenic and spoilage microorganism (Bryne, 2004; Parekh and Subhash, 2008; Okonkwo, 2011). Dairy products are consumed by millions on daily basis worldwide and as such the potential for food-borne illness is a major concern to producers, regulators and consumers (Bryne, 2004). Fresh milk may be contaminated with different microorganisms depending on methods used in cleaning and handling of milk during processing and may originate from udder, the exterior of the udder, milking equipment used and milker's hand (Bramley and McKinnon, 2000; Douglas *et al.*, 2002; Oliver *et al.*, 2005; Bashir and Usman, 2008; Shojaei and Yadollahi, 2008). Bacteria in raw milk can affect the quality, safety and consumer acceptability of dairy products (Elmoslemany *et al.*, 2009). Such microorganisms include *Bacillus cereus*, *Listeria monocytogenes, Yersinia enterocolitica, Salmonella spp. Escherichia coli, Stuphylococcus aureus and Campylobacter jejuni* (Navratilova *et al.*, 2004; Bashir and Usman, 2008; Elmoslemany *et al.,* 2009). Most of the food-borne illnesses associated with milk consumption are linked to post-pasteurization contamination (Olsen *et al.,* 2004) as proper pasteurization supposed to destroy most of the pathogenic bacteria in milk, Post-pasteurization contamination of milk is mostly by contaminated hands of dairy workers, unsanitary utensils and polluted water supply (Pantoja *et al.*, 2009). Detection of specific pathogens (bacterial, coliform, yeast and mould) and their toxins are used as index of contamination of milk and its products with possibility of presence of pathogens which may constitute health hazards to consumers (Parekh and Subhash, 2008).

In Nigeria, most dairy farms that produce fresh milk for human consumption are not subjected to quality control to ascertain the safety of the milk for public consumption (Bertu *et al.*, 2010). However, during this study it was commonly observed that the pasteurization methods include heating of milk in large pots using kerosene, gas or in some instances fire woods. In all of these methods, automated temperature regulator is absent. Rather, visual observation of the milk being heated is often carried out to assess pasteurization parameters. The visual method is ineffective in ascertaining whether the milk pasteurization temperature is up to 63-76 ^{0}C. It is also practically impossible to apply such pasteurization techniques as High Temperature Short Time (HT ST) at 72-76 ^{0}C for 15 seconds which uses the function of time temperature designed to kill pathogenic microorganism (ICMSF, 1998). In addition, there is high risk of post pasteurization contamination of milk with food-borne pathogens due to hygiene problems during preparation and handling (Obi and Ikenebomeh, 2007).

2.2.2 Pathogens occurring in raw milk and dairy products in Africa

The major pathogens of concern in milk and dairy products have traditionally included *Mycobacterium bovis*, *Brucella abortus* and *Coxiella burnettii*, which are the causative agents of bovine tuberculosis and a form of human tuberculosis, brucellosis and Q fever, respectively. Unfortunately, while these pathogens and their diseases have been reported to be largely eradicated in many developed countries, they still persist or are re-emerging in some countries in

Africa (Ducrotoy *et al.*, 2017). *Mycobacteriumbovis*, the causative agent for bovine tuberculosis, has been detected in milk and dairy products in different African countries including South Africa (Sichewo *et al*, 2019), Mozambique, Nigeria, Tunisia and Zambia (Machado *et al*, 2018). Thus, the consumption of unpasteurized raw milk and dairy products continue to be a major risk for exposure to *M. bovis* in Africa. While bovine tuberculosis is known to be widespread in Africa, the limited or lack of sufficient data to expose the true epidemiological picture and burden of the disease in many African countries is a major concern, particularly when the burden of bovine tuberculosis might be considerably underestimated in humans (Olea-Popelka *et al.*, 2017). *Coxiella burnetii*, an obligatory intracellular Gram-negative bacterium belonging to the family of Coxiellaceae is the causative organism of Q fever, a zoonosis of almost worldwide distribution except in New Zealand (Eldin *et al.*, 2016). The most common reservoirs for *C. burnetii* include cattle, sheep and goats, and are considered the main sources of human infection. Thus, consumption of non-pasteurized milk and their products in Africa may be a significant source of human contamination with *C. burnetii*, as this pathogen has been detected in up to 63% of cattle milk samples in Nigeria (Vanderburg *et al.*, 2014). Furthermore, *C. burnetii* has been detected in milk samples in Gambia and Senegal (Waasen *et al.*, 2014). The presence of *C. burnetii* in milk samples raises concern on the role of milk as a source for human infection, particularly in regions where unpasteurized milk is consumed. While Q fever is usually not considered a tropical disease, *C. burnetii* was found as the etiological agent in 5% of severe pneumonia cases in Tanzania (Prablu *et al.*, 2011). Additionally, a study of a cohort of severely ill febrile patients in Tanzania revealed 26.2% zoonoses, among which 30% were reportedly Q fever (Crump *et al.*, 2013). Addition to that, *C. burnetii* accounts for about 1 to 3 % of infective endocarditis in Tunisia and Algeria while Q fever accounts for about 5% of acute febrile illnesses in Burkina Faso (Vanderburg *et al.*, 2014). About 9% of community-acquired pneumonia among patients aged above 15 years in Cameroon tested positive for *C. burnetii* (Vanderburg *et al.*, 2014), with *C. burnetii* being the third most frequently isolated agent of pneumonia, after *Streptococcus pneumoniae* and *Mycoplasma pneumoniae* in Cameroon Koulla.

Species of Brucella including *Brucella abortus*, *B. melitensis*, *B. suis* and *B. canis* are all capable of producing brucellosis in humans, with the disease being considered to represent one of the highest public health burdens of any zoonosis globally (Al Dahouk *et al.*, 2017). Ruminants are the primary hosts for *B. abortus* and *B. melitensis*, and humans become infected by consuming raw milk and dairy products, by direct contact with aborted foetuses, afterbirth and parturition fluids and during slaughter practices. Although there is scanty prevalence data on brucellosis in Africa, it is suspected that the disease may be endemic in the region due to the high level of infection among dairy herds in different parts of the region (Musallam *et al.*, 2019). Caine, Nwodo & Okoh, 2017) estimated that up to 30% of milk and dairy products at selling points in Bamako, Mali were contaminated with Brucella. More recently, *Brucella* spp., particularly *B. abortus*, have been reported in milk and dairy products with high prevalence in some African countries such including South Africa, Uganda, Togo, Mali, Burundi, Cameroon, Senegal and Niger (Hoffman *et al.*, 2016). These reports indicate that brucellosis or the causative microorganisms are widespread among dairy supply chains of Africa, and this presents a serious public health threat to local populations, particularly consumers of raw milk and traditional dairy products, as well as dairy farm workers. Other pathogens of significant safety concern in the African dairy chain are toxigenic strains of *Escherichia coli*, *Bacillus cereus* and *Listeria monocytogenes*. Strains of toxigenic *E. coli* have been reported in raw milk from different African countries such as Benin, Egypt, Ethiopia, Ghana, Nigeria, South Africa, Tanzania and

Zambia (Ombrak *et al.*, 2016). Shiga toxin producing *Escherichia coli* (STEC) has emerged as a group of highly pathogenic *E. coli* strains characterized by the production of one or more Shiga toxins. Similarly, *B. cereus* are of particular concern in food safety and public health due of their capacity to cause disease in humans through the production of various forms of enterotoxins and emetic toxins (Sergeev *et al.*, 2006). Strains of *B. cereus* possessing various forms of virulent factors have been detected in raw milk and traditional dairy products in Ghana and Cote d'Ivoire. *Listeria monocytogenes*, among other human pathogens is considered a major microbiological and public threat associated with consumption of raw milk. *L. monocytogenes* has traditionally been a major public health issue in temperate regions including Europe and the US, particularly, due to their ability to grow at low temperature environments (Buchanan *et al.*, 2017). However, they have recently been isolated from different animal and milk products across Africa. The prevalence and characteristics of *L. monocytogenes* in raw milk and traditional dairy products in Ghana has been reported (Owusu-Kwasteng *et al.*, 2018). *L. monocytogenes* has also been recently reported to be prevalent in milk from other African countries including Egypt, Nigeria, Morocco and Tanzania. Other pathogens that have been detected in milk and milk products in Africa include *Campylobacter jejuni*, *K. pneumonia* and *S. aureus*.

2.2.3 Sources of microbial contamination in milk

Milk is sterile when it is in the udder of a healthy animal but becomes contaminated with bacteria mainly during and/or after milking (Karimuribo *et al*., 2005; Makerere University, 2011). Milk from subclinical mastitic cows usually contains aetiological agents but milk from non-mastitic cows is often contaminated from extraneous dirt or poor quality water (Kivaria *et al.*, 2006).

Microbial contamination in milk comes from milk itself as it can be naturally contaminated or from infected or sick animal, human, environment, water and equipment used for milking and storage of milk. These sources of contamination include disease-causing organisms (pathogens) shedding in milk, infected udder and/or teats, animal skin, faecal soiling of the udder, contaminated milking and storage equipment and water used for cleanliness. Other bacterial sources are from air, milkers, handlers, drugs or chemicals used during treatment of animal and from water used for adulteration by unscrupulous and unfaithful workers/sellers who may be contaminated and may cause additional health problems (Karimuribo *et al.*, 2005; Swai and Schoonman, 2011). Exposure of milk to these sources or conditions may lead to increased microbial contamination and affect its quality. Although, sometimes recontamination may occur after processing and this is mainly due to unhygienic conditions, poor or improper handling of milk during consumption (Parekh and Subhash, 2008). In general quality of milk may be lowered when it is contaminated by a number of factors such as adulteration, contamination during and after milking, presence of udder infections, mastitis (inflammation of mammary gland) disease and drugs residues used for treatment of disease which is considered to be public health concern and one of the most important causes of economic losses in the dairy industry worldwide including Morogoro and Nigeria at large (Karimuribo *et al.*, 2005; Syit, 2008; Mdegela *et al.*, 2009).

2.2.4 Milk-borne infections and pathogenic microorganisms

Various bacteria may have access to milk and milk products from different sources and cause different types of milk-borne illnesses. Sometimes milk and milk products may carry microorganisms or their toxic metabolites (poisons/toxins). Some of these microorganisms are pathogenic and cause illness to humans while others cause spoilage in milk rendering it unsuitable (unsafe) for human consumption (Kivaria *et al.*, 2006; Parekh and Subhash, 2008; Bukuku, 2013). Many milk-borne epidemics of human diseases are spread through consumption of contaminated milk (Parekh and Subhash, 2008). Few examples of the known milk-borne diseases are bovine tuberculosis, brucellosis, anthrax, listeriosis, salmonellosis, leptospirosis, Q fever, campylobacteriosis and *E. coli* O157:H7 as an emerged new milk-borne bacterial pathogen reported recently with a very serious health effects (Sivapalasingams *et al*., 2004). These are zoonotic diseases which are transmitted to consumers and pose a risk to public health. To protect consumers and public health against these milk-borne infections it requires proper hygienic milking and milk handling procedures. Common bacteria reported to be isolated from milk include *Staphylococcus* spp., *Listeria* spp., *Salmonella* spp., *E. coli* spp., *Campylobacter* spp., *Mycobacterium* spp., *Brucella* spp., *Coxiella burnetii*, *Yersinia* spp., *Pseudomonas aeroginosa* and *Corynebacterium ulcerans.* Others are *Proteus* spp., *Leptospira* spp., *Clostridium* spp., *Streptococcus* spp, *Klebsiella* spp., *Enterobacter* spp. and *Bacillus* spp. (Shirima *et al.*, 2003; Sivapalasingams *et al.*, 2004; Al-Tahiri, 2005; Donkor *et al*., 2007; Parekh and Subhash, 2008). All these are pathogenic bacteria that pose serious threat to human health and contribute up to 90% of all dairy related diseases (De Buyser *et al*., 2001; Sivapalasingams *et al.*, 2004; Donkor *et al*., 2007). Therefore, proper milking, cleaning and sanitizing procedures of equipment and environments are essential tool to ensure quality of milk. Many countries have implemented laws and regulations concerning the composition and hygienic quality of milk and milk products to protect both the consumers and the public health (Pandey and Voskuil, 2011). Unfortunately, these laws and regulations are not often adhered to in developing countries making milk-borne diseases a higher health risk to public. This is exemplified by over 75% of milk marketed in many developing countries is sold raw/unpasteurized through informal channels (Bertu *et al.*, 2010; Oliver and Murinda, 2011). Some studies show that a big percentage of people in Nigeria especially in rural areas consume raw milk (Mullins, 1993; Kurwijila *et al.*, 1995) which predisposes them to the risk of contracting zoonoses, and other milk-borne diseases.

2.2.5 Hygiene, handling and microbial quality of raw milk

Milk is a perishable product and an ideal medium for the growth of a wide variety of bacteria (Parekh and Subhash, 2008). When it is secreted from a healthy udder, raw milk contains only a very few bacteria of about 500 to 1,000 bacteria per milliliter (Omore *et al.*, 2005; Pandey and Voskuil, 2011). After milking environmental contamination occurs, which in turns increases the total bacteria count up to 50,000 per ml or may even reach several millions bacteria per milliliter (Pandey and Voskuil, 2011). That count level indicates a very poor hygienic standard of milk during milking and handling or milk of a diseased animal. The presence of coliform bacteria particulary *E. coli* in raw milk is an indicator of feacal contamination which implies poor hygienic conditions and un-sanitized environment since these bacteria are of fecal origin.

In developing countries like Nigeria, most of the milk is produced by smallholder farmers dominated by local herds of cattle (Pandey and Voskuil, 2011). Their milking units are widely distributed throughout in rural areas with a poor infrastructure, while most of the markets and customers are in urban areas. Therefore, the need for good hygienic practices and a streamlined collection, handling and transport system is important but has been always a challenge (Pandey and Voskuil, 2011). However, milk contains a natural inhibitory system or temporary germicidal or bacteriostatic properties which prevents a significant rise in the bacteria count during the first 2 - 3 hours (Swai and Schoonman, 2011; Pandey and Voskuil, 2011). If the milk is cooled to 4ºC within this period immediately after milking, it maintains nearly its original quality and remains safe for processing and consumption. Temperature of storage and time since milking are also important in determining milk quality, as these influence the rate at which the bacteria will increase in number (Omore *et al.*, 2005). To prevent a too high multiplication of bacteria, the milk has to be produced as hygienic as possible and should be cooled or heated at the earliest (Pandey and Voskuil, 2011).

2.2.6 Prevention and control of microbial contamination in milk

Prevention and control of microbial quality of milk is through elimination of organisms from human carriers by general improvements in water supplies, public health education, personal and environmental hygiene, also can be achieved through proper boiling or pasteurization of raw milk before processing and consumption. Pathogenic organisms from the lactating animals can be controlled through improvements in animal husbandry and maintenance of good animal practices, and those from the environments and equipment can be prevented by adhering to general hygienic practices and environmental cleanliness.

Generally, microbial contamination in milk can be minimized through adherence to effective good hygienic practices at farm level; and in order to protect the public against milk-borne infections it is important to screen milk which is informally taken to the market. The lack of awareness of milk-borne infections in many developing countries and consumption of raw milk predispose small-scale livestock keepers, consumers and the general public at risk of contracting these infections (Mosalagae *et al.*, 2011).

2.3 Pasteurized Milk

2.3.1 Microbiological quality of pasteurized milk

Milk is synthesized in specialized cells of the mammary gland and is virtually sterile when secreted into the alveoli of the udder (Tolle, 2010) and may be contaminated during milking and handling with equipment, personnel and environmental sources and may contain pathogens

(ICMSF, 1998). Pasteurization is the widely adopted milk process to ensure completely destruction of all pathogenic and spoilage microorganisms, commonly found in milk and inactivation or reduction of other non-pathogenic spoilage bacteria and certain undesirable enzymes to safeguard the food value of milk (Teka, 1997).

FAO/WHO (2004) defined pasteurization as "A micro biocidal heat treatment aimed at reducing the number of any pathogenic microorganisms in milk and liquid milk products, if present, to a level at which they do not constitute a significant health hazard. Pasteurization conditions are designed to effectively destroy the organisms *Mycobacterium tuberculosis* and *Coxiella burnetii*. Initially, pasteurization conditions were devised to inactivate *M. tuberculosis* (North and Park, 2007) but subsequently, *C. burnetii* appeared as the most heat-resistant organism present in the milk and therefore, pasteurization was redesigned to achieve at least a 5-log reduction of *C. burnetii* in whole milk (Hudson *et al*., 2003). The HTST pasteurization kills 99.999% of pathogens (FDA, 2009) and is effective in reducing the viable population of *Mycobacterium avium* sub sp. *paratuberculosis* (4-5 log) but its efficacy depends on the total viable concentration (Okura *et al*., 2012). Various recommended temperature-time combinations applicable for different pathogenic organisms have been delineated in Table 1. Pasteurization efficiency can be determined by Phosphatase test. Alkaline phosphatase, an enzyme naturally present in milk of all mammals have a thermal resistance greater than that of the most heat resistant non-spore-forming pathogens commonly found in milk (Sharma *et al*., 2003) and hence, its destruction confirms proper pasteurization (Ludikhuyze *et al*., 2000). Positive Phosphatase activity is the indicative of inadequate pasteurization or contamination of pasteurized milk with raw milk or post-process bacterial contamination (Vega-Warner *et al*., 1999).

Microbiological analysis of pasteurized milk indicated presence of pathogens like *Staphylococcus* sp., *Salmonella* sp. (Singh *et al*., 2011), coliform (Aglawe and Wadatkar, 2012) from India, *Salmonella* (Okpalugo s*et al*., 2008) from Nigeria, *Enterobacter* spp., *Escherichia coli* from Jamaica (Anderson *et al*., 2011), *Staphylococcus aureus* from Brazil (De Oliveira *et al*., 2011), coliform, *B. cereus* from Kuwait (Al-Mazeedi*et al*., 2013) and *E. coli* and *S. aureus* from Iran (Vahedi *et al*., 2013). Silva *et al*. (2010) noted complete deactivation of phosphatase and *Salmonella* sp. but presence of coliform in 57.5% samples of pasteurized milk from Brazil. Incidence of pathogens in pasteurized milk (Ryan *et al*., 2007; Upton and Coia, 2004; Silva *et al*., 2010) and food-borne outbreaks due to inadequate pasteurization or post-pasteurization contamination (Da Silva *et al.*, 1998; ICMSF, 1998) have been reported. Presence of *Salmonella* in pasteurized milk due to improper pasteurization resulting from malfunctioning of a pasteurizer valve (Bergquist and Pogosian, 2000) and post-pasteurization contamination of pasteurized milk with *Bacillus cereus* from packaging paper and board (Vaisanen *et al*., 2011; Pirttijarvi *et al*., 1996) and filling machine (Eneroth *et al*., 2001) have also been reported. Murphy (1997) attributed unclean equipment, improper

Table 2.1: Decimal reduction time of pathogen in milk

Pathogens	Temperature (°C)	D time	References
Bacillus spp.	95.0	1.2-36.0 min	Wong *et al*. (2008)
	100.0	2.0-5.4 min	Wong *et al*. (2008)
Brucella abortus	61.5	23 min	Foster *et al*. (2003)
	72.0	12-14 sec	Foster *et al*. (2003)
Campylobacter spp.	60.0	0.12-0.14 min	Sorqvist (2009)
Clostridium botulinum	100.0	240 min	Jay (2006)
	125.0	5 sec	Collins-Thompson and Wood (2003)
Coxiella burnetii	62.2	30 min	Enright *et al*. (2007)
	73.4	15.2-17 sec	Enright *et al*. (2007)
Escherichia coli O157:H7	63.0	16.2 sec	D'Aoust *et al*. (2008)
Listeria monocytogenes	63.3	33.3 sec	Bunning *et al*. (2006)
	68.9	7.0 sec	Bunning *et al*. (2006)
Mycobacterium avium sub sp. *Paratuberculosis*	63.0	12.2-17.8 sec	Pearce *et al*. (2001)
	66.0	5.2-6.3 sec	Pearce *et al*. (2001)
Mycobacterium bovis	64.0	6.6 sec	Kells and Lear (2000)
	69.0	0.6 sec	Kells and Lear (2000)
Pathogenic *Streptococcus*	66.0	0.1-0.2 min	ICMSF (1996a)
Salmonella spp.	62.8	0.11 min	Doyle and Mazzotta (2000)
	71.7	0.004 min	Doyle and Mazzotta (2000
Staphylococcus aureus	65.0	0.2 min	ICMSF (1996b)
	75.0	0.02 min	ICMSF (1996b)
Yersinia enterocolitica	62.8	0.7-17.8 sec	Francis *et al*. (2000)

Sanitary practices and milk stone deposition for higher total viable count in laboratory pasteurized milk, Therefore, to ensure safe pasteurized milk proper pasteurization and prevention of post-pasteurization contamination is important.

2.3.2. Factors affecting microbiological quality of pasteurized milk

Shelf life of pasteurized milk is influenced by the quality of the raw milk (Rysstad and Kolstad, 2006), duration of storage of raw milk prior to processing, the heat-treatment employed, concentration of heat-resistant microorganisms, extent of post pasteurization contaminants, packaging system adopted, post-pasteurization storage conditions (Cromie, 2001) and effect of light (Rysstad and Kolstad, 2006).

2.3.3 Types of milk

Type of milk influences the shelf-life of milk due to diverse chemical composition and enzyme activity. Significantly, lower shelf-life of skim milk than whole milk during storage at 4.5°C or 7°C may be attributed to relatively higher protease activity in the skim milk or inhibition of protease or protection of protein from enzymatic proteolysis due to fat in whole milk (Janzen *et al*., 2002).

2.3.4 Microbiological quality of raw milk

Microbiological quality of pasteurized milk is dependent on the microbial load as well as the types of organisms present in the raw milk. Raw milk may contain heat-resistant bacterial spores of different genera such as *Bacillus* spp. and *Paenibacillus* spp. (Ralyea *et al*., 1998; Fromm and Boor, 2004; Huck *et al*., 2007b; Ranieri and Boor, 2009) and serve as the major source of *Bacillus cereus* spores in pasteurized milk (Lin *et al*., 1998) whereas only *Paenibacillus* spp. can outgrowth at refrigeration temperatures and represents major factor for limited shelf-life (Huck *et al*., 2007a,b; Ranieri and Boor, 2009; Ranieri*et al*., 2009). Amongst psychrophilic, thermoduric and thermophilic organisms, psychrotrophs are the major contributor of total microbial flora in raw milk (98.1, 1.4 and 0.5%, respectively) and the corresponding figures in pasteurized milk are 53.0, 39.5 and 7.5%, respectively (Mahari and Gashe, 2010). *Bacillus cereus*, a gram-positive, aerobic or facultative anaerobic spore-forming, motile, rod-shaped bacterium are thermally resistant and can survive milk pasteurization. Sutherland *et al*. (1996) denoted that based upon growth temperature strains of *B. cereus* can be divided into two groups as psychrotrophic (grow at 5°C and relative rapidly at 10°C) and mesophilic (fail to grow below 8°C and only grow slowly at 10°C). Pasteurization will actually induce spore germination by eliminating competing flora (Granum and Lund, 1997) and psychrotrophic spores will thus germinate and grow during refrigerated storage (Kramer and Gilbert, 2009).

2.3.5 Heat-treatment employed

Heat treatment applied to any food induced reduction in the number of organism present and the bactericidal effect is influenced by following factors (Hudson *et al*., 2003):

i. Properties of the organism
ii. Variation in the heat susceptibility of different strains of the organism
iii. Physiological state of the organism prior to treatment
iv. Chemical composition of the food

Milk is generally subjected to High Temperature Short Time (HTST) pasteurization at 71°C/15sec (Linton, 2013) or the Low Temperature Long Time (LTLT) pasteurization at 63°C/30 min (Teka, 1997) and the selection criteria should be based on the type and initial bacterial concentration in milk (Dumalisile *et al*., 2005; Hanson *et al*., 2005; Ranieri*et al*., 2009). Jayamanne and Samarajeewa (2010) noted that both HTST and LTLT pasteurization of milk were efficacious in destroying *L. monocytogenes*, when present in lower concentration (10^2 CFU mLG^{1}) but not at higher concentration (10^{7} CFU mLG^{1}). Ranieri *et al.* (2009) encountered lower microbial population in pasteurized milk heated at 60ºC followed by a thermal treatment at 72.9°C/25 sec than those subjected to 85.2 ºC/25 sec. Pasteurization of milk at lower temperature (76.1°C vs.79.4°C) induced significantly lower bacterial count (log CFU mLG^{1}) in pasteurized milk (1.39 vs. 1.58), which remained lower (3.74 vs. 4.82) even after 21 day post-processing storage at 6°C (Martin *et al*., 2012) due to residual natural antibacterial activity of lacto-peroxidase system. Complete destruction of the lacto-peroxidase enzyme in milk at 80°C/15 sec (Griffiths, 2006) but retention of upto 90% activity at 72°C/2 min and 36% activity at 76°C/40 sec (Marin *et al*., 2003) have been reported.

Heating of milk at a temperature range of 72.9-85.2°C did not exhibit any variance in the lethal effect on the different isolated bacterial genera but the endospore-forming psychrotolerant bacteria present in milk grow more effectively in pasteurized milk (Ranieri *et al*., 2009) and has emerged as a key hurdle to extending product shelf life beyond 14 days (Meer *et al*., 2001; Fromm and Boor, 2004; Durak *et al*., 2006). Optimum temperature for spore generation is 65-75ºC (Coghill and Juffs, 2009) and an elevated pasteurization temperature of 80-90°C resulted in a decline in the shelf life of milk attributable to growth stimulate of spores, decline in the affectivity of antimicrobial compounds and production of growth factors (Vatne and Castberg, 2012). Milk processed at 76°C had the lowest bacterial growth rate and longest shelf life and no improvement in the shelf life could be achieved at elevated pasteurization temperatures of 84.0 and 92.2°C as maximal bacterial growth was observed at 86.0°C (Simon and Hansen, 2001).

2.3.6 Storage conditions

Pasteurized milk has a shelf life of 2-20 days and is dependent on quality of raw milk, processing method, hygienic conditions during filling and maintenance of temperature during the entire cold chain (Rysstad and Kolstad, 2006). Janzen *et al*. (2002b) reported no significant effect of age of raw milk (0-6 days at 4.5°C) or duration of storage of the pasteurized milk (0-20 days at 4.5°C) on microbiological quality of pasteurized milk with an initial bacterial population of <1000 and <100 mLG^1 coliform. Storage temperature has a greater influence on microbiological shelf life of pasteurized milk (Petrus *et al*., 2010) and refrigerated pasteurized milk has a shelf-life of approximately 10-20 day when stored at 6.1°C (Labuza, 2012). Burdova *et al*. (2002) denoted a decrement in shelf life of full cream pasteurized milk (3-11 days) and skimmed pasteurized milk (32.57-10.71 days) with an elevation in storage temperature from 4-10°C due to more enhanced proteolytic and lipolytic activities of psychrotrophic microorganisms after 2-3 days at 10ºC in contrast to 4-6 days 4ºC. Minimum bacterial growth at 4-7°C but 15 times more activity at an elevated temperature of 15°C was noted during storage of milk (Calderon *et al*., 2006). Schroder *et al.* (2012) noted a decline in shelf life of the commercial pasteurized milk from 3-5 days with an elevation in storage temperature from 5-11ºC. Zahar *et al.* (1996) observed that storage of pasteurized milk at a higher temperature (25°C) induced rapid enhancement in microbial growth (CFU mLG^1) after 20-24 h (10^7-10^8) in contrast to those held at lower temperature (7°C) after 5 days (10^5-10^6) or 7 days (10^7-10^8).

During refrigerated storage psychrotrophic strains appear as the most important organisms limiting the shelf life of pasteurized milk (Griffiths, 2002; Ternstrom *et al*., 2013) and even though mesophilic strains do not grow at low temperatures, they serve as a breeding ground for the colonization of other bacteria in biofilms (Kumar and Anand, 1998). Further, storage studies of pasteurized milk at 6ºC indicated dominance of genus Bacillus (>85%) upto 7 days followed by a shift genus *Paenibacillus* (92%) upto 21 days (Ranieri *et al*., 2009).

2.3.7. Post pasteurization contaminants

Microbial spoilage of processed fluid milk is due to Gram (+) ve organisms surviving pasteurization temperatures or post-pasteurization contamination from Gram (-) ve bacteria (Ternstrom *et al*., 1993; Boor and Murphy, 2002). Detection of *L. monocytogenes, E. coli*(Hosein *et al*., 2008), *M. Avium* sub sp *paratuberculosis* (Paolicchi *et al*., 2012), *Pseudomonas* spp. (Samet-Bali *et al*., 2013) and bacterial phosphatase (Moshoeshoe and Olivier, 2012) in pasteurized milk was attributed to a faulty pasteurization process (Hosein *et al*., 2008; Samet-Bali *et al*., 2013), post-pasteurization contamination (Paolicchi *et al*., 2012; Moshoeshoe and Olivier, 2012) or improper post-pasteurization storage (Hosein *et al*., 2008). Mesophilic aerobic counts of pasteurized milk (7×10^{5} CFU mLG^{1}) enhanced 2-4fold increase as it left the pasteurizing unit due to its contamination with utensils used for holding and the plastic sheets used for packaging of pasteurized milk (Mahari and Gashe, 2010).

Post-pasteurization contaminations of milk products are mainly due to the filling machines or containers (Dogan and Boor, 2003; Waak *et al*., 2002) and gaskets with biofilms (Austin and Bergeron, 1995). Biofilm formation on milk post-pasteurization contact surfaces (Chmielewski and Frank, 2003; Dogan and Boor, 2003) and isolation of *Bacillus cereus* from the post-pasteurization equipment surfaces of a dairy processing unit indicated that the equipment surfaces can act as reservoirs for milk recontamination (Salustiano *et al*., 2009), thereby reducing the efficiency of pasteurization and sanitation treatments (Malek *et al*., 2012). Biofilms are matrix-enclosed bacterial population adherent to each other and/or to surfaces or interfaces (Costerton *et al*., 2005) and may have a bacterial count upto 10^{8} CFU cmG^{2} (Marques *et al*., 2007). Biofilms are difficult to eradicate employing conventional cleaning and disinfection regimens due to their resistant phenotype (Simoes *et al*., 2010) and disinfectants do not penetrate the biofilm matrix (Simoes *et al*., 2006). Amongst different sanitizer chlorine (Trachoo and Frank, 2002) and ozone (Dosti *et al*., 2005) were effective for inactivating biofilm micro flora. Nada *et al*. (2012) reported a decline in total viable count (3.11±0.30-2.18±0.54) in pasteurized milk and suggested additional investment for automated cleaning and disinfection system.

2.3.8. Process innovations for extended shelf life of pasteurized milk

An extension in the shelf-life of raw milk could be achieved with the addition of CO_2 (King and Mabbit, 2012; Rajagopal *et al*., 2005) and N_2 (Murray *et al*., 2003) or N_2 flushing through the headspace of the milk-containing vessel (Munsch-Alatossava *et al*., 2010) due to decline in bacterial count and reduction of proteolytic and lipolytic activities (King and Mabbit, 2012; Rajagopal *et al*., 2005).

The HTST pasteurization was ineffective in destroying spore-forming bacteria (Tomasula *et al*., 2011). Spores from milk can be removed employing Bactofugation or Microfiltration and latter technology is more efficient than former. TeGiffel and van der Horst (2003) reported greater removal of aerobic spores from milk employing Microfiltration (99.1-99.9%) than Bactofugation (94-98%). Microfiltration of milk for 10 min employing 0.8 μm membrane, capable of removing 5.91±0.05 log 10 spores/mL prior to HTST pasteurization (72°C/18.6 sec) is recommended and the pasteurized milk obtained showed no growth of spore-forming bacteria up to 7 days when stored at 4°C (Tomasula *et al*., 2011). Schmidt *et al.* (2012) reported that introduction of microfiltration induced a decline in microbial loads (5-6 log10 units to <1 CFU mLG^1) and spoilage occurred during storage (4-10°C) when microbial load reached >6 log10 CFU mLG^1.

2.4. Fermented Milk

2.4.1 History of microbial fermentation of cow milk

Historically, milk and dairy products have been significant components in the diets of Africans and continue to play an important and increasing role in the diets of the growing population of both rural and urban communities (Wurzingern *et al.,* 2009). Generally, milk and dairy products are rich in nutrients, delivering high quality proteins, micronutrients, vitamins and energy-containing fats (Schonfeld and Hall, 2012). Milk, thus, provides an ideal environment for the growth of wide variety of food-borne microorganisms and zoonotic agents (Quigley *et al.,* 2012). The microbiological quality of milk, at the point of milking from a healthy animal, is theoretically expected to be safe for human consumption. However, once it is secreted from the udder, milk can easily be contaminated by spoilage microorganisms and food-borne pathogens from various sources including animal faeces, soil, air, feed, water, equipment, animal hides and people. Thus, the prevalence of pathogenic and spoilage microorganisms in milk and dairy products is influenced by a high number of factors and their combinations. These factors may include health status of the dairy herd, hygiene level in the dairy farm environment, milking and pre-storage conditions, available storage facilities and technologies, farm management practices, geographic location and season (Muehlhoff *et al.*, 2013). In addition to microbial hazards, milk and dairy products can also contain chemical hazards and contaminants mainly introduced through the environment, animal feedstuffs, animal husbandry and industry practices. Thus, safety and production are intrinsically linked in the dairy food chain; from production through handling and processing to consumption. Therefore, in order to minimize the food safety risks associated with milk and dairy products, there is the need for a continuous system of preventive measures beginning with safety of animal feed, through good farming practices and on-farm controls, to good manufacturing and hygiene practices, consumers safety awareness, and proper application of food safety management systems throughout the dairy chain (Kenny, 2013). Food-safety risks associated with raw milk and dairy products consumption vary considerably between developed and developing countries. While the dairy sector in developed nations is largely industrialized, characterized by routine application of pasteurization technologies, the dairy sector in developing countries is dominated by many smallholder dairy farmers and processors (Kenny, 2013).

In most countries in Africa, the informal sector which handles most of the milk and dairy products is characterized by unpasteurized milk sold through small-scale channels that lack a cold chain and has little or no regulatory control (Omore, 2001). This review, therefore, provides a comprehensive overview of the microbial food safety issues associated with raw milk production and traditional dairy products in Africa.

2.4.3 Micro organism and milk fermentation

Fermented milk products are popular around the world and are important for delivering nutrients, for providing beneficial microbes to promote a balanced gut microbiota and for imparting desirable organoleptic properties on foods (Sybesma *et al*., 2015; Singh *et al*., 2017; Anal, 2019). The common fermented dairy products on the world market include cheese, yogurt, kefir, and many others. Most of these products derive their recipes from artisanal or traditional processes that involve spontaneous fermentation by complex microbial communities (Smid, 2015). In Africa, many traditional fermented (dairy) products made at household level exist, whose recipes and production techniques are handed down from one generation to another, i.e., from mother to daughter or father to son.

2.4.4 Importance of microbial fermented cow milk

Fermented dairy products are foods widely consumed worldwide and they have shown a substantial consumption increase in recent years and market trends suggesting that this will even increase. There is a growing consumer interest in fermented dairy products due to the nutritional and health benefits offered by these products because their effect on the bacterial microbiota of the intestine contributes to a healthy life and to increase life expectancy (Bourrie *et al*., 2016, Chen *et al*., 2019). Fermentation processes generally enhance the nutritional interest of many foods and increase the bioavailability of nutrients. The fermentation action of specific lactic acid bacteria (LAB) strains may lead to removal of toxic or anti-nutritional factors, such as lactose and galactose, from fermented milks to prevent lactose intolerance and accumulation of galactose (Shiby & Mishra, 2013). The transformation of lactose into lactic acid is the most important fact, in addition to other bioactive components. Triglyceride lipolysis is not a significant activity due to LAB has not lipase, but it has a casein proteolytic activity and produces release of amino acids and peptides. Furthermore, bacterial enzymes transform the milk carbohydrates into oligosaccharides, some of which have prebiotic properties (Granier, *et al.*, 2013). In addition to the production of lactic acid, the production of other compounds produced by LAB depends on the bacterial strains, the conditions of the fermentation process and the fermentation medium. The most common strains of LAB used for fermentation of milk are Streptococcus thermophilus, usually in association with Bifidobacteria, such *Bifidobacterium lactis*, *Bifidobacterium longum* and *Bifidobacterium animalis*, or with Lactobacilli such as *Lactobacillus acidophilus*, *Lactobacillus rhamnosus,* and *Lactobacillus casei* (Granier *et al.*, 2013).

Different LAB produce different fermentation products, although they have in common that they are alive in the product and can interact with microbiota during intestinal transit and the cells of the intestinal wall (Granier *et al*., 2013). In this sense, fermented dairy products are an excellent matrix for developing a large variety of innovative health-promoting products and functional foods. The actual trends in the food industry and the increasingly demand for healthy foods have led to the development of products providing functional components, such as prebiotic substances or probiotic bacteria. Functional foods containing prebiotics and probiotics have sparked the interest of the dairy industry due to scientific evidence related to their positive health benefits. In fact, many of the foods containing probiotics and prebiotics are fermented dairy products, such as yogurt, which is the most studied fermented dairy product, kumys, skyr, yakult, and kefir (Bourrie *et al*., 2016, Chen *et al*., 2019).

2.4.5 Components of fermented dairy products

The most important biogenic metabolites include proteins, peptides, oligosaccharides, vitamins and organic acids, including fatty acids;

1. **Proteins**

Cultured dairy products are composed of high-quality proteins, such as casein (α-s1, α-s2, β-casein, κ-casein) and whey proteins (β-lactoglobulin, α-lactoalbumin, lactoferrins, immunoglobulins, glucomacropeptide, enzymes and growth factors). Specific peptides are released during proteolysis of LAB. These peptides are bioactive and have immune modulatory, antifungal, antimicrobial, antioxidant and anti-carcinogenic activities (Fernandez, Picard-Deland, Le Barz, Daniel, & Marette, 2016). In addition, due to this proteolytic effect of some LAB, the digestive process increases the digestibility and biological value of the protein (Tojo Sierra, Leis Trabazo, & Barros Velázquez, 2006). The milk LAB proteinases, such as those of *Lactococcus lactis* emit biologically active *oligopeptides* from α- and β-caseins, which have amino acid sequences that are present in casomorphines, lactorphines, casokinines and immune peptides that are peptides with some biological activities, some similar to morphine. The oligopeptides have similar characteristics to analgesics, stimulate the excretion of insulin and somatostatin, prolong the gastrointestinal reabsorption of nutrients, modulate the transport of amino acids in the intestine and also act as antidiarrheal agents. These atypical opioid peptides differ from endogenous opioids, such as enkephalins and endorphins, only in their N-terminal sequences (Verruck *et al*., 2019)

In addition, Bacteriocins act against other bacteria with bactericidal or bacteriostatic activity. This ability can be very useful and represent an opportunity to search for new bacteriocins in complex microbiota, such as those of a traditional fermented product (Hill *et al*., 2017).

In addition, bioactive peptides are encrypted in larger proteins and, when released after proteolysis, have been associated with health promotion through a number of mechanisms such as ACE inhibitor, antithrombotic, antihypertensive, antioxidant, immunomodulation, modulation of apoptosis and opioid and anti-opioid activities. LAB has proteases and peptidases that can release encrypted peptides during milk fermentation or after ingestion of cultured products containing LAB in the intestinal lumen (Hill *et al*., 2017).

2. Lipids

Yogurt has a lower fat content than milk, due to the dairy ingredients used in its preparation. Fatty derivatives are also found by the bacteria, which contribute to the aroma (Tojo Sierra *et al*., 2006). Depending on the origin of the milk and the manufacturing process, the lipid content in the yogurt can vary in quantity, but the quality does not change significantly compared to the original milk.

Triglycerides are more than 95% of lipids of yogurt. In spite of the content of saturated fats (72%), the health benefits appear to be attributed to yogurt lipids, which also contain 25% monounsaturated and 3% polyunsaturated fatty acids and are vectors of fat-soluble vitamins A, D, E and K. In addition, dairy products contain high levels of conjugated linoleic acid (Fernandez *et al*., 2016).

3. Carbohydrates

Lactose is the main carbohydrate available in dairy products which gives rise to lactic acid after fermentation. Depending on the type of product and industrial additives, this disaccharide can reach up to 98% of the total carbohydrates in natural yogurt. Its hydrolysis in glucose and galactose occurs mainly in the digestive tract by the β-galactosidase of the intestinal brush border. In addition, it contains oligosaccharides, polysaccharides and depending on the strains, some types of exopolysaccharides (homo and heteropolysaccharides) produced by LAB (Fernandez *et al*., 2016).

4. Vitamins and minerals

Fermented dairy products are rich in many vitamins and minerals highly bioavailable (Fernandez *et al*., 2016). They represent an important contribution of vitamins A, B_1, B_2, B_6, B_{12}, niacin, pantothenic acid and folic acid, as well as vitamin D, calcium, phosphorus, potassium, magnesium, zinc and potassium iodide (Moreno-Montoro, 2015, Tojo Sierra *et al*., 2006). Many of these micronutrients have a higher bioavailability in the fermented milk products than in raw milk due to the process of acidity and fermentation, which mainly affects the content of vitamins (Fernandez *et al*., 2016).

In addition, the contribution of lactic acid seems to play an important role in the absorption of calcium, inhibition of the microbiota pathogenic and in the stimulation of intestinal secretion (Tojo Sierra *et al*., 2006).

2.5 Prebiotics

A prebiotic is a component with selective fermentation that produces specific changes in the composition of the gastrointestinal microbiota, as well as in its activity with beneficial effects on the health of the host (Hill *et al*., 2017). The gastrointestinal microbiota produces a selective fermentation of prebiotics which modulates intestinal health through the production of bioactive metabolites, (Druart *et al*., 2015) especially short-chain fatty acids (acetate, propionate, butyrate, lactate) (Chen *et al*., 2019) which are generated by fermentation of complex carbohydrates, (Zaiss, Jones, Schett, & Pacifici, 2019); and poly-unsaturated fatty acids (Druart *et al*., 2015) showing an efflux from the gut into the systemic circulation. Short-chain fatty acids have a profound impact on intestinal cells and participate in the control of various processes such as mucosal proliferation, inflammation, colorectal carcinogenesis, mineral absorption and elimination of nitrogenous compounds (Zaiss *et al*., 2019). Different pathways are proposed to increase the amount of short fatty acids including, through probiotics, prebiotics and symbiotics. (Chen *et al*., 2019) Metabolites of bacterial origin account for about 10% of circulating metabolites and they have emerged as key regulatory metabolites (Zaiss *et al*., 2019). These components are non-digestible and selectively stimulate the growth of specific microorganisms.

The symbiotic is a combination of probiotics and prebiotics in the same dairy product. The function of the prebiotic is to improve the survival, growth and performance of probiotics or other beneficial bacteria in the colon inducing health benefits (Hill *et al*., 2017). Both lactose and exo-polysaccharides are a known source of prebiotics (Aryana and Olson, 2017). Another source of prebiotics are galactooligosaccharides, polydextrose, sialyllactose and sialyllactose that could significantly improve the absorption and synthesis of B vitamins (Allen *et al*., 2019), of particular interest are micronutrients, such as B vitamins, precursors of indispensable metabolic cofactors, that are produced *de novo* by some gut bacteria but must be provided exogenously in the diet for many other bacterial strains (Rodionov *et al*., 2019).

The use of probiotics, prebiotics and symbiotics in the treatment or prevention of cancer is being largely investigated. There is evidence that these act as anti-carcinogenic agents or antimutagenic agents through the diet (Hill *et al*., 2017).

2.6 Probiotics

Probiotics are live microorganisms that confer a benefit to the health of the host when administered in adequate amounts. In the global guidelines on probiotics and prebiotics published in 2013 by the World Gastroenterology Organization it confirmed that the effectiveness of probiotics is specific to the strain and the specific dose, dispelling the myth that any yogurt can be considered a probiotic. Three broad categories of probiotics were defined in 2014 (McFarland, 2015).

i. Those who not have health claims (generally they are considered safe, does not require proof of effectiveness).
ii. As a dietary supplement with a specific health claim (define the strain used, evidence-based effectiveness of clinical trials or meta-analysis and use to strengthen the immune system).
iii. As a probiotic drug (clinical trial for specific indication or disease, define the strain used, risk–benefit and compliance with the regulations that legislate the drugs).

It was found that probiotics are especially indicated in the prevention of diarrhea associated with antibiotics, treatment of *Helicobacter pylori* infection, treatment of pediatric acute diarrhea, prevention of allergies, treatment of chronic disease irritable bowel syndrome, treatment of inflammatory bowel disease, treatment of vaginitis and bacterial vaginosis, prevention of necrotizing enterocolitis in newborns, prevention of traveler's diarrhea, treatment of acute diarrhea in adults, treatment of constipation, treatment of *Clostridium difficile* infection, sepsis, dental infections, obesity. The findings of clinical effectiveness vary according to the probiotic strain and the type of indication (McFarland, 2015)

2.7 Yeasts

A unique feature of the traditional production of fermented dairy products is a large amount of yeast in the grain and the fermented milk. Although most of the microorganisms probiotics marketed are bacteria such as lactobacilli and bifidobacteria, there are some other like *Saccharomyces boulardii* (Bourrie *et al*., 2016).

It has been shown that *S. boulardii* improves symptoms of diarrhea associated with *Clostridium difficile*, as well as that it reduces inflammation and it alters the immune status and reactions in the intestine, for this reason is diarrhea treatment's caused by *C. difficile*. Some yeasts of the kefir have immunomodulatory characteristics, *Kluyveromyces marxianus* B0399 has the ability to adhere to Caco-2 cells. When the yeast is co-incubated with Caco-2 cells stimulated with lipopolysaccharide, it was observed a reduction in the secretion of IL-10, IL-12, IL-8 and IFN-γ. In addition, *K. marxianus* B0399 caused a reduction in the secretion of proinflammatory cytokines TNF-α, IL-6 and MIP1α in peripheral blood mononuclear cell which had been stimulated with lipopolysaccharide (Maccaferri, Klinder, Brigidi, Cavina, & Costabile, 2012).

2.8 Exclusion of Pathogens

Probiotics can change the intestinal microbiota when installed in the intestinal transit, or by promoting the growth of beneficial microorganisms present. The consumption of kefir or kefiran in an animal model increased count of beneficial bacteria, mostly of the *Lactobacillus* and *Bifido bacterium*, in addition to reducing harmful microbial species such as Clostridium perfringens. The consumption of kefir makes less severe the infection by *Giardia intestinalis* in C57BL/6 mice, due to the modulation of the immune system. The Lactobacillus specific strains that have been isolated from kefir can adhere to Caco-2 cells preventing them from adhering to *Salmonella typhimurium* and *Escherichia coli* O157: H (Bourrie *et al*., 2016) In addition, *Lactobacillus* have the ability to protect vero cells from shiga toxin type II produced by E. coli O157: H7 and inhibit the ability of Bacillus cereus extracellular factors to cause damage to Caco-2 cells. The consumption of LAB can decrease the effect of Escherichia coli thanks to the anti-E metabolites that avoid colonization by pathogenic bacteria (Shiby & Mishra, 2013).

2.9 Antibacterial and Antifungal Properties

The bioactive peptides produced during fermentation of milk by Lactobacillus helveticus have been proposed as an alternative for the control of the bacterial infection due to its antimicrobial and immune-stimulating properties (Matar, *et al.*, 2001).

The potential stimulatory effect of cell-free supernatant of milk fermented by Lactobacillus helveticus LH-2 and its fraction peptide F5 was investigated in macrophages. The free fraction of cells from the fermented milk increased the production of IL-6, TNF-α, IL-1β through stimulation of macrophages, accompanied by a greater production of nitric oxide and phagocytic activity. The nitric oxide, whose synthesis is induced by TNF-α, is one of the cytotoxic agents by which macrophages can kill bacteria and other pathogens, as well as tumor cells. In addition, the

TNF-α is a main component of host defense against trauma and infection and is of great importance because it induces the gene expression of various cytokines and nitric oxide synthesis. These effects suggest that the F5 peptide fraction could exert a modulation of macrophage functions (Tellez, *et al.*, 2010).

Supplementation of a replacement diet with goat's milk fermented with *Lactobacillus rhamnosus* increases resistance to infections by *Salmonella typhimurium* and *Streptococcus pneumoniae* in immunocompromised hosts. In addition, it accelerated the recovery of the clinical nutritional parameters such as body weight and thymus. The recovery of the serum protein profile studied could be the result of a higher bioavailability of peptides and amino acids, which would facilitate its absorption at the intestinal level. In addition, the inclusion of the fermented goat milk in repletion diet improved the hematological parameters. The early normalization of leukocytes, neutrophils and lymphocytes in micés blood treated with fermented goat milk it would be important for the recovery of the immunity against infections. It is likely that the stimulation of immunity by the fermented goat milk depends of *L. rhamnosus* and also of byproducts such as bioactive peptides (Salva *et al.*, 2011).

On the other hand, the kefir has been shown to have a multitude of antibacterial and antifungal activities. It has been found that the kefir fermented milk has a similar function to ampicillin, amoxicillin, azithromycin, ceftriaxone and cetoconazol. Besides the antimicrobial effects of kefir fermented milk, there are microorganisms that have themselves antimicrobial properties. *Lactobacillus plantarum* produces the bacteriocin ST8KF that exhibits antimicrobial action against Enterococcus mundtii and Listeria innocua. Other Lactobacillus species derived from kefir grains, such as *Lactobacillus acidophilus* and *Lactobacillus kefiranofaciens*, as well as some strains of *Streptococcus thermophilus*, have demonstrated antimicrobial activity against a range of pathogens including *Echerichia* coli, *Staphylococcus aureus, Salmonella typhimurium, Salmonella enteritidis and Yersinia enterocolitica* (Bourrie *et al*., 2016).

Other *lactobacilli* of the kefir also have antimicrobial activity against *Salmonella typhimurium* and E. coli. Lacticin 3147 has antimicrobial activity, affecting *Bacillus subtilis,* Ba*cillus cereus, Clostridium sporogenes, Clostridium tyrobutyricum, Enterococcus faecium, Enterococcus faecalis, Listeria innocua, Listeria monocytogenes, Staphylococcus aureus* and *Clostridium difficile* (Bourrie *et al*., 2016).

2.10 Anti-Carcinogenic Effects

The effects of yogurt and LAB on cancer and intestinal inflammation have been extensively studied. The preventive effect of probiotics on the carcinogenesis may be associated with the modulation of the immune response and changes in the intestinal microbiota, preventing the increase of bacteria that become procarcinogens in carcinogens (De Moreno *et al.,* 2010).

2.10.1 Colon cancer

In a murine colon cancer model, the consumption of yogurt inhibits tumor growth through the reduction of the inflammatory response through the increase of IL-10-secreting cells, apoptosis and the decline of the procarcinogenicas enzymes (De Moreno *et al.,* 2010).

The intestinal enzyme activities of β-glucuronidase and nitrorreductasa in a model of colon cancer were increased after dimethylhydrazine (DMH) injection, contributing to its power mutagenic. The injection of DMH produced lower levels of enzymatic activity in mice fed with yogurt than in the control group with tumor. However, this effect was not observed when mice were given the bacteria derived metabolites of yogurt. These results show that the bacteria in yogurt can be involved in the decline of the procarcinogens enzymatic activities and in the intestinal microbial changes (De Moreno *et al.,* 2005).

The administration of yogurt to mice injected with DMH increases the number of cells that encode IgA and CD4 T lymphocytes in the lamina propria of large intestine with a decrease in the IgG and CD8 T-cells. The increase in the number of cells that secrete IgA and no increase in IgG cells in the intestine of mice fed with yogurt could limit the inflammatory response, because the IgA is considered an important barrier in colonic neoplasia (Moreno *et al.*, 2007).

In addition to yogurt, kefir produces high level of TNF-α and IFN-γ that will lead to high level of IgA secretion (Sharifi *et al*., 2017). On the other hand, bioactive peptides in kefir induce activation of macrophages and phagocytosis and nitric oxide (NO) production (Sharifi *et al*., 2017). The mice carriers of tumors have high amounts of inducible nitric oxide synthase (iNOS) (+) cells, which suggests an increase in the production of nitric oxide (NO) by these cells. The synthesis of the enzyme iNOS could be induced by IFN-γ that increase in the intestinal tissue in the DMH group. In the mice with tumor fed with yogurt the cells iNOS (+) lowered when the inflammation decreased (Moreno *et al*., 2007).

The lack of enzymatic induction of iNOS in DMH-yogurt group and control group with yogurt alone can show the way through which the yogurt can regulate the immune system modulating the inflammatory response. Despite the increase in the number of secretory cells of IFN-γ (+), the production of NO does not increased and, as a result, it was not observed tumor growth, only cellular infiltration. Therefore, it is suggested that the large number of IFN-γ (+) cells in mice fed with yogurt could be related to the increased number of immune cells in the intestine and it could be regulated by other cytokines such as IL-10. Feeding with yogurt produced by itself the greatest number of cells IL-10 (+), which shows that the administration of this fermented milk contributed to maintaining a regulated immune response in the intestine of mice fed with yogurt (Perdigón, *et al.*, 2002).

The ability of kefir supernatant to exert protective effects in DNA damage induced by carcinogen agents was shown at all the concentrations used in human colon adenocarcinoma cells (Rafie *et al*., 2015, Sharifi *et al*., 2017).

Fermented milks may modulate the immune system of the mucosa. The administration of fermented products may have an impact on the intestinal microbiota, stimulate immune cells associated to the intestine and it is useful against the intestinal inflammation and colon cancer (De Moreno *et al.,* 2010).

2.10.2 Breast cancer

In recent years considerable progress has been made in the understanding of the molecular factors involved in the development of breast cancer. There are genetic and environmental factors that increase the chances of breast cancer and the types of breast cancer most common are dependent on estrogen. Some factors, such as diets rich in fermented dairy products, can inhibit the growth of many types of cancer, including breast tumors (De Moreno *et al*., 2007).

Fermented milks have fractions of peptides produced during fermentation that can stimulate the immune system and inhibit the growth of tumors (Matar *et al*., 2001). Milk fermented with Lactobacillus helveticus R389 slows the growth of breast tumor. This fermented milk decreases IL-6 and increases IL-10 and IL-4 in serum, mammary glands and immune cells (De Moreno et al., 2010). The decrease in IL-6 also occurred in mice fed with kefir or KF (the free fraction of cells of the kefir) (De Moreno *et al*., 2006, Rafie *et al*., 2015). Microbial proteolysis could result in bioactive peptides since the peptides are different after LAB fermentation. This fact can be demonstrated through the mutagenic effect exerted by fermented milk by Lactobacillus helveticus R389, a bacterium with high protease and peptidase activity, while a mutant strain (L89), which is deficient in proteolytic activity, did not exert this effect. Similarly, the number of IgA secretory cells in the small intestine increased (Moreno *et al*., 2007) thanks to the fact that fermented dairy products induce the secretion of TNF-α that leads to a high level of IgA secretion (Sharifi *et al*., 2017).

The number of CD4 cells increased, while the number of CD8 cells remained unchanged in the group fed with fermented milk by Lactobacillus helveticus R389 and injected with tumor cells. This result was different in the control group with tumor, which had more CD8 cells than CD4 cells (Moreno *et al*., 2007).

Seven days of cyclic administration of fermented milk with Lactobacillus helveticus R389 delayed or stopped the development of breast cancer. Tumor growth decreased in mice after 2 days of feeding cyclical with kefir, and the same cyclic feeding with KF showed the most significant delay of tumor growth. The pattern of cytokines was similar for all three products in connection with the delay in the development of the tumor (De Moreno et al., 2010). KF had a significant impact on the size of the tumor, the apoptosis and the immune recruitment in a model of murine breast cancer, resulting in an increase in apoptosis of the tumor cells and an increase of the population CD 4 of T-cells (Bourrie *et al*., 2016). Kefir show significant dose-dependent suppressive effects on breast cancer cells proliferation with no inhibitory effects on normal cells (Rafie *et al*., 2015).

In addition, Lactobacillus acidophilus isolated from yogurt reduced tumor growth rate and increased lymphocyte proliferation in a mouse model of breast cancer (Pei et al., 2017). Sharifi *et al*. (2017) reported that fermented dairy products induce apo

2.11 Pastoralists Milk Quality

Microbial load is a major factor in determining milk quality (Fatine *et al*., 2012). It indicates the hygienic level exercised during milking, cleanliness of the milk utensils, condition of storage, manner of transport as well as the cleanliness of the udder of the individual animals. Milk from a healthy udder contains few bacteria but it picks up many bacteria from the time it leaves the teat of the cow until it is used for further processing. Milk directly obtained from a healthy udder is considered to be sterile, and most microbial contamination of milk and milk products occurs during milking, storage, transportation, and processing (Vairamuthu *et al.*, 2010). Normally, milk produced by healthy cows contains a very low concentration of micro-organisms, since the teat canal can act as an anatomical-mechanical and chemical-cellular barrier. In principle, when pathogenic bacteria enter the udder, the defense system of the udder sends a vast number of leucocytes into milk to remove the bacterial pathogens (Blowey and Edmondson, 2010). The sudden increase of SCC (Somatic Cell Count) in milk is a primary feature of inflammation. If the inflammatory reaction cannot destroy bacteria, affected cows remain contagious.

Microbial contamination of food caused by improper handling and poor environmental hygiene and sanitation is the leading cause of foodborne morbidity and mortality, especially in developing countries (Grace, 2015). Food can be a vehicle for a number of pathogens belonging to bacterial, viral, and parasitic agents (Fleckenstein *et al.*, 2010). Salmonella infection is a major health problem both in developed and developing countries. Specifically, non-typhoid *Salmonella spp*. are responsible for a number of health problems in humans such as gastroenteritis, bacteremia, and subsequent focal infection (Eng *et al*, 2015). These types of infections could be highly problematic especially in immunocompromised individuals. There are a variety of animal source foods associated with Salmonella infection in humans. Some of these foods are ground beef, chicken, eggs, and unpasteurized dairy products (de FreitasNeto *et al.*, 2010). Transmission to people occurs primarily through ingestion of inadequately processed or contaminated food or water (Ferens and Hovde, 2011).

Microorganisms can enter into milk during milking stage, storage or transportation to the market (Garedew *et al.*, 2012). Once they enter into milk, microorganisms can multiply and cause changes to its quality and safety value. If pathogenic microorganisms are involved, they can cause harm to consumers by causing human illness and disease (Griffiths, 2010, Barros *et al.*, 2011, Dhanashekar *et al.*, 2012). Raw milk with high microbial load has poor keeping quality and products manufactured from it are of inferior quality and have a reduced shelf life (Hayes *et al.,* 2011).

The safety and wholesomeness of milk intended for human consumption are affected by a number of complex and interlinked factors (Fox *et al.*, 2017). Contaminated milk can harbor a variety of pathogenic microorganisms such as *Salmonella spp., Escherichia coli O157:H7,* toxigenic *Staphylococcus aureus*, and *Listeria monocytogenes*; all of these cause significant human illnesses (Mhone *et al.*, 2015). Darapheak *et al*. (2013) showed an increased risk of diarrhea in children consuming milk in Cambodia. In pastoral communities, milk is widely consumed in raw form and makes a substantial contribution to protein and micronutrient requirements of the community (Elhadi *et al.*, 2015). The trade-offs, however, are health risks that come with poor hygienic practice of milk handling and consumption.

Quality and safety measures for milk are not common in traditional smallholder or extensive livestock production in developing countries (Kamana *et al.,* 2017). As a result, milk is produced under unhygienic conditions leading to high microbial contamination and spoilage with associated health risks to consumers (Kamana *et al.,* 2014). A study identified appropriate risk reduction strategies in pastoral milk production and consequent health risks associated with particular foods (Kebede *et al.*, 2019). Milk somatic cell count is widely used to monitor udder health. SCC and bacteriological examination indicate the status of mammary gland health (Harmon, 1994).

Mastitis is the inflammation of the udder. Over 200 different organisms are known to cause bovine mastitis (Blowey and Edmondson, 2010). They can be divided into two groups: contagious and environmental pathogens according to their origins. Mastitis caused by contagious pathogens such as *Staphilococus aureus* or *Streptococcus agalactiae* are widespread, usually causing subclinical infections and a large milk SCC increase (Blowey and Edmondson, 2010). Environmental pathogens such as *Str*. *uberis* and *Str*. *dysagalactiae* cause considerably less SCC elevation. Thus the SCC level varies largely depending on the type of bacteria infecting the udder. The SCC may be affected by several factors, such as bacterial infection, age and stage of lactation, environmental and management factors or a combination of these factors (Blowey and Edmondson, 2010). The level of inflammation in the udder can be affected by several factors.

Milk SCC increase with advancing age and with exposure to previous infections (Harmon, 1994). This is due to the increased period of exposure of the udder experienced with infection over the lactations. Milk SCC is often high in the first 7 to 10 days after calving and in late gestation (Blowey and Edmondson, 2010). High SCC in the first weeks after calving appears to be a part of the cow's natural immune system response in preparation for calving and enhances the mammary glands defense at parturition time. Udder quarters with no infection have a rapid decline in SCC within a few weeks postpartum (Bartlett *et al*., 1990). Towards the end of lactation, since the amount of milk produced is diminishing SCC increases in milk (Blowey and Laven, 2004).

Bacterial contamination of raw milk can generally occur from three main sources; within the udder (contagious), outside the udder and from the surface of equipment used for milk handling and storage and different other sources (environmental): air, milking equipment, feed, soil, faeces and grass (Coorevits *et al*., 2008). It is hypothesized that differences in feeding and housing strategies of cows may influence the microbial quality of milk (Coorevits *et al*., 2008). Bacteria in raw milk can affect the quality, safety, and consumer acceptance of dairy products. Use of non-potable water may also cause entry of pathogens into milk. It is known that tropical conditions which have a hot, humid climate for much of the year are ideal for quick milk deterioration, because the temperature is ideal for growth and multiplication of many bacteria (Godefay and Molla, 2000). Information on the bacterial content of a milk sample may reflect on the state of health of the cow, the conditions under which the milk is stored and distributed, and its public health significance.

2.11.1 Contagious factors

Raw milk as it leaves the udder of healthy cows normally contains very low numbers of microorganisms and generally will contain less than 1000 colony-forming units of total bacteria per milliliter (cfu/ml). In healthy cows, bacterial colonization within the teat cistern, teat canal, and on healthy teat skin does not significantly contribute total numbers of bacteria neither in bulk milk, nor to the potential increase in bacterial numbers during refrigerated storage.

While *Staph. aureus* and *Strep. agalatiae* are rarely found outside of the mammary gland, environmental mastitis pathogens (*Strep. uberis* and coliforms) can occur in milk as a result of other contributing factors such as dirty cows, poor equipment cleaning and/or poor cooling. Increases in SCC can sometimes serve as supportive evidence that mastitis bacteria may have caused increases in the bulk tank counts.

Mastitis may cause an alternation in fat, lactose and protein content in milk (Nielsen *et al.*, 2005). Declining fat content during mastitis is due to the reduced synthetic and secretory capacity of the mammary gland. Free fatty acids in mastitis milk may increase as a consequence of inflammation, probably caused by increased activity of the enzyme lipase. Protein composition changes towards increased whey protein content, while content of casein proteins declines (Walstra *et al.*, 2006). It is established that mastitis bacteria can affect the quality of milk. Ma *et al.* (2000) confirmed that mastitis caused by *Stretococcus agalactiae* adversely affected the quality of pasteurized fluid milk.

2.11.2 Environmental factors

Stress of various types, such as estrus, disease, vaccination, drug administration (Blowey and Laven, 2004) and heat stress that can alter either the hormonal or physiological state of the animal (Rhone *et al*., 2008) may affect the SCC of individual cows. Stress may increase the number of leucocytes in blood (Blowey and Laven, 2004). The cows that are susceptible to heat stress in the tropics either through direct exposure, their skin color or increased environmental temperatures may be at increased risk of developing new infections, which in turn give rise to higher SCC and reduced milk yield (Rhone *et al.*, 2008).

It is generally known that milk SCC is higher in the afternoon milking than in the morning milking (Blowey and Laven, 2004). This is due to the shorter milking interval and lower milk yield in the afternoon resulting in a concentration effect (Hale *et al*., 2003). Somatic cell count can vary from day to day depending on the hygienic conditions and/or function of the milking machine.

The exterior of the cow's udder and teats can contribute microorganisms that are naturally associated with the skin of the animal as well as microorganisms that are derived from the environment in which the cow is housed and milked. In general, the direct influence of natural inhabitants as contaminants in the total bulk milk count is considered to be small and most of these organisms do not grow competitively in milk. The contribution of microorganisms from teats soiled with manure, mud, feeds or bedding cannot be overemphasized.

Teats and udders of cows inevitably become contaminated while they are lying in stalls or when allowed in dirty lots. Organisms associated with bedding materials that contaminate the surface of teats and udders include Streptococci, Staphylococci, spore-formers, coliforms and other Gram-negative bacteria. The influence of dirty cows on Total Bacteria Counts (TBC) depends on the extent of soiling of the teat surface and the udder preparation procedures employed. Milking heavily soiled cows could potentially result in bulk milk counts exceeding 10,000 cfu/ml. Generally, thorough cleaning of the teat with a sanitizing solution (predip) followed by thorough drying with a clean towel is effective in reducing the numbers of bacteria in milk from soiled teats. The degree of cleanliness of the milking system probably influences the total bulk milk bacteria count as much, if not more, than any other factor. Milk residue left on equipment/contact surfaces supports the growth of a variety of microorganisms. Organisms considered to be natural inhabitants of the teat canal and teat skin are not thought to grow significantly on soiled milk contact surfaces or during refrigerated storage of milk. This generally holds true for organisms associated with contagious mastitis (*Staph. aureus* and *Strep. agalactae)* though it is possible that certain bacteria associated with environmental mastitis (coliforms) may be able to grow significantly. Bacteria from environmental contamination (bedding or manure) are more likely to grow on soiled equipment surfaces. Water used on the farm might also be a source of bacteria.

In general, these organisms are not thermoduric and will not survive pasteurization. Under conditions of poor cooling with temperatures greater than 45°F, bacteria are able to grow rapidly and can become predominant in raw milk. Streptococci have historically been associated with poor cooling of milk. These bacteria will increase the acidity of milk. Certain bacteria are also responsible for a "malty defect" that is easily detected by its distinct odor. The types of bacteria that grow and become significant will depend on the initial contamination of the milk.

2.11.3 Different test procedures for microbes in raw milk

The Standard Plate Count (SPC) is used extensively in both regulatory and premium testing programs. In addition to the SPC, raw milk can be subjected to a number of other bacteriological tests that are used as indicators of how that milk was produced. These tests may be included in determining eligibility for premium payments or they may be used only as an added quality assurance tool. The bacteriological tests most often used in addition to the SPC are the Preliminary Incubation Count (PI), the Laboratory Pasteurization Count (LPC) and the Coliform Count. While the SPC gives an estimated count of the total bacteria in a sample, the PI, LPC and Coliform Count select for specific groups of bacteria that are associated with poor milking practices. Results of these testing procedures are used to help identify potential problems that may not be detected by the SPC (Richard, 2010).

Indirect methods such as the California Mastitis Test (CMT), Sodium Lauryl Sulphate Test (SLST), Surf Field Mastitis Test (SFMT) and White Side Test (WST) are available for the diagnosis of mastitis under field conditions (as cow side test). Aseptically collected milk from clean, healthy cows generally has an SPC less than 1,000 cfu/ml. higher counts suggest bacteria are entering the milk from a variety of possible sources. Though it is impossible to eliminate all sources of contamination, counts less than 5,000 cfu/ml are possible. The most frequent cause of a high SPC is poor cleaning of the milking system. Milk residues on equipment surfaces provide nutrients for growth and multiplication of bacteria that contaminate the milk at subsequent milk times. Other procedures that can elevate bulk-tank SPC are milking dirty udders, maintaining an unclean milking and housing environment, and failing to rapidly cool milk to less than 40°F.

Psychrotrophic bacteria are becoming increasingly dangerous to the dairy industry because they produce extracellular heat – resistant lipases and proteases (Shah, 1994). Milk altered by the activity of these enzymatic systems is depreciated and must be eliminated from processing. Psychrotrophic bacteria present in raw cow's milk include the Gram-negative genera *Pseudomonas, Alcaligenes, Achromobacter, Aeromonas, Serratia, Chromobacterium and Flavobacterium*, and the Gram-positive genera *Bacillus, Clostridium, Corynebacterium, Streptococcus, Lactobacillus, and Microbacterium* (Sørhaug and Stepaniak, 1997). The group of heat-resistant psychrotrophic bacteria surviving pasteurisation temperatures includes spore-forming *Bacillus spp*. producing extracellular proteases, lipases, and phospholipases (lecithinases), the heat resistance of which is comparable with that of enzymes produced by *Pseudomonas spp*. (Matta and Punj, 1999).

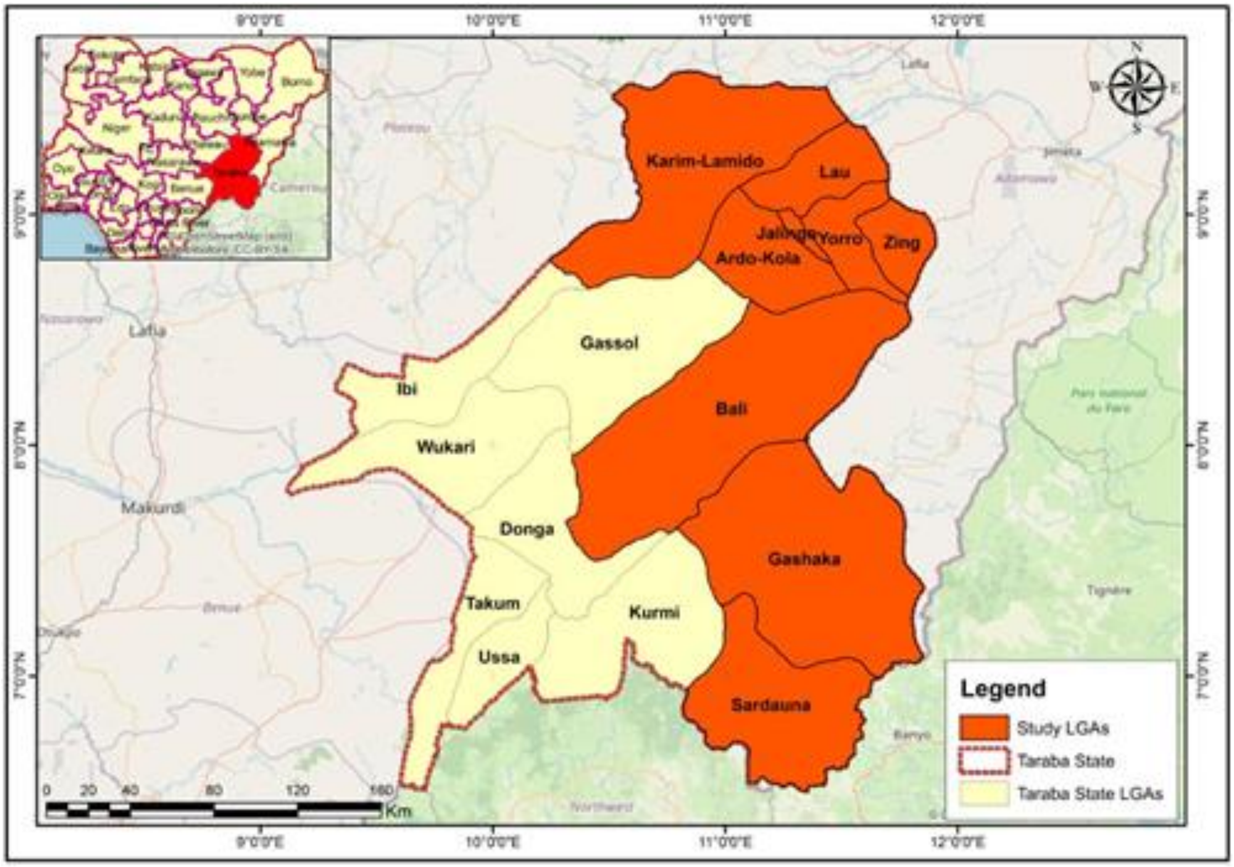
The current EU standards for top quality milk require that Total Bacterial Count (TBC) and Psychotrophic Bacterial Count (PBC) shall not exceed 30,000 cfu/ml and 5,000 cfu/ml, respectively, which corresponds to the ratio 6/1. Changes in this ratio, resulting mostly from increases in the proportions of proteolytic and lipolytic and mostly psychrotrophic bacteria in raw milk are regarded as a frequent cause of the current unexplained problems in milk processing.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 The Study Areas

The study was carried out in Taraba state. The climate of Taraba state is marked by an annual average temperature of 33°C but high level of cold in January and an increased rainfall in August. The percentage of rainfall in Taraba state is 40.35% with 54.98% relative humidity. The state is usually very warm in March with 40.44°C, and an average wind of 8.84km/h. Taraba is a hub for livestock activities with a significant number of nomadic settlements. Taraba state projected livestock population is 23,549,584 million; 5,577,980 cattle, 3,061,666 sheep, 3,686,973 goats, 3,212,979 pigs and 8,009,986 poultry (Ayi., *et al.,* 2020).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Kurmi
Ussa
Sardauna
Lafia
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0 20 40 80 120 160 Km
Legend
Study LGAs
Taraba State
Taraba State LGAs

3.2 Phases of the Study

The study was carried out in Four Phases designated study 1, 2, 3 and 4 as follow:

Study 1: Understudied the socio-economic characteristics of milk producer groups in the study area through qualitative research technique. (Survey, using a structured questionnaire)

Study 2: Investigation of the presence and types of mastitis causing organisms in the area of the study (samples collected included: swap samples of teat before washing, after washing with water, after washing with disinfectant and samples of the bedding soils)

Study 3: Identification and classification of types of microbes present in milk and milk products; raw milk immediately after milking, overnight raw milk, locally pasteurized and locally fermented milk.

Study 4: Investigation of milk nutrient composition among smallholder dairy farmers samples includes (raw milk immediately after milking, overnight raw milk, locally pasteurized, and locally fermented milk samples, parameters included :milk fat, Solid Non Fat (SNF), Milk Density, Milk Protein, Milk Lactose, Added Water, Milk Freezing point, , Milk PH, Milk Salts and Milk Temperature.

3.3 Demographics or Socio-Economic Characteristics/Experimental Design

A cross-sectional study survey was conducted to determine the demographic information of dairy producers, information on herds owned by pastoralists, milk production practices by pastoralists and preview factors predisposing milk produced by pastoralists to contamination through questionnaires. A total of 200 questionnaires were administered to four local governments in Taraba. A total of 200 raw, pasteurized and fermented milk samples from pastoralists were collected for nutrient composition analysis, detection of presence and types of microbes. nutrient analysis done includeded; crude protein, fats, salts, Protein added water, Solid Non Fat (SNF)

The magnitudes of microbial contamination of the raw (unpasteurized) cow milk samples were also be determined to identify presence and types of micro-organisms present in milk samples.

The target farmers were the small holder nomadic/transhumance pastoralists, agro-pastoralists who normally keep traditional cattle managed under extensive husbandry system and peri-urban farmer. The traditional cattle rarely get veterinary services although some practices tick control through the use of acaricides.

3.4 Study 1: Characterization of milk, milk products and socio-economic structure of smallholder cattle rearing households in Taraba State

3.4.1 Questionnaire administration

Three stage sampling method was used in the selection of respondents for the study. The first stage concerned the sampling of four dairy producing Local government areas in Taraba state that are of within 100km radius from the state capital, namely: Jalingo, Bali, Ardo-kola, and Gassol, four Local Governments Areas. The second stage was the purposive selection of three districts within each Local Government Areas with high concentration of cattle and noticeable dairy activities within their communities structured questionnaires (pre-tested) through interviews were used for data collection. The questionnaires were pre-tested on 60 small holder dairy farmers randomly selected from one of smallholder dairy clusters in the study area.

Face to face key informant interviews and questionnaire approach were also used. The questionnaires which were divided into four sections with each section addressing one objective, which were cattle farmers demography, constraints associated with milk transaction, constraints associated with cattle reproduction and management and constraints associated with feeds, weather and diseases respectively. 200 dairy cattle farmers comprising of both males and females were selected using stratified random sampling and were interviewed. The consent of the participants were sought and they were assured that information obtained from them will be taken with high level of confidentiality and will be used solely for the purpose of the study , how -ever they were free to retract their interview at any point in time that they feel uncomfortable with the participation.. The farmers were interviewed directly individually and in groups through an interpreter where necessary based on the structured questionnaire designed for the study in line with the standard design by (Waters-Bayer and Bayers, 1994).

3.4.2 Statistical analysis

Study survey; Descriptive statistics; particularly percentages, means, standard deviations and counts from multiple responses analysis were used to determine distributions and magnitudes of variables among the respondents.

3.5 Study 2: Investigation of Presence and Types of Mastitis Causing Organisms in the Area of the Study

3.5. 1 Determination of mastitis causing organisms in dairy farms

There are numerous works on the prevalence of mastitis in bovine milk but less attention has been paid to the mastitis causing organisms and at what stage they are introduced and level of their resistance. Thus this work investigated presence and types of mastitis causing organism and their level of resistance.

3.5.2 Collection of samples for identification of mastitis causing organisms

Samples collected included:

i. Swap sample of the untouched udder of the cow
ii. Swap sample of the udder after being washed with ordinary water
iii. Swap sample of the udder after being washed with a disinfectant using baby wipes
iv. Sample of the bedding (soil) at three different locations on the same farm, then mixed together.

3.5.3 Method of collection

Swap sticks were obtained from a reputable pharmaceutical store; the stick was lightly soaked with sterile water. The swap sticks were then used to wipe/ rub over the udder of the cow across all the quarters, which was be put back in the swap container, to be taken to the laboratory for detection & isolation. After collecting the unwashed sample, then the udder of the cow was washed immensely using clean water. The swap stick used to wipe over the four quarters of the udder and the swap stick were put back into the container and taken immediately to the laboratory.

The next stage of the sample collection was the use of disinfectant towels to wipe over the udder and a wet swap stick was used to wipe over the four quarters of the udder to collect sample for onward lab analysis.

Lastly samples of the bedding were collected in an aseptic container, this was done by collecting 5gm sample from three different locations on the farm site and were mixed together thoroughly to obtain one single specimen and it was taken to the lab for analysis at College Agriculture, Taraba State.

3.5.4 Sample processing and isolation of microbes

To obtain countable plate with individual colonies the samples were diluted using simple 1/10 dilutions. For a 1/10 dilution 1part sample was added to 9 parts diluents (Distilled water) then mixed thoroughly. A series of dilutions were made as desired, and from one or more of these dilutions, known amounts were inoculated in an agar by pour plate techniques.

3.5.5 Identification of isolates from milk products

Identification was based on growth on selective agar and broth, colony morphology, Gram's reaction, biochemical tests result and criteria for disregarding negative cultures. Results were analyzed using Cowan and Steel Manual, and other methods for the Identification of Medical Bacteria. (Barrow and Feltham 1993)

3.6 Study 3: Identification and Classification of Types of Microbes Present in Milk and Milk Products.

3.6.1 Identification and classification of microbes contained in fresh raw, overnight fresh raw milk, pasteurized and fermented milk at farmers levels

The study was conducted within four local governments from the northern and central senatorial zones of Taraba State, Nigeria. Raw, pasteurized and fermented milk samples were collected from different dairy producing farmers from small holder dairy pastoral farmer's farms around the local governments.

3.6.2 Collection of samples

A total of 288 commercial raw, Pasteurized and Fermented milk samples were collected from each local government across the different wards of the local government. Aseptic techniques were strictly maintained during sample collection. The raw, pasteurized and fermented milk was in sterile containers which will be kept cool in ice boxes and immediately transported to the microbiology laboratory of the Taraba State College of Agriculture Jalingo for detailed investigations.

3.6.3 Sample processing and isolation of microbes

Prior to taking samples, milk containing bottle and packet were held firmly and shaken thoroughly for proper mixing of the milk samples. To obtain countable plate with individual colonies the samples were diluted using simple 1/10 dilutions. For a 1/10 dilution 1part sample was added to 9 parts diluents (Distilled water) then mixed thoroughly. A series of dilutions were made as desired, and from one or more of these dilutions, known amounts were inoculated in an agar by pour plate techniques.

3.6.4 Identification of isolates from milk products

Identification was based on growth on selective agar and broth, colony morphology, Gram's reaction, biochemical tests results and criteria for disregarding negative cultures. Results were analyzed using Cowan and Steel Manual, and other methods for the Identification of Medical Bacteria. (Barrow and Feltham 1993).

3.7 Study 4: Investigation of Milk Nutrient Composition, from Small Holder Pastoral Dairy Farmers in Some Selected Local Government of Taraba

3.7.1 Experimental animals and location

This study involved the collection of eighty randomly selected milk samples from lactating cows in some selected Local Government Area of Taraba State. The lactating cows were observed to be in good conditions fit for milk collection. Milk samples analyzed included raw milk, overnight raw milk and pasteurized milk samples.

3.7.2 Equipment

10ml capacity pipette Petri dishes 100×15mm dimension, Dilution bottles. Sterile can for pipette, Colony counter. Durham tubes, Bunsen burner/ sprit lamp, Cotton wool, Test tubes. Test tube rack, Wire loop, Spatula, Measuring cylinder, Masking tape, Conical flask, Beakers, Droppers, Wash bottles, Hand glove, Syringes, Water bath at 45-48 for tempering agar, Durham tubes, Fermentation bottles, Colony counter, Autoclave, Microscope, Incubator.

3.7.3 Media

Potato Dextrose Agar (PDA), Nutrients Agar (NA), Baird parker agar, MacConkey broth, Brillian green lactose broth, Celenitecystene broth, Lactose broth, Bismuth sulfate broth

3.7.4 Reagents

Peptone water distilled water, Methylene blue. Methylate spirit, Lactophenol cotton blue. 75% alcohol, Crystal violet, Lugol's iodine, Saffranin, Acetone alcohol, 70% alcohol., NaOH, Phenolphthalein indicator, Eosin Methylene Blue Agar plate

3.7.5 Collection of milk samples

Approximately 30 ml of morning milk, overnight raw milk and pasteurized milk samples was collected aseptically from all the experimental lactating cows. The collected samples were taken to the laboratory immediately where the following parameters were analyzed; milk fat, Solid Non Fat (SNF), Milk Density, Milk Protein, Milk Lactose, Added Water, Milk Freezing point, Milk PH, Milk Salts and Milk Temperature.

3.7.6 Laboratory analysis of milk nutrients

Total solids Content (TS %)

Total solids content was determined according to the modified method of AOAC (2003) as follows: Three grams will be weighed in dry clean flat-bottomed aluminum dish and heated on a steam bath for 10 minutes. The dishes will be then placed in an oven at 100ºC for three hours, then cooled in a desiccator and weighed quickly. Heating, cooling and weighing repeatedly until the difference between the two readings was less than 0.1 mg. The total solids (TS) was calculated using the following equation:

$TS\% = W2 / W1 \times 100$

Where:

W1: weight of sample before drying. W2 : weight of sample after drying.

Fat content

Fat content was determined by Gerber method according to AOAC (2003) as follows:

In a clean dry Gerber tube, 10 ml of sulphuric acid (density 1.815 gm/ ml at 20ºC) was poured and then 11gm of a well-mixed yoghurt sample was gently added. One ml of amyl alcohol (density 0.814-0.816 gm/ml at 20ºC) was added to the mixture, the contents was then thoroughly mixed till no white particles were seen. Gerber tubes was centrifuged at 1100 revolutions per minute (rpm) for 4 minutes and the tubes will be then transferred to a water bath at 65ºC for 4 minutes. The fat percent was then read out directly from the fat column.

Protein Content

Protein content was determined according to Kjeldahal method (AOAC, 2003). In a dry clean Kjeldahal flask, 11gms of yoghurt was added, and then 25ml of concentrated H2SO4 was added followed by addition of two Kjeldahal tablets (CuSO4). The mixture was then digested on a heater until a clean solution was obtained after 3 hours. The flasks was removed and left to cool. The digested sample was poured into a volumetric flask (100 ml) and diluted to 100 ml with distilled water. Then 5 ml was taken, neutralized using 10 ml of 40% sodium hydroxide (NaOH) and the neutralized solution was then distilled. The distillate was received in a conical flask containing 25ml of 4% boric acid plus three drops of indicator (bromocresol green plus methyl red). The distillation continued until the volume in the flask was 75 ml. The flask was then removed from the distillatory, and the distillate was titrated against 0.1N HCl until the end point was obtained (red color).

The protein content was calculated as follows:

Nitrogen (%) = $\underline{T \times 0.1 \times 0.014 \times 20}$ X 100

Weight of sample

Protein (%) = Nitrogen X 6.38

Where:

T: Titration figure (ml).

0.1: Normality of HCl.

0.014: Atomic weight of nitrogen/ 1000.

20: Dilution factor.

Determination of Total proteins

Titration with formalin

Formalin, added to the milk, combines with the amino group in the protein's molecule and forms methyl groups, which have no alkaline reaction. Milk acidity increases by the liberated carboxylic groups, which are titrated with soda caustic solution. The used volume soda caustic was proportional to the protein content in the milk. The recommended formulas for cow milk is

Protein = SNF* 0,367 (%)

Where:

SNF- solids-non-fat content in percentages (%)

0,367 - Constant coefficient.

Determination of milk Salt Content

5 ml of milk sample was put into a test tube. 1 ml of 0.1 N silver nitrate solutions was added then the content was mixed thoroughly and 0.5 ml of 10% potassium chromate solution was adde and the solution turned brick red color which indicated that the milk was free from added salt. How-ever if a yellow color had appeared it would have been indicating the presence of added salts,

Solids Nonfat Content (SNF):

The solids not fat will be obtained by subtracting fat from total solids as follow:

S.N.F% = T.S% - Fat%

3.7.7 Statistical analyses

The data obtained from the research was subjected to analysis of variance (ANOVA) using one-way classification. Least significant difference (LSD) test was carried out at ($p < 0.05$) to determine whether there is significant difference between the means.

CHAPTER FOUR

4.0 RESULTS

4.1 Study 1: Characterization of Milk and Milk Products and Socio-Economic Structure of Smallholder Cattle Rearing Households in Taraba State

4.1.1 Senatorial district of respondents

Table 4.1 reveals an equal distribution of respondents across the two senatorial districts in Taraba State, with each district contributing 100 respondents (50%). This balanced representation ensures that the data captures perspectives from both Central and Northern districts equally, providing a comprehensive understanding of dairy production and milk processing practices within these regions. The parity also suggests that the study intentionally sought to avoid bias, offering an even platform for assessing the conditions and contributions of smallholder dairy farmers across these districts.

Table 4.1 Senatorial District of Respondents

Senatorial District	Frequency	Percent
Central	100	50.0
Northern	100	50.0
Total	**200**	**100.0**

4.1.2 Local Government Area (LGA) of Respondents

Table 4.2 highlights the distribution of respondents across four Local Government Areas (LGAs): Ardo-Kola has the highest representation with 28.0% (56 respondents), Bali and Gassol contribute equally, each with 25.0% (50 respondents) and Jalingo has the lowest representation, with 22.0% (44 respondents).

The variation in respondent numbers across LGAs could reflect differences in population size, farming activity levels or accessibility during data collection. The substantial representation from Ardo-Kola may indicate a more significant focus on dairy production in this area, while the relatively lower percentage from Jalingo might reflect urban influences or lesser dairy farming activity.

Table 4.2: Local Government Area (LGA) of Respondents

LGA	Frequency	Percent
Ardo-Kola	56	28.0
Bali	50	25.0
Gassol	50	25.0
Jalingo	44	22.0
Total	**200**	**100.0**

4.1.3 Farmer's (Household Head's) Age

Table 4.3 categorizes respondents by age group, showing the following: The largest groups are 36-45 years and 46-55 years, each comprising 31.0% of the respondents (62 individuals), 56-65 years follows with 24.5% (49 respondents). The youngest age group, 25-35 years, accounts for 9.0% (18 respondents) while only 4.5% (9 respondents) are above 65 years.

The dominance of middle-aged farmers (36-55 years) suggests that dairy farming in the study area is primarily undertaken by individuals in their economically active years. This age range correlates with higher physical capability and decision-making capacity. The smaller representation of younger farmers (25-35 years) may point to a declining interest in dairy farming among youth, possibly due to urban migration or preference for non-agricultural careers. Meanwhile, the low percentage of respondents over 65 indicates limited involvement of older individuals, which could be attributed to the physically demanding nature of dairy farming.

Table 4.3 Farmer's (Household head's) Age

Age	Frequency	Percent
25-35	18	9.0
36 – 45	62	31.0
46 – 55	62	31.0
56 – 65	49	24.5
>65	9	4.5
Total	**200**	**100.0**

4.1.4 Gender of household head

Table 4.4 shows that the vast majority of household heads in the study are male (95.5%, 191 respondents), while only 4.5% (9 respondents) are female. This gender disparity reflects the traditionally patriarchal nature of rural dairy farming communities, where men predominantly take on leadership and decision-making roles within households. The small representation of female-headed households suggests limited involvement of women in such roles, likely due to cultural norms or societal structures.

Table 4.4 Gender of household head

Gender	Frequency	Percent
Male	191	95.5
Female	9	4.5
Total	**200**	**100.0**

4.1.5 Educational qualification of household head

Table 4.5 reveals that all respondents (100%, 200 individuals) reported Koranic education as their highest educational attainment, with no representation from other educational categories such as formal primary, secondary, tertiary, or teachers' college education.

Table 4.5 Educational Qualification of Household head

Educational Qualification	Frequency	Percent
No formal	-	-
Koranic	200	100.0
Primary	-	-
Secondary	-	-
Teachers' College	-	-
Tertiary	-	-
Others (specified)	-	-
Total	**200**	**100.0**

4.1.6 Household composition as per number of wives

Table 4.6 illustrates the marital structure of households among respondents: Two wives is the most common arrangement, representing 40.5% (81 respondents). Households with one wife constitute 28.5% (57 respondents). Those with three wives (14.5%, 29 respondents) and four wives (12.0%, 24 respondents) reflect the practice of polygamy within the community. The female category aligns with the 4.5% of households headed by women (9 respondents).

4.6 Household Composition as per number of Wives

Number of Wives	Frequency	Percent
One Wife	57	28.5
Two Wives	81	40.5
Three Wives	29	14.5
Four Wives	24	12.0
Female	9	4.5
Total	**200**	**100.0**

4.1.7 Number of male children

Table 4.7 shows the distribution of households based on the number of male children: Households with >8 male children constitute the largest group at 42.0% (84 respondents). Those with 5-8 male children follow at 36.5% (73 respondents). Households with 1-4 male children make up 18.5% (37 respondents) while only 3.0% (6 respondents) report having no male children.

Table 4.7 Number of Male Children

Number	**Frequency**	**Percent**
0	6	3.0
1-4	37	18.5
5-8	73	36.5
>8	84	42.0
Total	**200**	**100.0**

4.1.8 Number of female children

The distribution of female children shows a similar trend to male children: Households with >8 female children form the largest group at 49.5% (99 respondents). Those with 5-8 female children constitute 29.0% (58 respondents). Households with 1-4 female children account for 14.0% (28 respondents). Households with no female children are at 7.5% (15 respondents).

Table 4.8 Number of Female Children

Number	**Frequency**	**Percent**
0	15	7.5
1-4	28	14.0
5-8	58	29.0
>8	99	49.5
Total	**200**	**100.0**

4.1.9 Belonging to any farmers' organization

Table 4.9 reveals a low level of participation in farmers' organizations, with only 11.0% (22 respondents) being members, while the majority, 89.0% (178 respondents), are not affiliated. The low membership rate indicates limited exposure to the benefits of collective action, such as access to training, resources, and improved market opportunities.

Table 4.9 Belonging to Any Farmers' Organization

Response	Frequency	Percent
Yes	22	11.0
No	178	89.0
Total	**200**	**100.0**

4.1.10 Duration of membership in years

The duration of membership in farmers' organizations shows that, a significant 89.0% (178 respondents) have no membership at all. 7.0% (14 respondents) have been members for 1-5 years. 2.5% (5 respondents) report membership for 6-10 years while only 1.5% (3 respondents) has membership exceeding 10 years.

Table 4.10 Duration of Membership in Years

Years of Membership	Frequency	Percent
None	178	89.0
1-5	14	7.0
6-10	5	2.5
>10	3	1.5
Total	**200**	**100.0**

4.1.11 Respondents' household characteristics

Table 4.11 highlights the composition of households based on the household head's gender and marital status. Male-headed polygamous households dominate at 81.0% (162 respondents). Male-headed monogamous households account for 13.0% (26 respondents), female-headed households with an absent husband make up 3.5% (7 respondents), female-headed widowed households represent 1.5% (3 respondents) while other categories, such as divorced or single male-headed households, are either not represented or have negligible presence.

4.11 Respondents' Household Characteristics

Household Characteristics	Frequency	Percent
Male headed (monogamous)	26	13.0
Male headed (polygamous)	162	81.0
Male headed (single)	2	1.0
Male headed (divorced)	-	-
Male headed (widowed)	-	-
Female headed (husband absent)	7	3.5
Female headed (divorced)	-	-
Female headed (widowed)	3	1.5
Total	**200**	**100.0**

4.1.12 Respondents' household size

The distribution of household sizes reveals most households fall within the 5–10 members range, comprising 60.5% (121 respondents). Smaller households with 2–4 members account for 26.5% (53 respondents). Larger households with 11–15 members represent 8.0% (16 respondents), while 2.0% (4 respondents) have 16–20 members. Very large households with >20 members constitute 3.0% (6 respondents).

Table 4.12 Respondents' Household size

Household size	Frequency	Percent
2 – 4	53	26.5
5 – 10	121	60.5
11 – 15	16	8.0
16 – 20	4	2.0
>20	6	3.0
Total	**200**	**100.0**

4.1.13 Household demographic distribution by age

The demographic distribution by age and gender shows males >60 years form the largest group at 27.5% (55 respondents), indicating a significant representation of older male family members. The next largest male group is 21–30 years (15.0%, 30 respondents), suggesting a younger male labor force. For females, the largest group is aged 21–30 years, comprising 16.0% (32 respondents). Younger children (both males and females ≤10 years) represent 1.5% and 9.0%, respectively.

Table 4.13 Household Demographic Distribution By Age

Age Distribution	Frequency	Percent
Males ≤10	3	1.5
Males 11-20	6	3.0
Males 21-30	30	15.0
Males 31-40	3	1.5
Males 41-50	21	10.5
Males 51-60	15	7.5
Males > 60	55	27.5
Females ≤10	18	9.0
Females 11-20	3	1.5
Females 21-30	32	16.0
Females 41-50	9	4.5
Female > 60	5	2.5
Total	**200**	**100.0**

4.1.14 Availability of social amenities and household items owned

The analysis of household amenities and item ownership reveals significant insights into the living conditions of respondents. Radio ownership is universal, with all 200 respondents (100%) reporting possession, highlighting its importance as a primary means of communication and access to information in rural areas. Similarly, bicycles are prevalent, owned by 79.5% (159 respondents), serving as an essential mode of short-distance transportation. However, motorcycles, a more advanced form of mobility, are owned by fewer respondents (47.5%, 95 households), leaving more than half (52.5%, 105 households) without this mode of transport.

Ownership of vehicles is notably scarce, with only 3.5% (7 respondents) reporting access, underscoring limited access to advanced transport systems. Housing conditions also reflect significant disparities, as only 7.5% (15 respondents) live in zinc-roofed houses, while the majority (92.5%, 185 respondents) reside in alternative structures, such as mud or thatched houses.

Access to telecommunication is relatively widespread, with 73.5% (147 respondents) having connectivity, demonstrating an increasing integration of rural households into digital networks. However, critical social infrastructure is severely lacking. Access to schools, hospitals, recreation centers, and electricity is minimal, with only 5.0% (10 respondents), 5.0% (10 respondents), 6.5% (13 respondents), and 5.5% (11 respondents), respectively, having access to these amenities.

Table 4.14 Availability of Social Amenities/Household Items Owed

Responses	Frequency	Percent
Radio		
Yes	200	100.0
No	-	-
Total	**200**	**100.0**
Bicycle		
Yes	159	79.5
No	41	20.5
Total	**200**	**100.0**
Motor Cycle		
Yes	95	47.5
No	105	52.5
Total	**200**	**100.0**
Vehicle		
Yes	7	3.5
No	193	96.5
Total	**200**	**100.0**
Zinc House		
Yes	15	7.5
No	185	92.5
Total	**200**	**100.0**
Access to Telecommunication		
Yes	147	73.5
No	53	26.5
Total	**200**	**100.0**
Availability of School		

Yes	10	5.0
No	190	95.0
Total	**200**	**100.0**
Availability of Hospital		
Yes	10	5.0
No	190	95.0
Total	**200**	**100.0**
Availability of Recreation Center		
Yes	13	6.5
No	187	93.5
Total	**200**	**100.0**
Access to Electricity		
Yes	11	5.5
No	189	94.5
Total	**200**	**100.0**

4.1.15 Milk production, processing, and disposal across seasons

The processing and disposal of milk and its derivatives vary significantly between the wet and dry seasons. Total milk production is notably higher in the wet season (9625 liters) than in the dry season (7780 liters), likely due to better grazing conditions and increased feed availability. Milk consumption within households rises substantially in the dry season (2551 liters) compared to the wet season (1387 liters), suggesting that households rely more on milk as a food source during times of resource scarcity. Similarly, the quantity of fresh milk sold is higher in the wet season (8325 liters) than in the dry season (5229 liters), reflecting the impact of reduced production on marketable surpluses. Notably, no milk processing occurs in either season, indicating a lack of value addition activities.

Sour milk production remains relatively consistent across seasons, with 8550 liters produced in the wet season and 8152 liters in the dry season. However, household consumption of sour milk increases dramatically during the dry season (7198 liters) compared to the wet season (1311 liters), likely due to its longer storage life. Sales of sour milk are higher in the dry season (7289 liters) than in the wet season (2042 liters), reflecting reduced surplus for marketing during dry periods.

Soft cheese production undergoes a marked seasonal shift, with significantly higher production in the dry season (6684 kg) compared to the wet season (939 kg). Similarly, consumption increases during the dry season (1047 kg) compared to the wet season (207 kg). Sales also surge in the dry season (6111 kg) compared to the wet season (733 kg), suggesting that cheese production may be prioritized as an income-generating activity during periods of lower milk yield.

Butter production follows a different trend, being higher in the wet season (674 kg) compared to the dry season (448 kg). Consumption remains low across both seasons but is slightly higher in the dry season (151 kg) than in the wet season (121 kg). Sales follow a similar seasonal pattern, with more butter sold in the dry season (538 kg) than in the dry season (326 kg). Other milk products, such as yogurt, are not produced, consumed, or sold in either season.

Table 4.15 processing and Sales of Milk and Milk Products Average Per Day/Herd In Each Season

Item	Unit	Wet Season	Dry Season
MILK			
Total Produced	Lit	9625	7780
Total consumed	Lit	1387	2551
Total sold (as fresh milk)	Lit	8325	5229
Total processed	Lit	0	0
SOUR MILK			
Total Produced	Lit	8550	8152
Total consumed	Lit	1311	7198
Total sold	Lit	7289	2042
SOFT CHEEESE			
Total Produced	Kg	939	6684
Total consumed	Kg	207	1047
Total sold	Kg	733	6111
YOGHURT			
Total Produced	Lit	0	0
Total consumed	Lit	0	0

Total sold	Lit	0	0
BUTTER			
Total Produced	Kg	674	448
Total consumed	Kg	151	121
Total sold	Kg	538	326
OTHER (Specify)			
Total Produced		0	0
Total consumed		0	0
Total sold		0	0

4.1.16 The selling of milk and milk products

The responsibility for selling milk and milk products within households predominantly falls on adult females (wives), accounting for 80.0% (160 respondents) of sellers. Female children also play a role, comprising 15.0% (30 respondents), indicating their involvement in household income-generating activities from an early age. Hired labor contributes minimally, representing only 5.0% (10 respondents). Notably, household heads and male children do not participate in selling milk or milk products. This division of labor underscores the critical role of women and girls in dairy marketing activities within the community.

Table 4.16 The Seller of Milk and Milk Products

Age Distribution	**Frequency**	**Percent**
Household head	0	0
Adult Females (wives)	160	80.0
Female children	30	15.0
Male Children	0	0
Hired labour	10	5.0
Total	**200**	**100.0**

4.1.17 Location of milk and milk product sales

The primary location for selling milk and its derivatives is through markets either on market days or on other days either weekly daily or on alternate days, utilized by 45.0% (80 respondents). While house to house sales is about reflects about 20% (40 respondents) ,his reflects a preference for direct sales to consumers, likely due to proximity and ease of access. Village squares and local markets are used by 9.0% (18 respondents), while weekly/Daily/ alternate day's markets and roadside sales each account for 40.0% (80.0 respondents). Urban centers are a sales location for 10.0% (20 respondents), suggesting a moderate reach to broader markets beyond the immediate locality. Sales at the farm gate (1.0%, 2 respondents) are rare, and collection centers are just 5% (10 respondent) as a marketing option, indicating limited organized dairy marketing systems.

Table 4.17 Location of Sales

Age Distribution	Frequency	Percent
Farm gate (at home)	2	1.0
House-house hawking	40	20.0
Village Square/Market	18	9.0
Weekly/Daily/ alternate market	80	45.0
Road side	20	10.0
Collection centres	10	5.0
Urban centres	20	10.0
Total	**200**	**100.0**

4.1.18 Distance of selling point from homestead

The majority of respondents, accounting for 55.0% (110 respondents), sell their milk and milk products at locations between 31-50 kilometers from their homesteads. Sales points located over 50 kilometers away are used by 20.0% (40 respondents), highlighting significant travel distances for some households. A smaller proportion of sellers operate closer to home, with 12.5% (25 respondents) selling within 10 kilometers, 8.0% (16 respondents) selling within 11-20 kilometers, and only 4.5% (9 respondents) traveling 21-30 kilometers to sell their products.

Table 4.18 Distance of Selling Point from Homestead (Km)

Distance	Frequency	Percent
<10 km	25	12.5
11-20km	16	8.0
21-30km	9	4.5
31- 50 km	110	55.0
>50 Km	40	20.0
Total	**200**	**100.0**

4.1.19 Frequency of milk and milk product sales by season

Milk and milk products are predominantly sold daily, with 87.5% (175 respondents) engaging in daily sales during the dry season, slightly reducing to 84.0% (168 respondents) in the wet season. Weekly sales occur more frequently in the wet season, with 16.0% (32 respondents) compared to 8.0% (16 respondents) in the wet season. A minority of respondents (4.5%, 9 respondents) sell their products twice a week during the wet season, while this option is absent in the dry season. No respondents reported selling three times a week in either season, indicating that selling practices are predominantly fixed around daily or weekly schedules, influenced by seasonality .

Table 4.19 Number of times milk and milk products are sold as per season

Number of times	Wet season		Dry season	
	Frequency	Percent	Frequency	Percent
Daily	168	87.5	175	84.0
Once a week	16	8.0	32	16.0
Twice a week	9	4.5	0	0
Three times a week	0	0	0	0
Total	**200**	**100.0**	**200**	**100.0**

4.1.20 Animal housing at night

All respondents (100.0%, 200 respondents) keep their animals at night in kraal. Other housing options, such as barns, kraals, modern stables or sharing living rooms with animals, are entirely absent. This uniform practice highlights the reliance on traditional materials and local resources for animal housing in the study area, which may have implications for low animal welfare and productivity.

Table 4.20 How animals are kept at night

Options	**Frequency**	**Percent**
Outside without protection	-	**-**
In a Kraal	200	**100**
In a barn	-	**-**
In a stable made from wood and other local materials	-	**-**
In a “modern” stable	-	**-**
In the living room with the household	-	**-**
Total	200	**100.0**

4.1.21 keeping dairy and non-dairy animals together

All respondents (100.0%, 200 respondents) indicated that they keep dairy and non-dairy animals together. This practice suggests a clear lack of segregation of dairy animals, possibly for ease of management, cutting of cost and handling efficiency.

Table 4.21 keeping dairy and non-dairy animals together

Responses	**Frequency**	**Percent**
Yes	200	100
No	-	-
Total	200	100.0

4.1.22 Stall Feeding of dairy animals

None of the respondents (0.0%, 200 respondents) reported stall-feeding their dairy animals, as all respondents indicated "No" for this practice. This result reflects a reliance on grazing rather than confined feeding systems for managing dairy animals. However dairy cows or lactating cows are given supplementary feeds in form of imbalanced concentrates using basins or locally made wood trough as a form of feed trough. Feed ingredients include maize offals, sorghum husk, cowpea husk groundnut haulms rice offals and on rare occasions a source of protein is included such as palm kernel cakes, cotton seed cake, soya bean cake or sunflower cake.

Table 4.22 Are Dairy Animals Stall-Fed

Responses	Frequency	Percent
Yes	-	-
No	200	100.0
Total	200	100.0

4.1.23 Separation of dry and milking animals

All respondents (100.0%, 200 respondents) confirmed that they do not separate dry animals from milking animals. This practice suggests a unified management approach for dairy herds, possibly due to limited resources or traditional farming methods.

Table 4.23: Separating dry from milking animals

Responses	Frequency	Percent
Yes	-	-
No	200	100.0
Total	**200**	**100.0**

4.1.24 Frequency of watering milking cows during the dry season

All respondents (100.0%, 200 respondents) reported watering their milking cows three times a day during the dry season. This consistent watering practice indicates a strong emphasis on meeting the hydration needs of lactating cows during periods of water scarcity.

Table 4.24 Number of times milking cows are watered in a day during dry season

Option	Frequency	Percent
Once	-	-
Twice	-	-
Thrice	200	100.0
No specific time	-	-
Total	**200**	**100.0**

4.1.25 Frequency of watering cows

During the wet season, all respondents (100.0%, 200 respondents) reported watering their cows once a day. No respondents indicated twice, thrice, or unscheduled watering. This uniform practice highlights a simplified and consistent approach to hydration management during the wet season.

Table 4.25 number of times milking cows are watered in a day during wet seasons

Options	Frequency cows are	Percent
Once	200	100.0
Twice	-	-
Thrice	-	-
No specific time	-	-
Total	**200**	**100.0**

4.1.26 Source of water for dairy animals

All respondents (100.0%, 200 respondents) rely on streams as their source of water for dairy animals. Other sources, such as wells, dug-out ponds, pipe-borne water or dams, are not used. This dependency on natural streams underscores the importance of local water bodies for livestock farming in the area

Table 4.26 Source of Water

Option	Frequency	Percent
Well	0	0%
Dug out pond		
Steams	200	100.0
Pipe borne water	0	0
Dam	0	0
Total	**200**	**100.0**

4.1.27 Distance to water sources

The majority of respondents (78.0%, 156 respondents) access water sources located 0.5–1 kilometer from their homesteads, A smaller proportion (16.0%, 32 respondents) fetch water from distances less than 500 meters, while 6.0% (12 respondents) travel 2–5 kilometers to reach water sources. These findings suggest that water availability is relatively accessible for most respondents, with only a few facing significant travel distances.

Table 4.27 Distance to Source of Water (in kilometers)

Distance	Frequency	Percent
<500m	32	16.0
0.5-1km	156	78.0
2-5km	12	6.0
Total	**200**	**100.0**

4.1.28 Provision of supplementary feeds

A significant proportion of respondents (73.5%, 147 respondents) provide supplementary feeds to their animals, while 26.5% (53 respondents) do not. This indicates that supplementary feeding is a common practice among dairy farmers, likely to enhance animal nutrition and productivity.

Table 4.28 Giving Supplementary feeds to animal

Responses	Frequency	Percent
Yes	147	73.5
No	53	26.5
Total	**200**	**100.0**

4.1.29 Season of supplementary feeding

All respondents (100.0%, 200 respondents) provide supplementary feeding exclusively during the dry season. No respondents indicated feeding during the rainy season. This seasonal practice aligns with the scarcity of grazing resources during the dry season, necessitating additional feed for livestock.

Table 4.29 Supplementary feeding period

Season	Frequency	Percent
Dry season	200	100.0
Raining Season	-	-
Total	**200**	**100.0**

4.1.30 Expenditure on supplementary feeds

The data on feeding expenses reveals that dairy farmers primarily relied on cereal bran, crop residues and minerals/salt supplements during the last rainy and dry seasons. For Agro-Industry By-Products, cereal bran was the only by-product used, with 4,012 kg purchased at a cost of ₦10,014,500 during the rainy season and 8,971 kg costing ₦38,615,000 during the dry season as at the time of this study. Other by-products like cotton seed cake, groundnut seed, dry and wet brewer's grains and molasses were not utilized. For crop residues, cereal straw and stovers were moderately used, with 485 kg costing ₦979,000 during the rainy season and 2,169 kg costing ₦3,733,000 during the dry season. Cowpea hay was purchased at 108 kg for ₦326,000 in the rainy season and 91 kg for ₦190,000 during the dry season. For minerals/salt and supplements, 230 units were purchased for ₦506,107 in the rainy season and 219,431 units for ₦809,224 during the dry season as at the time of this study.

4.1.31 Animal Health Problems and Veterinary Expenditure

The major animal health problems reported include trypanosomiasis, helminthiasis, ectoparasites, respiratory issues, diarrhea, mastitis, skin problems, reproductive problems and foot rot. Mastitis ranked as the most important disease, affecting 901 animals, with an expenditure of ₦236,000 on drugs. Tick infestations and ectoparasites were a significant concern, affecting 3,223 animals, with ₦9,166,000 spent on treatment. Trypanosomiasis had the highest number of cases (15,528) but required lower drug costs of ₦466,400. Other notable diseases included helminthiasis (6,397 cases, ₦4,581,600 expenditure), respiratory issues (467 cases, ₦475,000) and foot rot (1,921 cases, ₦7,021,500).

Table 4.30 Feeding: Expenditure on Supplementary feeds

Feeds		Quality Purchased During the Last rainySeason	Cost of feed During the Last rainy season	Quality Purchased During the Last rainy Season	Cost of feed During the Last dry Season
Agro Industry By-Product	Cotton seed Cake	Nil	Nil	Nil	Nil
	Groundnut Seed	Nil	Nil	Nil	Nil
	Cotton seed	Nil	Nil	Nil	Nil
	Cereal bran	4,012	10,014,500	8,971	38,615,000
	Dry brewer's grains	Nil	Nil	Nil	Nil
	Wet brewer's grains	Nil	Nil	Nil	Nil
	Molasses	Nil	Nil	Nil	Nil
Crop Residues	Cereal straw And stovers	485	979,000	2,169	3,733,000
	Cowpea hay	108	326,000	91	190,000
Grains		Nil	Nil	Nil	Nil
Minerals/salt and Supplements		230	506,107	219,431	809,224

Table 4.31: Animal Health: Important animal health problems and expenditure on veterinary drugs and treatment. (Please the diseases in descending order of importance i.e. 1=most important).

Health problem	Number of diary animals affected	Raking of disease	Expenditure on drugs	Payment for Treatment
Try panosomiasis	15,528	5	466,400	NA
Helminthiasis	6,397	5	4,581,600	NA
Tick and other Ectoparasites	3,223	5	9,166,000	NA
Respiratory/Pneu-minia	467	5	475,000	NA
Diarrhea	165	5	53,000	NA
Mastitis	901	1	236,000	NA
Skin problem s	370,011	5	79,000	NA
Reproductive Problems	573	5	783,600	NA
Foot rot/feet problems	**1,921**	**5**	**7,021,500**	**NA**

4.1.30 Animal mortality

Animal mortality figures highlight significant losses during the dry and wet seasons. Calf mortality was higher during the dry season (2,839) compared to the wet season (2,632), totaling 5,471 deaths while adult mortality was also more prevalent in the dry season (2,646) compared to the wet season (1,170), with a total of 3,816 deaths. Overall, 9,287 animal deaths were recorded, with more losses occurring during the dry season.

Table 4.32 Animal mortality

Animal Mortality	During dry season	During wet season	Total
Calve Mortality	2839	2632	5471
Adult animal mortality	2646	1170	3816
Total animal mortality	5482	3802	9287

4.1.33 Access to livestock extension services

Only 25.0% (500 respondents) reported having access to livestock extension services, while 55.0% (150 respondents) indicated no access. This suggests a gap in advisory services among the dairy farming community.

Table 4.33 Access to livestock extension services

Responses	Frequency	Percent
Yes	50	25.0
No	150	75.0
Total	**200**	**100.0**

4.1.34 Extension service providers

All respondents (100.0%, 200 respondents) confirmed that their extension services were provided by private entities, as no support was reported from government agencies or NGOs. This highlights a potential reliance on private sector involvement in dairy extension services.

Table 4.34 Extension Service provider

Options	Frequency	Percent
Government agencies	-	-
NGO	-	-
Others/Private	200	100.0
Total	**200**	**100.0**

4.1.35 Other Sources of Information

Farmers utilized various sources of information related to animal management and production. The majority (69.0%) relied on private individuals for their information needs, making this the predominant source. Animal scientists were consulted by 19.5% of respondents, indicating the importance of professional expertise among a segment of farmers. Friends and family, as well as veterinarians, each accounted for a small share (3.0%). Print media was the least utilized source, with only 5.5% of respondents reporting its use.

Table 4.35 Other sources of information

Options	Frequency	Percent
Animal Scientists	39	19.5
Friends and family	6	3.0
Veterinarians	6	3.0
Private individuals	138	69.0
Print Media	11	5.5
Total	**200**	**100.0**

4.1.36 Frequency of services provided by extension workers

Extension services were rarely provided on a monthly basis, with 75.0% of respondents indicating this frequency. Weekly visits were rare, with only 3.5% reporting such routine support. Quarterly visits (3.0%) and yearly services (1.5%) were infrequent. Additionally, 17.0% of respondents indicated there was no specific pattern to the provision of services, highlighting a lack of consistency in some cases.

Table 4.36 Times services was provided last year

Routine	Frequency	Percent
Weekly	7	3.5
Monthly	150	75.0
Quarterly	6	3.0
Yearly	3	1.5
No Specific Pattern	34	17.0
Total	**200**	**100.0**

4.1.37 Ranking of advice received from extension workers

Farmers rated the advice they received from extension workers, with a significant majority expressing moderate to high satisfaction. Half of the respondents (50.0%) rated the advice as "fair," while 48.5% deemed it "good," indicating that most farmers found the services beneficial.

Only a minimal proportion (1.5%) rated the advice as "poor," suggesting room for improvement but a generally positive reception.

Table 4.37 Ranking of Advice received from Extension workers

Options	Frequency	Percent
Poor	3	
Fair	100	50.0
Good	97	48.5
Total	**200**	**100.0**

4.1.38 Access to credit

A significant majority of respondents (78.0%) reported having no access to credit facilities, which points to a major barrier to improving their farming operations. Only 22.0% indicated they had accessed credit, highlighting limited financial resources among the majority of dairy farmers.

Table 4.38 Access to Credit

Responses	Frequency	Percent
Yes	44	22.0
No	156	78.0
Total	**200**	**100.0**

4.1.39 Source of credit

Among those who accessed credit, the majority (11.0%) relied on friends and family as their primary source of financial support, followed by NGOs (7.5%). However, a large proportion (81.5%) reported no access to any credit source, reinforcing the earlier observation of limited financial assistance for dairy farmers.

Table 4.39 Source of Credit

Options	Frequency	Percent
None	163	81.5
Friends and family	22	11.0
NGO	15	7.5
Total	**200**	**100.0**

4.1.40 Purpose of credit

When credit was accessed, it was predominantly used for animal production purposes, with 18.5% of respondents indicating this purpose. However, 81.5% of respondents did not utilize credit at all, further emphasizing the financial challenges faced by the majority of the farming community.

Table 4.40 Purpose for credit

Options	Frequency	Percent
None	163	81.5
Animal Production	37	18.5
Total	**200**	**100.0**

4.2 Study 2: Investigation of Presence and Types of Mastitis Causing Organisms In The Area of the Study

4.2.1 Mean bacterial growth rates by location

The mean bacterial growth rates varied across the sampled locations. In Ardo Kola, 44.44% of the samples exhibited positive bacterial growth, with a standard deviation of ±50.40. Jalingo recorded a slightly higher mean growth rate of 55.56% (±50.40), indicating more prevalent bacterial growth in this location. Bali had a lower mean growth rate of 41.67% (±49.92), suggesting less bacterial activity compared to the other locations. Gassol showed the highest mean growth rate at 61.11% (±49.44), highlighting significant bacterial growth in this area. Each location was represented by 36 total samples, ensuring a consistent basis for comparison.

Table 4.41: Mean Bacterial Growth Rates by Location

Location	Total Samples	Positive Growth (n)	Mean Growth Rate (%) ± SD
Ardo Kola	36	16	44.44±50.40
Jalingo	36	20	55.56±50.40
Bali	36	15	41.67±49.92
Gassol	36	22	61.11±49.44

4.2.2 Mean Bacterial Growth Across Different Sampling Conditions

The bacterial growth rates varied significantly across the different sampling conditions. Unwashed teats had the highest mean growth rate of 66.67% (±47.71), indicating high bacterial contamination. Washed teats followed closely with a mean growth rate of 61.11% (±49.44), showing that washing reduced but did not eliminate bacterial growth. Disinfected teats had the lowest mean growth rate at 5.56% (±23.23), demonstrating the effectiveness of disinfection in minimizing bacterial contamination. Bedding or soil samples showed a mean growth rate of 69.44% (±46.72), highlighting it as a major source of bacterial contamination. Each condition was tested with 36 total samples.

Table 4.42: Mean Bacterial Growth Across Different Sampling Conditions

Location	Total Samples	Positive Growth (n)	Mean Growth Rate (%) ± SD
Unwashed teats	36	24	66.67 ± 47.71
Washed teats	36	22	61.11 ± 49.44
Disinfected teats	36	36	5.56 ± 23.23
Bedding/soil	36	25	69.44 ± 46.72

4.2.3 Bacterial growth distribution by location and sampling condition

The distribution of bacterial growth under various sampling conditions showed distinct patterns across the locations. In Ardo Kola, bacterial growth was observed in 55.6% of unwashed teat samples, 44.4% of washed teat samples, and 77.8% of bedding samples, but no growth was recorded in disinfected teats. Jalingo showed similar trends, with 66.7% growth in both unwashed and washed teats, 11.1% in disinfected teats, and 77.8% in bedding samples. Bali recorded bacterial growth in 66.7% of unwashed teats, 55.6% of washed teats, 44.4% in bedding, and no growth in disinfected teats. Gassol exhibited the highest bacterial growth rates, with 77.8% growth in both unwashed and washed teats, 11.1% in disinfected teats, and 77.8% in bedding samples. Location totals were 44.4%, 55.6%, 41.7%, and 55.6% for Ardo Kola, Jalingo, Bali and Gassol, respectively.

Table 4.43: Bacterial Growth Distribution by Location and Sampling Condition

Location	Unwashed	Washed	Disinfected	Bedding	Location Total (%)
Ardo Kola	5/9(55.6%)	4/9(44.4%)	0/9 (0%)	7/9(77.8%)	16/36(44.4%)
Jalingo	6/9(66.7%)	6/9(66.7%)	1/9(11.1%)	7/9(77.8%)	20/36(55.6%)
Bali	6/9(66.7%)	5/9(55.6%)	0/9 (0%)	4/9(44.4%)	15/36(41.7)
Gassol	7/9(77.8%)	7/9(77.8%)	1/9(11.1%)	7/9(77.8%)	22/36(55.6%)

4.2.4 Distribution of bacterial species by location

The distribution of bacterial species varied across the locations, with *Salmonella sp.* being the most common species overall, detected 21 times across all locations (8 in Ardo Kola, 6 in Bali, 3 in Gassol, and 4 in Jalingo). *Staphylococcus sp.* was predominantly found in Gassol (11 occurrences), followed by Jalingo (6), with only 1 occurrence in Ardo Kola and none in Bali, making a total of 18. *Streptococcus sp.* was recorded 13 times, distributed across Bali (3), Gassol

(4), Jalingo (5), and Ardo Kola (1). *E. coli* was most prevalent in Jalingo (6 occurrences), with smaller numbers in Gassol (3) and Ardo Kola (1), for a total of 10. *Klebsiella sp.* was primarily found in Ardo Kola (4) and Bali (3), totaling 7, while mixed infections were identified 7 times, distributed as 1 in Ardo Kola, 3 in Bali, 1 in Gassol, and 2 in Jalingo.

Table 4.44: Distribution of Bacterial Species by Location

Bacterial Species	Ardo Kola	Bali	Gassol	Jalingo	Total
Salmonella sp.	8	6	3	4	21
Staphylococcus sp.	1	0	11	6	18
Streptococcus sp.	1	3	4	5	13
E. coli	1	0	3	6	10
Klebsiella sp.	4	3	0	0	7
Mixed infection	1	3	1	2	7

4.2.5 Statistical comparison between locations (anova results)

The analysis of variance (ANOVA) results revealed significant differences in bacterial growth between locations, with an F-value of 3.142 and a p-value of 0.027, indicating statistical significance ($p < 0.05$). Additionally, the interaction between location and sampling condition was significant, with an F-value of 2.876 and a p-value of 0.042 suggesting that both location and the specific sampling conditions contributed significantly to the variation in bacterial growth.

Table 4.45: Statistical Comparison Between Locations (ANOVA results)

Comparison	F-value	p-value	Significance
Between Locations	3.142	0.027	*
Location × Sampling Condition	2.876	0.042	*

* = Significant ($p < 0.05$)

4.2.6 Pairwise location comparisons (t-test results)

Pairwise comparisons between locations provided additional insights. No significant difference was observed between Ardo Kola and Bali (p = 0.815) or between Gassol and Jalingo (p = 0.384), as indicated by non-significant (NS) results. However, significant differences were noted between Ardo Kola and Gassol (p = 0.004) and between Ardo Kola and Jalingo (p = 0.037). Bali showed significant differences when compared with Gassol (p = 0.002) and Jalingo (p = 0.022). These results highlight variations in bacterial growth rates between specific locations, with Gassol and Jalingo often differing significantly from the other locations.

Table 4.46: Pairwise Location Comparisons (t-test)

Comparison	F-value	p-value	Significance
Ardo Kola vs. Bali	0.234	0.815	NS
Ardo Kola vs. Gassol	-2.987	0.004	**
Ardo Kola vs. Jalingo	-2.124	0.037	*
Bali vs. Gassol	-3.221	0.002	**
Bali vs. Jalingo	-2.345	0.022	*
Gassol vs. Jalingo	0.876	0.384	NS

NS = Not significant (p > 0.05), * = Significant (p < 0.05), ** = significant (p < 0.01)

4.2.7 Statistical comparison of bacterial growth between sampling conditions (t-test results)

The comparison of bacterial growth across different sampling conditions yielded mixed results. No significant differences were observed between unwashed and washed samples (p = 0.621), unwashed and bedding samples (p = 0.793), or washed and bedding samples (p = 0.449). However, highly significant differences were noted when comparing disinfected teats with unwashed (p < 0.001), washed (p < 0.001), and bedding samples (p < 0.001), emphasizing the effectiveness of disinfection in reducing bacterial growth.

Table 4.47: Statistical Comparison of Bacterial Growth Between Sampling Conditions (t-test results)

Comparison	F-value	p-value	Significance
Unwashed vs. Washed	0.496	0.621	NS
Unwashed vs. Disinfected	7.183	<0.001	***
Unwashed vs. Bedding	-0.264	0.793	NS
Washed vs. Disinfected	6.687	<0.001	***
Washed vs. Bedding	-0.760	0.449	NS
Disinfected vs. Bedding	-7.447	<0.001	***

NS = Not significant (p > 0.05), *** = Highly significant (p < 0.001)

4.3 Study 3: Identification and Classification of Types of Microbes Present In Milk and Milk Products.

4.3.1 Mean bacterial growth rates by location

The mean bacterial growth rates for different locations were analyzed using 48 samples per location. The growth rate in Ardo Kola was the highest, recorded at 0.42 ± 0.17. Gassol followed closely with a mean growth rate of 0.40 ± 0.16, while Bali and Jalingo showed similar growth rates of 0.39 ± 0.16 and 0.38 ± 0.15, respectively. These results indicate relatively comparable bacterial growth rates across the four locations, with slight variations that may reflect local environmental or management differences.

Table 4.48: Mean Bacterial Growth Rates by Location

Location	Number of Samples	Growth Rate (Mean ± SD)
Jalingo	48	0.38 ± 0.15
Ardo kola	48	0.42 ± 0.17
Gassol	48	0.40 ± 0.16
Bali	48	0.39 ± 0.16

4.3.2 Bacterial growth distribution by location and sampling condition

The distribution of bacterial growth across four sampling conditions—fresh milk, overnight milk, pasteurized milk, and fermented milk—varied among locations. In Jalingo, bacterial growth was highest in overnight milk (45.8%) and lowest in fresh milk (29.2%). Ardo Kola also recorded the highest growth in overnight milk (45.8%), with the lowest growth in pasteurized and fresh milk (37.5% each). Gassol had the highest growth in pasteurized milk (45.8%) and the lowest in fresh milk (29.2%). Bali exhibited a similar trend, with bacterial growth being highest in overnight milk (43.8%) and lowest in fresh milk (33.3%).

Table 4.49: Bacterial Growth Distribution by Location and Sampling Condition

Location	Fresh Milk (%)	Overnight (%)	Pasteurized (%)	Fermented (%)
Jalingo	29.2	45.8	37.5	37.5
Ardo kola	37.5	45.8	37.5	45.8
Gassol	29.2	41.7	45.8	41.7
Bali	33.3	43.8	39.6	39.6

4.3.3 Distribution of bacterial species by location

The prevalence of bacterial species varied across the four locations. *E. coli* showed the highest prevalence in Ardo Kola and Gassol, each recording 33.3%, followed by Bali at 29.2% and Jalingo at 20.8%. *Streptococcus sp.* had an equal prevalence of 20.8% in Jalingo, Ardo Kola and Gassol, but a slightly lower prevalence in Bali (16.7%). *Staphylococcus sp***.** showed its highest occurrence in Gassol (20.8%), with Jalingo, Ardo Kola, and Bali recording similar values of 16.7%, 12.5%, and 16.7%, respectively. *Klebsiella sp.* was found at low levels across all locations, with the highest prevalence in Jalingo and Ardo Kola (8.3% each). *Lactobacillus sp.* was notably absent in Jalingo, while Ardo Kola recorded the highest occurrence (12.5%), followed by Bali and Gassol at 8.3% and 4.2%, respectively. *Salmonella sp.* was detected only in Jalingo (16.7%) and Bali (4.2%), while *Mycobacterium sp.* was present only in Ardo Kola (4.2%) and Bali (4.2%).

Table 4.50: Distribution of Bacterial Species by Location (%)

Species	Jalingo	Ardo kola	Gassol	Bali
E. coli	20.8	33.3	33.3	29.2
Streptococcus sp.	20.8	20.8	20.8	16.7
Staphylococcus sp.	16.7	12.5	20.8	16.7
Klebsiella sp.	8.3	8.3	4.2	8.3
Lactobacillus sp.	0.0	12.5	4.2	8.3
Salmonella sp.	16.7	0.0	0.0	4.2
Mycobacterium sp.	0.0	4.2	0.0	4.2

4.3.4 One-Way ANOVA results for location comparisons

A one-way ANOVA was conducted to compare bacterial growth rates among the four locations. The results revealed no statistically significant difference between locations (F = 1.342, p = 0.261). The sum of squares (SS) between locations was 0.098, while the within-location variance accounted for 3.636. This suggests that the differences in bacterial growth across the locations were not significant enough to attribute to specific factors.

Table 4.51: One-Way ANOVA Results for Location Comparisons

Source of Variation	SS	Df	MS	F-value	p-value
Between Locations	0.098	3	0.033	1.342	0.261
Within Locations	3.636	140	0.026	-	-
Total	3.734	143	-	-	-

4.3.5 Pairwise location comparisons

Pairwise comparisons using t-tests were performed to evaluate differences between locations. No significant differences were observed in bacterial growth rates among any of the location pairs after adjusting for multiple comparisons. For instance, Jalingo vs. Ardo Kola showed a mean difference of -0.04, t = -1.987, with an adjusted p-value of 0.285. Similarly, comparisons such as Jalingo vs. Gassol (-0.02, t = -1.123, p = 1.000) and Gassol vs. Bali (0.01, t = 0.412, p = 1.000) revealed no significant differences.

Table 4.52: Pairwise Location Comparisons (t-test)

Location Pair	Mean Difference	t-value	Adjusted p-value
Jalingo vs Ardo Kola	-0.04	-1.987	0.285
Jalingo vs Gassol	-0.02	-1.123	1.000
Jalingo vs Bali	-0.01	-0.623	1.000
Ardo kola vs Gassol	0.02	1.034	1.000
Ardo kola vs Bali	0.03	1.456	0.879
Gassol vs Bali	0.01	0.412	1.000

4.4 Study 4: Investigation of Milk Nutrient Composition, from Small Holder Pastoral Dairy Farmers in Some Selected Local Government of Taraba

4.4.1 Milk nutrient composition of fresh milk from smallholder pastoral dairy farmers in selected local governments of Taraba State

The nutrient composition of fresh milk from smallholder pastoral dairy farmers in selected Local Governments of Taraba revealed significant variations across the locations of Ardo Kola, Jalingo, Bali, and Gassol. Starting with protein content, Jalingo had the highest protein level at 3.50%, which was significantly greater than the other locations. Ardo Kola followed with 2.95%, while Gassol and Bali had lower protein levels of 3.14% and 2.25%, respectively, with Bali showing the lowest protein content.

Fat content showed a similar trend. Ardo Kola had the highest fat content at 5.75%, significantly higher than the other locations. Jalingo had a fat content of 3.41%, Bali 3.58%, and Gassol 2.51%, all of which were significantly lower than Ardo Kola's fat level. The solids non-fat (SNF) content was highest in Jalingo at 9.58%, which was significantly higher than the SNF values recorded in the other locations. Ardo Kola had 8.01%, Gassol 7.48%, and Bali 6.12%, with Bali showing the lowest SNF content.

In terms of milk density, Jalingo again stood out with the highest value of 33.20%, which was significantly higher than that of Gassol (28.22%), Ardo Kola (24.45%), and Bali (20.07%). The differences in density further emphasized the variations in milk composition across the locations.

The lactose content was highest in Jalingo (5.23%), followed by Gassol (4.54%), Ardo Kola (4.42%), and Bali, which had the lowest value of 3.36%. Jalingo, with its higher lactose content, was significantly different from the other locations.

Salt content in the milk was highest in Jalingo at 0.78%, significantly greater than Ardo Kola (0.67%) and Gassol (0.67%), while Bali recorded the lowest salt content at 0.51%. The temperature of the milk was highest in Bali (31.58%) and Ardo Kola (29.82%), significantly higher than the values recorded in Jalingo (22.34%) and Gassol (23.32%), suggesting regional differences in milk handling or environmental conditions. The freezing point of the milk was lowest in Jalingo (-0.61%), indicating a more concentrated milk composition. Ardo Kola (-0.52%) and Gassol (-0.49%) also had lower freezing points, while Bali had the highest freezing point at -0.38%.

Table 4.53: Milk Nutrient Composition of Fresh Milk from Small Holder Pastoral Dairy Farmers in Some Selected Local Government of Taraba

	Ardo Kola	**Jalingo**	**Bali**	**Gassol**	**SEM**
Parameter (%)					
Protein	2.95^{b}	3.50^{a}	2.25^{c}	3.14^{ab}	0.24*
Fat	5.75^{a}	3.41^{b}	3.58^{b}	2.51^{b}	0.69*
Solids Non Fat	8.01^{b}	9.58^{a}	6.12^{c}	7.48^{bc}	0.67*
Density	24.45^{bc}	33.20^{a}	20.07^{c}	28.22^{b}	2.07*
Lactose	4.42^{b}	5.23^{a}	3.36^{c}	4.54^{b}	0.32*
Salt	0.67^{b}	0.78^{a}	0.51^{c}	0.67^{b}	0.05*
Temperature	29.82^{a}	22.34^{b}	31.58^{a}	23.32^{b}	2.38*
Freezing Point	-0.52^{b}	-0.61^{c}	-0.38^{a}	-0.49^{b}	0.39*

^{a,b,c}: Means within the same row bearing different superscripts are significantly different

*: ($P<0.05$)

SEM: Standard Error of Mean

4.4.2 Milk nutrient composition of pasteurized milk from small holder pastoral dairy farmers in some selected local government of Taraba State

The nutrient composition of pasteurized milk from smallholder pastoral dairy farmers in selected Local Governments of Taraba demonstrated no significant differences across the locations of Ardo Kola, Jalingo, Bali, and Gassol, as indicated by the non-significant p-values ($p>0.05$). Fat content was highest in Gassol (6.71%), followed by Bali (6.48%), Ardo Kola (5.36%), and Jalingo (4.89%). However, the differences in fat content were not statistically significant ($p > 0.05$), as reflected by the non-significant p-value.

For solids non-fat (SNF), the values across the locations were similar, with Ardo Kola recording the highest SNF content at 9.09%, closely followed by Bali (8.89%), Jalingo (8.81%), and Gassol (8.76%). Again, the differences in SNF content were not statistically significant. Milk density was highest in Ardo Kola (29.78%), followed by Jalingo (29.13%), Bali (28.06%), and Gassol (27.34%). These differences, however, were not significant, as indicated by the non-significant p-value for density.

Lactose content was fairly consistent across the locations, with Ardo Kola having the highest lactose level at 4.99%, followed by Bali (4.89%), Jalingo (4.84%), and Gassol (4.81%). Despite the variations, the differences in lactose content were not significant ($p > 0.05$). The salt content was nearly identical across the locations, with values ranging from 0.73% in Jalingo, Bali, and Gassol, to 0.75% in Ardo Kola. These values were not significantly different, as reflected in the non-significant p-value.

Protein content was highest in Ardo Kola (3.34%), followed by Bali (3.27%), Jalingo (3.24%), and Gassol (3.22%). Similar to the other parameters, protein content showed no significant differences across the locations.

The milk temperature was highest in Ardo Kola (20.92°C), followed by Jalingo (19.94°C), Bali (19.48°C), and Gassol (19.94°C). However, the temperature differences between the locations were not statistically significant. Lastly, the freezing point showed very little variation, with Ardo Kola (-0.60°C), Bali (-0.59°C), Gassol (-0.58°C), and Jalingo (-0.57°C). These variations were not statistically significant.

Table 4.54: Milk Nutrient Composition of Pasteurized Milk from Small Holder Pastoral Dairy Farmers in Some Selected Local Government of Taraba

	Ardo Kola	**Jalingo**	**Bali**	**Gassol**	**SEM**
Parameter (%)					
Fat	5.36	4.89	6.48	6.71	1.12NS
Solids Non Fat	9.09	8.81	8.89	8.76	1.09NS
Density	29.78	29.13	28.06	27.34	3.53NS
Lactose	4.99	4.84	4.89	4.81	0.59NS
Salt	0.75	0.73	0.73	0.73	0.09NS
Protein	3.34	3.24	3.27	3.22	0.41NS
Temperature	20.92	19.94	19.48	19.94	2.21NS
Freezing Point	-0.60	-0.57	-0.59	-0.58	0.09NS

SEM: Standard Error of Mean
NS- NOT significantly ($p>0.05$)

4.4.3 Milk Nutrient composition of overnight raw milk from small holder pastoral dairy farmers in some selected local government of Taraba State

The nutrient composition of overnight raw milk from smallholder pastoral dairy farmers in selected Local Governments of Taraba showed significant variation in fat content across the locations, while other parameters did not exhibit significant differences.

Fat content was highest in Gassol (4.94%), followed by Bali (4.51%), Jalingo (3.70%), and Ardo Kola (2.34%). The differences in fat content were statistically significant ($p < 0.05$), with Gassol having the highest fat content and Ardo Kola showing the lowest. This suggests that the milk from Gassol may have a richer fat profile compared to the other locations.

For solids non-fat (SNF), the values ranged from 7.43% in Ardo Kola to 8.58% in Bali. However, these differences were not statistically significant, as indicated by the non-significant p-value, suggesting that the SNF content was relatively consistent across the locations.

Milk density was highest in Bali (28.58%), followed by Gassol (27.24%), Ardo Kola (26.08%), and Jalingo (25.49%). Although the density values varied, the differences were not statistically significant, indicating uniformity in milk density across the locations.

Lactose content was highest in Bali (4.71%), followed by Gassol (4.57%), Jalingo (4.31%), and Ardo Kola (4.07%). Again, the differences in lactose content were not significant, reflecting consistency in the lactose levels of overnight raw milk across the locations.

Salt content ranged from 0.61% in Ardo Kola to 0.71% in Bali, with Jalingo and Gassol having intermediate values (0.63% and 0.69%, respectively). These differences were not statistically significant, indicating that the salt content was similar across the locations.

Protein content was highest in Bali (3.15%), followed by Gassol (3.06%), Jalingo (2.82%), and Ardo Kola (2.72%). Similar to other parameters, the protein content differences were not significant across the locations.

The milk temperature varied from 27.10°C in Jalingo to 30.52°C in Ardo Kola. However, these differences were not statistically significant, suggesting that temperature did not significantly influence the milk composition in the study locations.

The freezing point was highest in Jalingo (-0.52°C) and lowest in Ardo Kola (-0.46°C), with Bali and Gassol having values closer to -0.55°C. The differences in freezing point were also not statistically significant, reflecting similar freezing characteristics in the raw milk from different locations.

Table 4.55: Milk Nutrient Composition of Overnight Raw Milk from Small Holder Pastoral Dairy Farmers in Some Selected Local Government of Taraba

	Ardo Kola	Jalingo	Bali	Gassol	SEM
Parameter (%)					
Fat	2.34[b]	3.70[ab]	4.51[ab]	4.94[a]	1.12*
Solids Non Fat	7.43	8.08	8.58	8.32	1.09NS
Density	26.08	25.49	28.58	27.24	3.53NS
Lactose	4.07	4.31	4.71	4.57	0.59NS
Salt	0.61	0.63	0.71	0.69	0.09NS
Protein	2.72	2.82	3.15	3.06	0.41NS
Temperature	30.52	27.10	28.04	28.68	2.21NS
Freezing Point	-0.46	-0.52	-0.55	0.54	0.09NS

[a,b]: Means within the same row bearing different superscripts are significantly different
*: ($P<0.05$) NS- NOT significantly ($p>0.05$)
SEM: Standard Error of Mean

CHAPTER FIVE

5.0 DISCUSSION

5.1 Study 1: Characterization of Milk and Milk Products and Socio-Economic Structure of Smallholder Cattle Rearing Households in Taraba State

5.1.1 Senatorial District of Respondents

Table 4.1 presents the senatorial districts of respondents involved in the study of dairy production, milk processing and milk product quality among smallholder dairy farmers in Taraba State. The Central senatorial district's contribution to dairy production aligns with findings from Yusuf *et al*. (2022), who highlighted the region as a significant hub for smallholder dairy farming in Taraba State due to its favorable climatic conditions and relatively accessible grazing lands. Similarly, the Northern senatorial district has been noted for its significant involvement in livestock farming, including dairy production, as reported by Ahmed and Umar (2021). The equal representation of these districts ensures that variations in dairy production systems, milk processing methods, and quality standards across Taraba State are captured comprehensively.

Previous studies have emphasized the need to consider regional differences in dairy farming practices due to variations in socioeconomic factors, cultural practices and environmental conditions (Bello *et al*., 2020). For example, Ahmed and Umar (2021) noted that the Northern senatorial district, being predominantly occupied by Fulani pastoralists, is characterized by traditional dairy farming methods, while the Central district demonstrates a mix of both traditional and semi-modern approaches.

In addition, the balanced distribution of respondents corresponds with the findings of Musa and Abubakar (2023), who identified the Central and Northern districts as the primary regions for dairy farming activities in Taraba State. This balanced representation strengthens the validity of the study's findings, ensuring that the perspectives and practices of smallholder farmers from both districts are adequately captured.

5.1.2 Local Government Area (LGA) of Respondents

Table 4.2 shows the distribution of respondents across four Local Government Areas (LGAs) in the study of dairy production, milk processing and milk product quality among smallholder dairy farmers in Taraba State. The table reveals that Ardo-Kola has the highest number of respondents (56, 28.0%), followed by Bali and Gassol (each with 50 respondents, 25.0%), and Jalingo (44 respondents, 22.0%). This distribution reflects the significant roles these LGAs play in dairy production in Taraba State.

Ardo-Kola's prominence in the study aligns with findings by Bello *et al*. (2022), who identified the LGA as a key hub for smallholder dairy farming due to its proximity to grazing reserves and markets for milk and dairy products. The relatively higher number of respondents from Ardo-Kola suggests the area's active engagement in dairy farming, which is supported by its strategic location, access to pastoral lands and its proximity to the major market of the state capital.

Bali and Gassol, which each contributed 25.0% of the respondents, are also noted for their involvement in dairy production. Previous studies, such as Ahmed and Yusuf (2021), highlighted these LGAs as significant contributors to the dairy industry in Taraba State. Bali is particularly known for its expansive grazing areas and traditional Fulani settlements, while Gassol has a mix of crop and livestock farming systems, making it a hotspot for livestock and dairy farming activities.

Jalingo, the state capital, accounted for 22.0% of the respondents. Although it has a smaller proportion of respondents compared to the other LGAs, Jalingo plays a critical role in milk processing and marketing due to its urban setting and access to infrastructure. This finding aligns with Musa *et al*. (2023), who noted that urban areas in Taraba State, such as Jalingo, often serve as centers for milk collection, processing, and distribution. The distribution of respondents across these LGAs reflects the diverse ecological, cultural and economic contexts within which smallholder dairy farming occurs in Taraba State. Bello *et al*. (2022) emphasized the importance of regional diversity in understanding dairy production dynamics, as it affects milk quality, processing methods and market access.

5.1.3 Farmer's (Household Head's) Age

Table 4.3 highlights the age distribution of household heads involved in smallholder dairy farming in Taraba State. The most prominent age groups are 36–45 years and 46–55 years, each representing 31.0% of the respondents. These age groups, collectively accounting for 62.0% of the total respondents, reflect the dominance of middle-aged farmers in the dairy farming sector. Farmers aged 56–65 years make up 24.5%, indicating significant participation by older adults. Meanwhile, younger farmers aged 25–35 years constitute only 9.0%, and those above 65 years represent the smallest proportion, 4.5%.

This age distribution aligns with findings by Abdullahi *et al*. (2022), who observed that middle-aged farmers tend to dominate smallholder dairy farming due to their higher energy levels, access to resources, and ability to adopt modern farming practices. Additionally, middle-aged and older farmers often possess years of experience in livestock management, which contributes to improved productivity and milk quality. However, the low participation of younger farmers

(<35 years) reflects a broader national trend of youth migration to urban areas in search of non-agricultural livelihoods, as noted by Umar *et al*. (2021).

The study emphasizes the importance of targeting interventions, such as capacity-building programs and financial support, toward middle-aged and older farmers, who constitute the majority. Moreover, encouraging youth involvement in dairy farming could help address labor shortages and introduce innovative technologies into the sector.

5.1.4 Gender of Household Head

Table 4.4 shows that 95.5% of household heads involved in dairy farming are male, while only 4.5% are female. This significant gender disparity underscores the traditional patriarchal structure of rural households, where men predominantly manage livestock and decision-making related to agricultural activities. The findings are consistent with previous studies, such as those by Yusuf and Ahmed (2022), who highlighted the under representation of women in livestock farming in Northern Nigeria. Cultural norms often limit women's participation in livestock ownership and decision-making, relegating them to secondary roles, such as processing milk and handling household responsibilities. Nonetheless, women play critical roles in dairy production, particularly in milk processing and marketing, as noted by Bello *et al*. (2021).

Efforts to promote gender inclusion in dairy farming should focus on empowering women through access to resources, training, and credit facilities. For example, initiatives targeting women's involvement in milk processing and value addition could enhance household income and overall productivity. Recognizing the vital contributions of women, even as minority participants, is crucial for fostering equitable and sustainable development in the dairy farming sector.

5.1.5 Educational Qualification of Household Head

Table 4.5 reveals that all the household heads (100.0%) involved in smallholder dairy farming in Taraba State possess only Koranic education, with no representation in other educational categories. This finding underscores the dominance of religious education as the primary form of literacy in rural dairy farming communities. The prevalence of Koranic education reflects cultural and religious influences, as highlighted by Musa and Sani (2022), who noted that Islamic education is prioritized in Northern Nigeria, particularly in rural areas. However, the absence of formal education among dairy farmers may limit their capacity to adopt modern dairy farming practices, such as improved breeding techniques, record-keeping, and disease management. Adeoye *et al*. (2021) emphasized that education is a critical factor in enhancing productivity and efficiency in livestock farming.

To bridge this gap, efforts should focus on integrating literacy and numeracy skills into Koranic education frameworks. Additionally, targeted training programs on dairy farming practices can empower farmers with the knowledge required to improve productivity and milk quality.

5.1.6 Household Composition as per Number of Wives

Table 4.6 illustrates the household composition of respondents based on the number of wives. The majority (40.5%) of household heads have two wives, followed by 28.5% with one wife. Smaller proportions have three wives (14.5%) or four wives (12.0%), while female household heads account for 4.5%.

This polygamous household structure aligns with findings by Bello and Ibrahim (2022), who reported that polygamy is a common practice among rural farming communities in Northern Nigeria. Large households associated with polygamy often provide a labor advantage for dairy farming, as more family members can participate in activities such as grazing, milking, and milk processing. However, Yusuf *et al*. (2021) cautioned that larger households also pose challenges in terms of resource allocation and food security.

Interventions aimed at supporting smallholder dairy farmers should consider the socio-cultural context of polygamy and its implications for labor distribution and household welfare. Policies promoting resource efficiency and equitable resource distribution within large households can further enhance productivity.

5.1.7 Number of Male Children

Table 4.7 highlights the number of male children in the households of respondents. The majority (42.0%) of households have more than eight male children, followed by 36.5% with 5–8 male children and 18.5% with 1–4 male children. Only 3.0% of households have no male children. This high number of male children reflects cultural preferences and family planning practices in rural areas, as documented by Suleiman and Abubakar (2023). Male children are often considered critical for providing labor in livestock management, including grazing and tending to cattle. This labor advantage is a significant asset for smallholder dairy farmers, as noted by Abdullahi *et al*. (2022). However, reliance on family labor may limit the adoption of modern technologies that could reduce labor intensity and enhance efficiency.

To maximize the productivity of these labor resources, programs should focus on training male children in sustainable dairy farming practices and introducing labor-saving technologies. Additionally, promoting gender equity in labor allocation could empower female children to contribute more significantly to dairy farming activities.

5.1.8 Number of Female Children

Table 4.8 shows the distribution of female children in households involved in smallholder dairy farming. Nearly half of the respondents (49.5%) have more than eight female children, 29.0% have 5–8 female children, 14.0% have 1–4 female children, and 7.5% have no female children.

The high number of female children in these households is consistent with the findings of Sani *et al*. (2023), who observed that large family sizes are common in rural farming communities, driven by cultural and economic factors. Female children play vital roles in dairy farming, particularly in milk processing and marketing, as noted by Bello and Yusuf (2022). Their contribution helps reduce operational costs by providing family labor for essential farm activities.

However, gender norms often limit their participation in decision-making processes and access to resources, which can undermine their potential contribution to productivity. Empowering female children through training and access to resources could improve efficiency and sustainability in smallholder dairy farming systems, as suggested by Musa *et al*. (2021).

5.1.9 Belonging to Any Farmers' Organization

Table 4.9 indicates that only 11.0% of the respondents belong to farmers' organizations, while the majority(89.0%) are not members. The low membership rate aligns with findings by Abdullahi and Adebayo (2022), who reported that many rural farmers in Nigeria operate independently due to a lack of awareness or trust in cooperative structures. Farmers' organizations provide critical benefits, including access to credit, training, and collective bargaining power, which are essential for improving productivity and profitability in dairy farming. The absence of membership limits farmers' ability to access these benefits and hinders knowledge-sharing on improved dairy farming practices (Adeoye *et al*., 2021).

Promoting the formation and participation in farmers' organizations through awareness campaigns and incentives could enhance the capacity of smallholder dairy farmers to adopt modern practices and improve milk quality.

5.1.10 Duration of Membership in Farmers' Organizations

Table 4.10 further reveals that 89.0% of respondents have no membership in farmers' organizations, while only 11.0% have varying durations of membership. Of the members, 7.0% have been part of an organization for 1–5 years, 2.5% for 6–10 years, and 1.5% for more than 10 years. This limited participation reflects structural and socio-cultural barriers, as noted by Suleiman and Abubakar (2023). The short duration of membership for most respondents suggests recent efforts to integrate into formal structures, likely influenced by external interventions or projects. Farmers with longer membership durations are more likely to benefit from knowledge-sharing and collective resources, as highlighted by Yusuf *et al*. (2021).

To enhance participation and duration of membership, stakeholders should address barriers such as lack of trust, inadequate sensitization, and the perceived irrelevance of farmers' organizations to local farming practices. Establishing community-led cooperatives tailored to the specific needs of dairy farmers could increase trust and participation rates.

5.1.11 Respondents' Household Characteristics

Table 4.11 reveals that the majority of households (81.0%) are male-headed and polygamous, followed by 13.0% male-headed and monogamous households. Female-headed households make up a smaller proportion, with 3.5% having an absent husband and 1.5% being widowed. Single or divorced male-headed households and divorced female-headed households were not reported in the sample.

These findings are consistent with Abdullahi *et al*. (2022), who reported that polygamous households dominate rural farming communities in northern Nigeria due to cultural and religious norms. Such households often have larger family sizes, which provide an ample labor force for dairy farming activities. Similarly, studies by Bello and Yusuf (2023) highlighted the prevalence of male-headed households in smallholder farming systems, as decision-making and land ownership are predominantly male-dominated in these settings.

However, the presence of female-headed households, though minimal, aligns with Suleiman and Abubakar (2023), who identified widowhood or spousal absence as common reasons for women assuming household leadership in rural areas. These households often face challenges such as limited access to resources, decision-making power, and farm inputs, affecting their productivity. Addressing gender disparities in resource allocation and providing targeted support to female-headed households could enhance their contributions to the dairy sector.

5.1.12 Respondents' Household Size

Table 4.12 shows that the majority of households (60.5%) have 5–10 members, followed by 26.5% with 2–4 members, and 8.0% with 11–15 members. Only 5.0% of households exceed 15 members. This pattern supports findings by Yusuf *et al*. (2022), who noted that medium-sized households are prevalent among smallholder farmers in northern Nigeria. These households benefit from having enough family labor for dairy farming without the constraints of excessive resource sharing associated with larger households.

However, larger households (above 15 members) may struggle with meeting household needs, including education and healthcare, which can indirectly impact their productivity. Studies by Musa *et al*. (2021) emphasized that household size significantly influences farm labor availability and resource management in rural settings. Balancing household size with economic capacity is essential for sustaining productivity and improving living standards among smallholder dairy farmers.

5.1.13 Household Demographic Distribution by Age

Table 4.13 highlights the demographic distribution of household members by age and gender. Among males, the largest group comprises those over 60 years (27.5%), followed by those aged 21–30 years (15.0%). For females, the highest proportion falls within the 21–30 age group (16.0%), followed by those aged 10 years or younger (9.0%). The dominance of older males aligns with findings by Sani *et al*. (2023), who reported an aging population among rural farmers, reflecting a reliance on older household heads for decision-making. This demographic trend poses a risk of reduced productivity and slower adoption of innovative dairy farming practices. Conversely, the higher proportion of younger females highlights their potential as labor resources in dairy farming, particularly in milk processing and marketing.

These results echo Bello *et al*. (2022), who emphasized the importance of engaging younger household members in agricultural training programs to improve their skills and productivity. Additionally, providing incentives for younger males to engage in dairy farming could mitigate the challenges posed by an aging farming population.

5.1.14 Availability of Social Amenities/Household Items

The availability of basic amenities in the study area is generally low, with most households lacking key services such as access to electricity, schools, hospitals and recreational centers. Only 5.5% of respondents have access to electricity, and 5% have access to schools and hospitals, with minimal access to other amenities like recreation centers (6.5%) and zinc houses (7.5%). This suggests that infrastructure challenges persist in rural Taraba State, potentially limiting the capacity of smallholder dairy farmers to scale up production and improve milk quality. These findings align with those of Nnadi *et al*. (2023), who observed that limited access to electricity and healthcare in rural Nigerian communities significantly affects productivity, including in the dairy sector. Furthermore, these infrastructure limitations could explain the low rates of milk processing and value-added product development seen in the study, as farmers may lack the facilities or resources to process milk efficiently.

5.1.15 Milk Processing and Marketing

The data from Table 4.15 shows that milk production is substantial during both wet and dry seasons, with a higher volume produced in the dry season (9,625 liters) compared to the wet season (7,780 liters), this is mainly attributed to the need for the dairy farmers to migrate their animals farther away during the rainy seasons in search of grazing fields as the nearby areas are usually over taken by arable crop farmers for farming activities with little or no cattle routes to navigate the paths to the grazing field, so in order to avoid or minimize conflict with the farmers, the livestock owners resort to diving the heard into three with two thirds of the animals leaving for further locations and a few remaining just enough to provide milk for the children with little of the excess milk to sell and meet petty financial needs. The second major reason responsible for the availability of the milk in higher volumes during the dry season than the wet season is the fact that supplementary feeds are provided during the dry season and in a higher quality which helps in improving the plane of nutrition of the lactating dairy cows, and enhances milk secretions. However, milk processing remains grossly reduced during the wet seasons (for products like butter or cheese), with the majority of milk being consumed fresh or sold as fresh milk (8,325 liters in the dry season and 5,229 liters in the wet season). The lack of processing could be attributed to insufficient access to processing facilities due to high cost of set up and running, further emphasizing the gap in infrastructure.

This finding corresponds with a study by Bello *et al*. (2022), which highlighted that poor infrastructure and limited processing capacity among smallholder dairy farmers in Nigeria hinder their ability to add value to milk, impacting their income and sustainability. The absence of yogurt production and minimal butter and cheese sales further indicate that smallholder dairy farmers in Taraba State may not be able to diversify milk usage or reach wider markets, a point also made by Adebayo *et al*. (2021), who noted that diversification of dairy products is critical for improving farmers' income but is often impeded by infrastructural challenges.

Milk consumption in Taraba State appears to be quite low, with only 1,387 liters consumed in the wet season and 2,551 liters in the dry season, even though larger quantities of milk are produced. This low consumption rate might reflect the lack of proper storage and processing options, leading to most milk being sold fresh or fermented rather than retained for household use or processed into products like cheese or yogurt. The findings align with those of Abdulrahman *et al*. (2023), who found that low milk consumption and limited processing were common among smallholder dairy farmers in rural Nigerian states, often due to poor storage and preservation facilities.

5.1.16 Seller of Milk and Milk Products

The data in Table 4.16 reveals that the majority of milk and milk products are sold by adult females (wives), accounting for 80% of the sellers. Female children also contribute to milk sales, though at a lower rate (15%), while hired laborers account for only 5%. This pattern suggests that the responsibility of selling milk and milk products is largely handled by women in the household, particularly the wives. This trend aligns with findings by Salisu *et al*. (2021), who observed that in rural Nigeria, women are primarily responsible for the marketing and sale of dairy products, often as a means of supplementing household income. The absence of male involvement in milk sales in this study may reflect traditional gender roles in rural areas, where men tend to focus on farming activities, while women handle other household duties, including economic activities like selling of milk.

These findings are consistent with those of Adebayo *et al*. (2022), who noted that women, especially wives, often take on the economic responsibility of marketing livestock products in rural Nigeria. This could also highlight an opportunity for empowerment, as increased support and training for women in milk sales could improve household income and dairy sector productivity.

5.1.17 Location of Sales

Table 4.17 shows that most milk and milk products are sold through market outlets on daily weekly or alternate basis, this accounts for 70% of the sales. Other locations such as village squares/markets, weekly markets, and urban centers contribute less significantly, at 9%, 5%, and 10%, respectively. The very small percentage of sales made at the farm gate (1%) suggests that many farmers do not sell milk directly from their farms, likely due to the lack of proper infrastructure or the need to reach a wider market.

This is consistent with research by Nnadi *et al*. (2023), which found that in many rural Nigerian communities, house-to-house hawking is a common method of marketing perishable products such as milk, due to limited access to established market locations. Moreover, the preference for hawking can be attributed to the need for farmers to ensure that their milk reaches consumers quickly before spoilage occurs, as fresh milk has a short shelf life without proper storage.

5.1.18 Distance of Selling Point from Homestead

The data from Table 4.18 reveals that most farmers (55%) sell milk at locations more than 30 kilometers away from their homesteads. A significant portion of sales (20%) occurs at distances greater than 50 kilometers. These long distances indicate that milk producers are traveling substantial distances to access markets, which may increase the costs and reduce the profitability of their dairy activities.

This finding is consistent with the study by Garba *et al*. (2021), which found that rural dairy farmers often face challenges in accessing local markets due to poor road infrastructure, forcing them to travel long distances to sell their products. The need to travel far for milk sales can be a significant barrier, limiting the efficiency of milk distribution and increasing transaction costs. In addition, this also reflects the limited presence of local collection centers or organized milk marketing groups, as only 0% of respondents reported selling through such centers.

5.1.19 Number of Times Milk and Milk Products are Sold Per Season

Table 4.19 illustrates that the majority of smallholder dairy farmers in the wet and dry seasons sell their milk and milk products daily, with 87.5% in the wet season and 84.0% in the dry season reporting daily sales. Weekly sales are relatively less frequent, with only 8.0% selling once a week in the wet season and 16.0% in the dry season. This indicates a consistent daily demand for milk, which is typical for fresh milk in rural areas due to its perishable nature.

The high frequency of daily sales is consistent with findings from previous studies, such as those by Abubakar *et al*. (2020), who observed that rural dairy farmers tend to sell milk daily to prevent spoilage and meet local demand, particularly in regions where refrigeration or cold chain facilities are lacking. The absence of sales beyond daily or weekly intervals further supports the trend of perishable milk being marketed in small quantities to maintain freshness.

In line with findings by Haji *et al*. (2021), daily milk sales are critical for the sustainability of smallholder dairy farming in areas where storage facilities are inadequate. The frequency of sales also emphasizes the importance of establishing more efficient milk distribution systems to reduce the burden on farmers and increase the profitability of milk production.

5.1.20 How Animals Are Kept at Night

The data in Table 4.20 shows that all the surveyed farmers (100%) keep their animals in stables made from wood and other local materials at night. This suggests a uniformity in how smallholder farmers protect their animals during the nighttime, with a preference for locally available materials over modern infrastructures. The lack of other options such as kraals or barns indicates limited access to modern or well-constructed animal housing.

This finding is consistent with research by Kuru *et al*. (2019), who found that traditional housing made from locally available materials is still the most common method of animal housing in rural Nigeria, largely due to financial constraints and limited access to modern agricultural infrastructure. The reliance on wooden stables may also indicate challenges in providing adequate protection from environmental hazards such as predators or adverse weather conditions.

The use of simple animal housing structures underscores the need for policies that provide farmers with access to affordable materials or financial support to upgrade animal housing. Improved housing could enhance animal welfare and productivity, as noted by Olayemi *et al*. (2022), who stressed the importance of better livestock housing for improving the overall health and productivity of farm animals.

5.1.21 Keeping Dairy and Non-Dairy Animals Together

Table 4.21 reveals that 100% of the farmers do not keep dairy and non-dairy animals together. This suggests a strong practice of segregating livestock types, likely due to different management needs, feed requirements, or disease control measures. The separation of dairy animals from non-dairy livestock is common in smallholder farming systems, as dairy animals often require more specialized care and attention. This finding aligns with the observations of Oyebanji *et al*. (2022), who found that in Nigeria, smallholder farmers often maintain separation between dairy and non-dairy livestock to ensure optimal management and prevent the spread of diseases. The distinct management practices for dairy and non-dairy animals are vital for improving productivity and maintaining the health of the herds.

Furthermore, the separation of livestock types may also reflect the distinct economic value placed on dairy animals, as emphasized by Daramola *et al*. (2021), who noted that dairy farming is seen as a more capital-intensive and high-value activity in rural farming systems, necessitating more specialized management practices.

5.1.22 Stall Feeding of Dairy Animals

Table 4.22 shows that 100% of the smallholder dairy farmers surveyed do not stall-feed their dairy animals. This suggests that all the farmers provide their animals with grazing access rather than confining them in stalls. The lack of stall-feeding could be due to various factors such as limited availability of feed resources, the cost of supplementary feeds, or traditional farming practices that emphasize grazing.

This finding aligns with the observations of Oladosu *et al*. (2020), who found that in rural Nigeria, many smallholder dairy farmers prefer free-range grazing due to the low cost of resources compared to stall-feeding, which requires substantial investments in feed and infrastructure. Additionally, a study by Haji *et al*. (2021) noted that grazing is often considered a more sustainable and cost-effective method in regions where land and grazing areas are abundant, despite its potential impact on animal productivity. The absence of stall-feeding reflects the traditional farming systems in place in rural Nigeria and highlights the challenges smallholder farmers face in transitioning to more intensive dairy management systems.

5.1.23 Separating Dry from Milking Animals

According to Table 4.23, 100% of the respondents do not separate dry animals from milking cows. This indicates that the farmers keep both dry and milking cows together in the same management system. This practice could be due to limited space, resources, or a lack of understanding of the benefits of separating these groups for more efficient management.

This practice aligns with findings from other studies, such as those by Haji *et al*. (2021), who observed that many smallholder dairy farmers in rural Nigeria often do not have the resources to maintain separate enclosures or feeding programs for dry and milking cows. According to the authors, while separating dry and milking animals could improve milk yield and reduce feed wastage, the reality of resource constraints often results in a more simplified management approach. The lack of separation between dry and milking animals may also contribute to inefficiencies in milk production, as dry cows typically require different nutritional and management strategies compared to milking cows.

5.1.24 Number of Times Milking Cows Are Watered in a Day During Dry Season

Table 4.24 shows that 100% of the respondents water their milking cows three times a day during the dry season. This suggests that smallholder dairy farmers are highly attentive to the hydration needs of their milking cows during the dry season, possibly due to the increased water loss from heat stress or the lack of sufficient natural water sources during this period.

This practice is consistent with findings by Oladosu *et al*. (2020), who noted that in areas with hot, dry climates, maintaining adequate water intake for dairy animals is crucial for milk production and animal health. Frequent watering can help prevent dehydration, which is known to reduce milk yield and increase the risk of health issues in dairy cattle. A study by Haji *et al*. (2021) also highlighted that proper water management is essential for maximizing milk production, particularly during dry seasons when water scarcity is a common concern. Frequent watering of cows during the dry season further underscores the importance of water as a critical resource in maintaining animal productivity and health in smallholder dairy farming systems.

5.1.25 Number of Times Milking Cows Are Watered in a Day

Table 4.25 shows that 100% of the smallholder dairy farmers water their milking cows once a day. This indicates that despite the significant importance of water intake for milk production, the farmers are providing water to their cows on a once-daily basis. This could suggest a reliance on limited water resources, particularly in areas with scarce water availability, or it may reflect a lack of access to sufficient infrastructure to provide multiple waterings per day.

This practice aligns with the findings of studies such as those by Oladosu *et al*. (2020), which emphasized that many smallholder farmers in rural Nigeria are constrained by water access, particularly during dry seasons, leading to infrequent waterings. Although watering cows once a day might be enough to meet basic hydration needs, it is known that more frequent watering is essential for maintaining high levels of milk production, especially during hotter months. Haji *et al*. (2021) observed that inadequate water intake can significantly impact milk yield and overall animal health.

5.1.26 Source of Water

According to Table 4.26, 100% of the respondents rely on streams as the source of water for their milking cows. This is indicative of the farmers' dependence on natural water sources, which may be subject to seasonal variations, contamination, and access challenges. The fact that all respondents use streams suggests limited access to more modern water supply systems like wells, pipe-borne water, or dams.

This finding is consistent with studies such as those by Haji *et al*. (2021), which reported that many rural smallholder farmers in Nigeria continue to depend on surface water sources like streams for livestock watering. Although streams provide an easily accessible water source, they can be unreliable during the dry season or in areas with limited rainfall, which can lead to periods of water scarcity and stress on milk production.

The dependence on streams also raises concerns about water quality, as surface water sources can be contaminated by human, animal, and agricultural activities, which might affect both animal health and milk quality.

5.1.27 Distance to Source of Water (in Kilometers)

Table 4.27 indicates that 78% of the respondents travel between 0.5-1 km to reach the water source, while 16% travel less than 500 meters, and 6% travel between 2-5 km. This suggests that most farmers have relatively easy access to water for their cows, though a significant portion still faces moderate distances to reach their water source.

These distances are similar to those reported by Haji *et al*. (2021), who found that many smallholder farmers in rural Nigeria typically have to walk short to moderate distances (ranging from 0.5 to 2 km) to access water for their livestock. The relatively short distances traveled by the majority of respondents may indicate that while water access is not an extreme challenge, it is still a considerable effort for farmers who must regularly provide water to their cows.

Longer distances to water sources, as seen in the 6% of respondents who travel up to 5 km, can increase labor costs and reduce the time available for other important farming activities, such as feeding and milking. Inadequate access to water may also limit milk production, especially during times of high heat stress or water scarcity.

5.1.28 Giving Supplementary Feeds to Animals

According to Table 4.28, 73.5% of the respondents provide supplementary feeds to their dairy animals, while 26.5% do not. This indicates that a significant portion of smallholder dairy farmers in the study area recognize the importance of supplementary feeding, especially in times when forage availability is limited or during stress periods such as the dry season. The practice of supplementary feeding can help enhance milk production and overall animal health, particularly when natural pastures are inadequate.

This finding aligns with research by Oladosu *et al*. (2020), which highlighted that supplementary feeding is a common practice among Nigerian smallholder dairy farmers, particularly during the dry season when forage quality and quantity decline. The importance of feeding supplements like minerals and vitamins is also well-documented in improving milk yield and reproductive performance (Nworgu *et al*., 2019).

5.1.29 Supplementary Feeding Period

Table 4.29 indicates that all respondents (100%) provide supplementary feeds during the dry season, while none do so during the rainy season. This seasonal feeding pattern is consistent with the common practice of smallholder dairy farmers in areas with seasonal rainfall, where the dry season presents a critical time for supplementing the animals' diet. During the rainy season, natural grazing usually provides enough nutrients for the animals, thus reducing the need for supplementary feeding.

This practice is in line with findings from a study by Haji *et al*. (2021), which observed that Nigerian farmers typically rely on supplementary feeds only when forage availability is at its lowest, i.e., during the dry season. Supplementary feeding during this period helps prevent a decline in milk production and maintain animal health when pasture quality diminishes.

5.1.30 Expenditure on Supplementary Feeds

Table 4.30 details the expenditure on supplementary feeds during the last rainy and dry seasons. It shows that for the dry season, significant amounts were spent on cereal bran and crop residues like cereal straw and cowpea hay. The cost of cereal bran alone was ₦38,615,000, which highlights its importance as a major supplementary feed. Conversely, no expenditures were made for products like cottonseed cake, groundnut seed, and wet brewer's grains, which may not be available or commonly used in the area.

The high expenditure on cereal bran and crop residues in the dry season reflects a trend seen in many smallholder dairy farming systems, where such resources are critical to maintaining animal productivity when fresh grazing materials are limited. Similar findings were noted by Oladosu *et al*. (2020), who reported that cereal by-products, such as cereal bran, are commonly used by Nigerian farmers to supplement the diet of dairy animals during the dry season. Additionally, the costs for minerals, salt, and supplements were considerable, indicating their importance in providing balanced nutrition.

The use of crop residues, such as cereal straw and cowpea hay, is also in line with Nworgu *et al*. (2019), who observed that Nigerian farmers commonly use available agricultural by-products for livestock feeding, particularly when feed resources are scarce.

5.1.31 Important Animal Health Problems and Expenditure on Veterinary Drugs and Treatment

Table 4.31 outlines the important animal health problems and associated expenditure on veterinary drugs and treatment. The diseases are ranked in descending order of importance, with the most critical issues affecting the highest number of dairy animals. The table shows that *trypanosomiasis*, *helminthiasis*, and tick and other ectoparasites are the top three health problems, each affecting a significant number of animals and requiring substantial expenditure on drugs. *Trypanosomiasis*, affecting 15,528 animals, ranks highest, followed by *helminthiasis* with 6,397 affected animals, and tick and other ectoparasites with 3,223 affected animals. The expenditure on veterinary drugs for these diseases is notably high, indicating their severe impact on animal health and productivity. The expenditure on tick control, at ₦9,166,000, stands out as particularly high, which emphasizes the importance of managing ectoparasite infestations in dairy herds.

Respiratory diseases, diarrhea, and mastitis are also significant issues, with respiratory problems (467 affected animals) and mastitis (901 affected animals) causing considerable financial implications, even though their affected numbers are relatively smaller.The relatively low cost of treatment for diseases like diarrhea and skin problems may suggest that they are less severe in terms of their impact on the herd, but still, their management requires some veterinary intervention. These findings are in line with studies such as those by Okwu *et al*. (2021), which observed that ectoparasites and trypanosomiasis are common causes of health problems in Nigerian dairy cattle, leading to considerable expenditure on treatment.

5.1.32 Animal Mortality

Table 4.32 presents the mortality rates of animals during both the dry and wet seasons. Calf mortality is notably higher in the dry season (2,839 calves) compared to the wet season (2,632 calves), while adult animal mortality is also higher during the dry season (2,646 adults) compared to the wet season (1,170 adults). The total mortality during the dry season (5,482 animals) is significantly higher than that during the wet season (3,802 animals). This may be due to environmental stress factors, such as heat, water scarcity, and reduced forage quality during the dry season, which can negatively impact the health and survival of livestock. The findings are consistent with previous research by Sanni *et al*. (2020), which highlighted higher mortality rates in livestock during the dry season, attributed to harsh environmental conditions.

5.1.33 Access to Livestock Extension Services

Table 4.33 reveals that 45% of respondents have access to livestock extension services, while 55% do not. This indicates that a significant portion of the dairy farmers lack access to professional advice and support regarding livestock management, health, and productivity. Access to extension services is crucial for improving farming practices, animal health management, and overall productivity. The low level of access (45%) could be a constraint to improving dairy farming in the region, as extension services play a pivotal role in disseminating knowledge about disease control, feeding practices, and other best practices. This finding is consistent with those by Okoruwa *et al*. (2020), who observed that limited access to extension services is a major challenge for smallholder dairy farmers in Nigeria, limiting their ability to address health problems and adopt modern farming practices.

5.1.34 Extension Service Provider

The findings on extension service provider indicate that all respondents (100%) rely exclusively on private sources for extension services, with no engagement from government agencies or NGOs. This highlights a significant gap in public extension service delivery. This finding aligns with Ogunniyi and Adebayo (2022), who reported that public extension services in Nigeria are often underfunded and inaccessible to farmers, leaving private providers to fill the gap. Similarly, Adebayo *et al*. (2023) emphasized the inadequacy of public extension services, which has forced farmers to rely more heavily on private sources.

5.1.35 Other Sources of Information

Farmers utilize a variety of information sources, with the majority (69%) relying on private individuals for guidance, followed by animal scientists (19.5%), print media (5.5%), and veterinarians or family and friends (3% each). These findings support the observations of Adeyemi and Alabi (2024), who noted that informal networks such as private individuals and peers play a crucial role in providing agricultural information, particularly where formal systems are underdeveloped. The limited involvement of veterinarians highlights a potential area for improvement, as access to professional veterinary advice could enhance livestock productivity and health (Ibrahim *et al*., 2023). Furthermore, the preference for private individuals corroborates the findings of Olajide and Akpan (2022), who emphasized the importance of peer networks in agricultural decision-making.

5.1.36 Frequency of Services Provided

Most respondents (75%) reported receiving extension services monthly, while smaller proportions received services weekly (3.5%), quarterly (3%), yearly (1.5%), or with no specific schedule (17%). This variability reflects the uneven availability of extension services, as noted by Ogunleye *et al*. (2022), who documented similar inconsistencies in service provision across regions. The irregular access to extension services, particularly among farmers receiving support without a specific schedule, is a recurring issue in Nigerian agriculture, as highlighted by Okorie *et al*. (2023). Yusuf *et al*. (2024) suggested that improving the consistency and accessibility of these services would significantly benefit smallholder farmers.

5.1.37 Ranking of Advice Received from Extension Workers

The findings show that half of the respondents (50%) rated the advice received from extension workers as fair, while 48.5% rated it as good, and only 1.5% described it as poor. This distribution indicates a generally positive perception of the quality of advice provided by extension workers, albeit with room for improvement. According to Yusuf *et al*. (2024), the effectiveness of extension advice significantly impacts farm productivity and adoption of best practices. Similarly, Olajide and Akpan (2022) noted that fair and good ratings often correlate with farmers' trust in extension workers, which is critical for successful service delivery. However, the small percentage of respondents rating the advice as poor underscores the need for targeted interventions to improve training and communication skills among extension agents (Adebayo *et al*., 2023).

5.1.36 Access to Credit

A significant majority of respondents (78%) reported having no access to credit, with only 22% affirming access to financial support. This finding aligns with Okorie *et al*. (2023), who highlighted that access to credit remains a major constraint for smallholder farmers in Nigeria. Limited financial resources impede farmers' ability to invest in inputs, technologies, and services that could enhance productivity. Ibrahim *et al*. (2023) further emphasized that improved access to credit facilities is essential for empowering farmers and fostering agricultural development.

5.1.39 Source of Credit

Among respondents who accessed credit, 11% relied on friends and family, 7.5% sourced credit from NGOs, and 81.5% reported no access to credit at all. This reliance on informal sources such as friends and family is consistent with findings by Ogunleye *et al*. (2022), who reported similar trends in rural areas where formal credit facilities are scarce or inaccessible. The limited role of NGOs in providing credit may reflect inadequate outreach or resources, as suggested by Adebayo *et al*. (2023). This finding reinforces the need for structured financial interventions to address the credit gap for smallholder farmers (Adeyemi and Alabi, 2024).

5.1.40 Purpose for Credit

The analysis revealed that 81.5% of respondents did not access credit, while 18.5% utilized credit for animal production purposes. This indicates that when credit is available, it is often directed towards productive agricultural activities, particularly livestock farming. The findings align with Okorie *et al*. (2023), who noted that financial support is a critical enabler for livestock production, as it allows farmers to invest in feed, veterinary services, and improved breeding practices. Similarly, Ogunleye *et al*. (2022) reported that access to credit for animal production contributes significantly to enhancing productivity and profitability among smallholder farmers.

However, the high proportion of respondents without access to credit underscores the persistent challenge of financial exclusion in rural farming communities, as also highlighted by Adebayo *et al*. (2023). This situation may be attributed to the limited presence of formal financial institutions and restrictive loan conditions, which deter farmers from seeking credit (Olajide & Akpan, 2022). Adeyemi and Alabi (2024) emphasize the need for tailored credit schemes targeting livestock farmers to address these gaps and support sustainable animal production systems.

5.2 Study 2: Investigation of Presence and Types of Mastitis Causing Organisms in the Area of the Study

5.2.1 Mean bacterial growth rates by location

The study assessed bacterial growth rates across four locations: Ardo Kola, Jalingo, Bali, and Gassol. The mean growth rate in Ardo Kola was 44.44% ± 50.40, with 16 out of 36 samples showing positive growth. In Jalingo, 20 out of 36 samples exhibited bacterial growth, resulting in a mean growth rate of 55.56% ± 50.40. Bali had a slightly lower mean growth rate of 41.67% ± 49.92, with 15 positive samples. Gassol recorded the highest mean growth rate at 61.11% ± 49.44, with 22 positive samples.

These findings indicate significant variation in bacterial growth rates across the locations. The observed differences may reflect variations in environmental factors such as temperature, humidity, and sanitation, which influence bacterial proliferation (Ogunleye *et al*., 2023). Similarly, Adebayo *et al*. (2022) highlighted that factors like soil composition and water quality significantly impact bacterial growth rates in agricultural settings.

The high growth rate observed in Gassol aligns with earlier findings by Okorie *et al*. (2021), who reported elevated bacterial activity in areas with increased agricultural runoff. Conversely, the lower rates in Bali might indicate more stringent hygiene practices or less conducive environmental conditions for bacterial growth. The results emphasize the need for location-specific interventions to manage bacterial contamination effectively. Enhanced monitoring and tailored hygiene protocols could mitigate bacterial proliferation, particularly in areas with higher growth rates, as suggested by Adebayo *et al*. (2022).

5.2.2 Mean bacterial growth across different sampling conditions

The study compared bacterial growth rates under various sampling conditions, including bedding/soil samples, unwashed, washed, and disinfected teats of milking cows. The mean bacterial growth rate for unwashed teats was the highest at 66.67% ± 47.71, with 24 out of 36 samples showing positive growth. Washed teats had a slightly lower mean growth rate of 61.11% ± 49.44, with 22 positive samples. In contrast, disinfected teats exhibited a significantly reduced mean growth rate of 5.56% ± 23.23, with only 2 samples testing positive for bacterial growth. Bedding/soil samples recorded the highest growth rate overall at 69.44% ± 46.72, with 25 positive samples.

These results demonstrate that proper teat hygiene, particularly disinfection, is highly effective in minimizing bacterial contamination. The findings are consistent with earlier studies, such as Adebayo *et al*. (2023), which emphasized the importance of disinfection in reducing microbial loads on dairy teats. Similarly, Ogunleye *et al*. (2022) highlighted the increased risk of contamination associated with environmental sources like bedding and soil, which aligns with the high growth rates observed in this study for bedding/soil samples.

The reduced bacterial growth in disinfected teats corroborates findings by Okorie *et al*. (2021), who reported that disinfection lowers bacterial loads by over 90% in dairy practices. Conversely, the elevated growth rates in unwashed teats and bedding/soil samples mirror observations by Olaniyan *et al*. (2022), where inadequate hygiene led to significant microbial contamination in dairy environments. The findings underscore the critical role of disinfection in maintaining milk safety and reducing bacterial contamination risks. Promoting hygiene practices such as regular disinfection of teats and bedding management can enhance milk quality and minimize health risks for consumers, as suggested by Adebayo *et al*. (2023).

5.2.3 Bacterial growth distribution by location and sampling condition

The bacterial growth distribution across different locations and sampling conditions revealed notable variations. In Ardo Kola, unwashed teats showed a growth rate of 55.6% (5/9), while washed teats had a slightly lower rate of 44.4% (4/9). No growth was recorded on disinfected teats (0/9), whereas bedding samples exhibited the highest growth at 77.8% (7/9). The total bacterial growth rate for Ardo Kola was 44.4% (16/36).

In Jalingo, bacterial growth was observed to be higher, with unwashed and washed teats both recording 66.7% (6/9). Disinfected teats had minimal growth at 11.1% (1/9), and bedding samples matched the highest growth rate of 77.8% (7/9). The overall growth rate for Jalingo was 55.6% (20/36).

Bali showed similar patterns, with unwashed teats and washed teats recording growth rates of 66.7% (6/9) and 55.6% (5/9), respectively. Disinfected teats showed no growth (0/9), while bedding samples had a lower growth rate of 44.4% (4/9). The total growth rate for Bali was 41.7% (15/36). In Gassol, the highest bacterial growth was recorded for unwashed and washed teats, both at 77.8% (7/9). Disinfected teats had a low growth rate of 11.1% (1/9), and bedding samples also recorded a growth rate of 77.8% (7/9). Gassol had the highest total bacterial growth rate among all locations, at 55.6% (22/36). The results reinforce earlier findings, such as those by Adebayo *et al*. (2023), who emphasized the role of proper hygiene in reducing bacterial contamination. The significantly reduced growth rates on disinfected teats align with the work of Okorie *et al*. (2021), which demonstrated the efficacy of disinfection practices in dairy farms. Similarly, the high bacterial growth in bedding samples supports the observations of Ogunleye *et al*. (2022), who identified bedding and soil as key contributors to microbial contamination in livestock environments.

These findings highlight the critical need for implementing stringent hygiene protocols in dairy farming. The high bacterial growth rates in unwashed and washed teats, particularly in Gassol and Jalingo, underscore the importance of educating farmers on best practices for teat cleaning and disinfection. Moreover, the consistently high contamination levels in bedding samples call for improved bedding management to minimize microbial risks, as recommended by Olaniyan *et al*. (2022).

5.2.4 Distribution of bacterial species by location and statistical analysis

The distribution of bacterial species by location provides valuable insights into microbial diversity and prevalence across different areas. Ardo Kola recorded the highest incidence of *Salmonella sp.* (8 isolates), aligning with findings from other studies that noted its prevalence in unhygienic farming practices (Adegboye *et al*., 2022). Conversely, *Klebsiella sp.*, which was more common in Ardo Kola and Bali, reflects site-specific contamination patterns likely linked to environmental conditions, as previously noted by Chukwuma *et al*. (2021). Gassol showed a higher frequency of *Staphylococcus sp.* (11 isolates), consistent with findings linking this pathogen to inadequate teat disinfection practices (Okeke & Yusuf, 2023).

Jalingo exhibited diverse bacterial species, including a notable frequency of *E. coli* (6 isolates) and *Streptococcus sp.* (5 isolates). This supports earlier studies demonstrating the high prevalence of these pathogens in urban dairy systems with limited biosecurity measures (Ibrahim *et al*., 2021). The mixed infections observed (7 cases across locations) also highlight the complexity of contamination, as previously documented in multi-pathogen environments (Usman & Ahmed, 2020).

The ANOVA results revealed significant differences in bacterial prevalence between locations (F-value = 3.142, p = 0.027) and between location × sampling condition (F-value = 2.876, p = 0.042). These findings corroborate previous reports on location-dependent variability in microbial loads due to environmental and management factors (Amadi *et al*., 2022). The higher contamination rates in Gassol and Jalingo, for example, could be attributed to their extensive dairy production systems and limited access to extension services, as highlighted by Bello *et al*. (2022

5.2.5 Pairwise location comparisons and statistical significance

The pairwise location comparisons using t-test results revealed several interesting findings. Significant differences were observed between Ardo Kola and Jalingo (p = 0.037), as well as Ardo Kola and Gassol (p = 0.004). These differences suggest potential variations in bacterial growth and contamination patterns linked to environmental and management factors at these locations. Similar findings were reported by Yusuf *et al*. (2021), who observed site-specific variations in bacterial contamination levels in rural and urban farming systems. The comparison between Bali and Gassol (p = 0.002) also demonstrated significant differences, emphasizing regional variability in microbial contamination, likely influenced by local farming practices (Chukwu *et al*., 2022).

Interestingly, no significant differences were found between Ardo Kola and Bali (p = 0.815) or Gassol and Jalingo (p = 0.384), suggesting that certain locations may have more uniform microbial conditions, as also indicated in studies by Ahmed *et al*. (2023), who noted that microbial diversity can remain relatively stable across certain geographical areas if farming practices and environmental conditions are similar.

5.2.6 Statistical comparison of bacterial growth between sampling conditions

The statistical analysis of bacterial growth across different sampling conditions (unwashed, washed, disinfected, and bedding) revealed significant findings. The comparison between unwashed and disinfected showed a highly significant difference ($p < 0.001$), indicating the efficacy of disinfecting practices in reducing bacterial growth, which aligns with findings from Adamu *et al*. (2022) and Okeke *et al*. (2023), who emphasized the importance of proper hygiene in preventing bacterial contamination in dairy animals. Similarly, significant differences were found between washed and disinfected teats ($p < 0.001$) and disinfected teats versus bedding ($p < 0.001$), highlighting that disinfected teats had the lowest bacterial growth compared to other sampling conditions.

On the other hand, no significant differences were observed between unwashed teats and bedding ($p = 0.793$), and between washed teats and bedding ($p = 0.449$), suggesting that bedding, though crucial for animal comfort, might still pose a risk for bacterial contamination if not properly managed (Akinmoladun *et al*., 2022). These findings reinforce the importance of adopting comprehensive hygiene measures, particularly disinfecting teats, to minimize bacterial contamination in dairy production systems.

5.3 Study 3: Identification and Classification of Types of Microbes Present in Milk and Milk Products.

5.3.1 Bacterial growth rates by location

The mean bacterial growth rates observed across the different locations indicate slight variability, with Ardo Kola showing the highest average growth rate at 0.42 ± 0.17, followed closely by Gassol at 0.40 ± 0.16. Bali and Jalingo exhibited relatively similar growth rates of

0.39 ± 0.16 and 0.38 ± 0.15, respectively. This variation in bacterial growth rates across locations suggests that environmental and management factors, such as sanitation and livestock handling practices, may contribute to differences in microbial activity in dairy farming systems (Ogunyemi *et al*., 2022). Similar findings have been observed in other studies that attributed regional differences in bacterial contamination to local farming practices and climate conditions (Oluwaseun *et al*., 2021).

5.3.2 Bacterial growth distribution by location and sampling condition

The bacterial growth distribution across various milk types, fresh milk, overnight milk, pasteurized milk and fermented milk further illustrates location-based patterns. In Jalingo, 45.8% of the bacterial growth was observed in overnight milk, with 37.5% observed in both pasteurized and fermented milk. In contrast, Ardo Kola exhibited 45.8% bacterial growths in fermented milk, with fresh and pasteurized milk both showing 37.5% bacterial contamination. Gassol displayed 45.8% bacterial growth in pasteurized milk, while Bali showed a relatively even distribution of growth in fresh milk, pasteurized milk, and fermented milk, each at approximately 39.6%. These results suggest that microbial contamination levels may differ based on the milk type and the specific location (Akinmoladun *et al*., 2023). The higher bacterial growth in certain milk types could be attributed to variations in handling practices, with overnight and fermented milk potentially providing more conducive environments for bacterial proliferation, as shown in studies by Nwachukwu *et al*. (2022).

5.3.3 Distribution of bacterial species by location

The distribution of bacterial species across locations shows notable differences in the prevalence of specific microorganisms. In Jalingo, *E. coli* was the most prevalent species, comprising 20.8%

of the bacterial isolates, followed by *Streptococcus sp.* at 20.8%. Ardo Kola had a higher proportion of *E. coli* (33.3%) and *Streptococcus sp.* (20.8%) isolates. Gassol and Bali showed similar patterns, with *E. coli* being the dominant species in both locations (33.3% and 29.2%, respectively). Other species such as *Staphylococcus sp.*, *Klebsiella sp.*, *Lactobacillus sp.*, *Salmonella sp.*, and *Mycobacterium sp.* showed varying prevalence rates across the locations, with *Klebsiella sp.* and *Lactobacillus sp.* being more common in Ardo Kola and Bali (8.3% and 8.3%, respectively). The presence of *Salmonella sp.* was observed in Jalingo (16.7%) and Bali (4.2%), while *Mycobacterium sp.* was found in Ardo Kola and Bali (4.2%). These findings align with previous studies that noted the prevalence of *E. coli* as a common contaminant in dairy products, which is often linked to improper hygiene and handling practices (Ogunyemi *et al*., 2022).

5.3.4 One-Way ANOVA results for location comparisons

The One-Way ANOVA results for location comparisons did not show statistically significant differences in bacterial species distributions across the locations (F-value = 1.342, p-value = 0.261). This suggests that, although certain locations showed variations in the types of bacterial species present, these differences were not statistically significant at the 5% level. This finding contrasts with studies where significant spatial differences in bacterial contamination were observed, possibly due to more pronounced variations in local environmental factors or farming practices (Akinmoladun *et al*., 2023). The lack of significant differences here may suggest that the locations studied, while showing variations in species composition, share common environmental and management factors influencing bacterial growth or there is the likelihood of cross migratory movement of animals within the locations which results to the spread of same bacteria spp

5.3.5 Pairwise location comparisons (t-test)

The pairwise t-test results provide further insight into the bacterial growth rate differences between locations. The mean differences between all pairs of locations were relatively small, with no statistically significant differences observed. For example, the comparison between Jalingo and Ardo Kola revealed a mean difference of -0.04 with a t-value of -1.987 ($p = 0.285$), indicating no significant difference. Similarly, the comparisons between Jalingo and Gassol, Jalingo and Bali, Ardo Kola and Gassol, and Ardo Kola and Bali also yielded non-significant results with adjusted p-values of 1.000 or 0.879. The comparison between Gassol and Bali showed a mean difference of 0.01 and a t-value of 0.412 ($p = 1.000$), which further supports the lack of significant differences between these locations.

These findings align with the results from the One-Way ANOVA, where no significant differences were found between the bacterial growth rates across locations ($p > 0.05$). Previous studies have reported similar findings where microbial growth rates did not significantly vary between certain geographical locations, suggesting that other factors, such as local environmental conditions or common agricultural practices, could contribute to this uniformity (Adesina *et al*., 2022). In contrast, studies in other regions have observed significant spatial differences in bacterial growth, often due to variations in agricultural practices, water sources, or farm hygiene (Oluwadare *et al*., 2021).The lack of statistically significant differences between locations in the current study suggests that bacterial growth rates are relatively consistent across the surveyed areas, which may reflect common environmental or management factors shared and cross movement of same animals among the locations.

5.4 Study 4: Investigation of Milk Nutrient Composition, from Small Holder Pastoral Dairy Farmers in Some Selected Local Government of Taraba

5.4.1 Milk nutrient composition of raw fresh milk from small holder pastoral dairy farmers in selected local government areas of Taraba State

The nutrient composition of fresh milk varied significantly across the study locations, with notable differences in key parameters such as protein, fat, solids non-fat (SNF), and lactose. For instance, the protein content was highest in Jalingo (3.50%) and lowest in Bali (2.25%), with intermediate values observed in Ardo Kola (2.95%) and Gassol (3.14%). Similar trends were observed for lactose and solids non-fat, with Jalingo consistently showing the highest values. These findings align with reports by Adamu *et al*. (2021)**,** who noted higher milk protein and lactose concentrations in areas with better feed availability , Level of enlightenment and management practices.

Fat content was significantly higher in Ardo Kola (5.75%) compared to other locations, which had values ranging between 2.51% and 3.58%. The elevated fat levels in Ardo Kola may be attributed to differences in cattle breeds or grazing patterns, as suggested by Oluwadare *et al*. (2022)**,** who found that pastoral systems relying on natural forage often yield milk with higher fat content.

Interestingly, the freezing point of milk differed across locations, with Jalingo showing the lowest value (-0.61°C) and Bali the highest (-0.38°C). This variation may reflect differences in milk adulteration or dilution, as freezing point is a reliable indicator of milk purity. The findings align with Adekunle and Ekeocha (2020)**,** who emphasized the freezing point as a key quality parameter influenced by water addition.

Temperature and density also displayed significant differences, with Bali recording the highest milk temperature (31.58°C) and the lowest density (20.07%), while Jalingo had the lowest temperature (22.34°C) and the highest density (33.20%). This could be narrowed down to proximity of Jalingo to the research site and it also suggests that Bali's milk may have been more prone to bacterial contamination due to higher storage temperatures, a concern highlighted by Olorunfemi *et al*. (2019) in their study on milk hygiene practices in rural settings.

5.4.2 Milk Nutrient composition of pasteurized milk from small holder pastoral dairy farmers in selected local government areas of Taraba State

The analysis of pasteurized milk from the selected local government areas in Taraba State showed no statistically significant differences ($p > 0.05$) in the nutrient composition across the locations. This uniformity likely reflects the standardization effect of pasteurization, which minimizes location-specific variations. These findings are consistent with the observations of Adamu *et al*. (2021)**,** who reported that pasteurization tends to stabilize milk composition, especially for parameters such as fat, solids non-fat, and lactose.

Fat content ranged between 4.89% in Jalingo and 6.71% in Gassol, with no significant differences. The slightly higher fat content in Gassol and Bali (6.48%) could be linked to breed variations or feeding practices before milk collection. However, these variations were not significant, corroborating the findings of Oluwadare *et al*. (2022)**,** who noted that pasteurization equalizes fat distribution by breaking down fat globules.

Solids non-fat, lactose, salt, and protein levels remained consistent across locations, with mean values of 8.89%, 4.89%, 0.73%, and 3.27%, respectively. This consistency aligns with previous studies, such as Adekunle and Ekeocha (2020)**,** who found that pasteurization has minimal impact on the solids non-fat and protein content of milk. The freezing point of milk across locations, ranged narrowly between -0.57°C and -0.60°C, indicating no significant variations. This result aligns with findings by Olorunfemi *et al*. (2019)**,** who emphasized that pasteurization does not alter the freezing point but may slightly reduce the variability caused by adulteration or storage conditions.

Temperature and density of the milk samples were also consistent, with mean values of 19.57°C and 28.58, respectively. The slight differences observed could be attributed to environmental factors during sample collection, handling or storage. These results support the conclusions of Chinaka *et al*. (2021)**,** who noted that pasteurized milk from pastoral systems tends to exhibit similar physical properties regardless of regional differences.

5.4.3 Milk Nutrient composition of overnight raw milk from small holder pastoral dairy farmers in selected local government areas of Taraba State

The nutrient composition of overnight raw milk collected from different locations in Taraba State exhibited significant differences ($p < 0.05$) for fat content, while other parameters showed no significant variation ($p > 0.05$). These findings are consistent with Adebayo *et al*. (2020)**,** who reported that storage conditions, including temperature and duration, can affect fat content more prominently than other milk components. Fat content was significantly higher in Gassol (4.94%) compared to Ardo Kola (2.34%), with intermediate values observed in Bali (4.51%) and Jalingo (3.70%). The higher fat content in Gassol aligns with the findings of Olayemi *et al*. (2021)**,** who noted that differences in fat content in raw milk could be attributed to breed variations, feed quality, and milking practices. Solids non-fat (7.43%–8.58%), lactose (4.07%–4.71%), salt (0.61%–0.71%), and protein (2.72%–3.15%) levels remained consistent across locations, with no significant differences. These findings corroborate Eze *et al*. (2019)**,** who observed minimal variability in these parameters in raw milk stored overnight under similar conditions. The consistency in solids non-fat and protein suggests uniformity in herd nutrition and management practices among the pastoralists. Density values ranged from 25.49 to 28.58, showing no significant differences. Similarly, the freezing point values, which ranged narrowly between -0.46°C and -0.55°C, were consistent with the standards reported by Ibrahim and Musa (2018) for raw milk from pastoral systems. Temperature variations among locations (27.10°C–30.52°C) were not statistically significant, reflecting the typical ambient conditions under which the milk was stored overnight. These findings are consistent with Chinwe *et al*. (2022), who highlighted that ambient storage has a minor effect on milk temperature but does not significantly influence other compositional parameters

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

The aim of the study was to determine dairy production, milk processing and milk products quality among small holder dairy farmers in four Local Government Areas (Ardo-Kola, Jalingo, Bali, and Gassol) of Taraba State, Nigeria. Four studies was carried out;

i. Survey studies to understudy the socio-economic characteristics of milk producers group in the study area through qualitative research technique,

ii. Investigation of presence and types of mastitis causing organisms in the area of the study,

iii. Identification and classification of types of microbes present in milk and milk products; raw milk immediately after milking, overnight raw milk, locally pasteurized and locally fermented milk and

iv. Investigation of milk nutrient composition among smallholder dairy farmers samples.

In study one, it reveals a traditional dairy farming system predominantly managed by male farmers, with 95.5% of households led by men and 81% being polygamous. The majority of household heads (62%) are middle-aged, falling between 36-55 years, with an exclusively Koranic educational background. However during the case of oral and group discussions investigations revealed that the women have absolute control of the milk and milk products, the women and children are responsible for tending to the cows, they milk, process and sell the milk. From the proceeds obtained from the sales of the milk and it's by products, the money is used to buy food stuff for both the home and the animals, while a certain amount is given to weekly group savings which is eventually used during ceremonies or buying of clothes for the children during festivities and also pay for children school fees either in formal education, qur'anic education or both.

Milk production demonstrates significant seasonal variations, with total production decreasing from 9,625 liters in the dry season to 7,780 liters in the wet season. Marketing is primarily conducted market sales on daily/weekly/ alternate days (45%), with adult females (80%) being the primary milk sellers. The study uncovered substantial challenges in livestock management, including prevalent animal health issues such as *Salmonella sp., Staphylococcus spp., Streptococcus spp, E.coli spp., Klebsia spp***.** and *mixed infestations.* Agricultural service access remains limited, with only 25% of farmers receiving livestock extension services, all sourced from private individuals and other non-governmental channels. Credit accessibility is equally constrained, with merely 22% of farmers accessing financial support, primarily from friends, family, and NGOs. Despite these challenges, farmers demonstrate resilience through adaptive strategies like providing supplementary feeds (73.5%) and maintaining consistent water provision for their livestock.

In study two, investigated the presence and types of mastitis causing organisms in the area of the study. Analyzing 144 total samples across different sampling conditions, the research revealed significant variations in bacterial prevalence and growth rates. Bacterial growth rates varied substantially between locations, ranging from 41.67% in Bali to 61.11% in Gassol. Sampling conditions dramatically influenced bacterial presence, with unwashed teats (66.67%) and bedding/soil (69.44%) showing highest growth rates, while disinfected teats demonstrated minimal bacterial growth (5.56%). Five primary bacterial species were identified: Salmonella sp. (21 isolates), Staphylococcus sp. (18 isolates), Streptococcus sp. (13 isolates), E. coli (10 isolates), and Klebsiella sp. (7 isolates). Statistical analysis revealed significant differences between locations (p=0.027) and sampling conditions (p=0.042).

Identification and classification of types of microbes present in milk and milk products was investigated in study three. Analyzing 192 samples across different milk conditions, the research investigated bacterial prevalence and distribution. Mean growth rates were relatively consistent across locations, ranging from 0.38 ± 0.15 in Jalingo to 0.42 ± 0.17 in Ardo Kola. Bacterial distribution varied across milk conditions: fresh milk (29.2-37.5%), overnight samples (41.7-45.8%), pasteurized milk (37.5-45.8%), and fermented milk (37.5-45.8%). Seven bacterial species were identified, with *E. coli* showing the highest prevalence (20.8-33.3%), followed by *Streptococcus* sp. (16.7-20.8%) and *Staphylococcus* sp. (12.5-20.8%). Statistical analysis revealed no significant differences between locations (p=0.261).

Study four, investigated milk nutrient composition across four local government areas in Taraba: Ardo Kola, Jalingo, Bali, and Gassol. Analysis covered fresh, pasteurized, and overnight raw milk samples, revealing significant variations in nutrient profiles. Fresh milk showed notable differences in protein (2.25-3.50%), fat (2.51-5.75%), and lactose (3.36-5.23%) content. Jalingo consistently demonstrated higher nutrient levels, while Bali exhibited the lowest values. Statistically significant variations were observed across locations for multiple parameters. Pasteurization and overnight storage marginally impacted milk composition, with fat and protein content remaining relatively stable across locations.

6.2 Conclusions

Based on the results obtained it can be concluded that:

1. The informal dairy sector in Taraba State faces significant challenges in maintaining milk quality and safety standards.
2. Current milk handling and processing practices among smallholder farmers contribute to bacterial contamination.
3. Pasteurization effectively improves milk quality parameters but is not consistently practiced.
4. Nutritional composition of milk varies significantly based on location and handling conditions.

6.3 Recommendations

Based on the results obtained the following recommendations are made:

1. Technical Improvements:

   i. Implement comprehensive training of trainers hygiene programs for dairy farmers who will go into hinter lands for training of livestock farmers on milk hygiene protocols, as the need for personal animal and animal products hygiene cannot be over emphasized

   ii. The establishment of milk collection centers (MCC) and Bulk milk collection centers (BMCC) in the various LGS and zones with solar powered cooling systems will go a long way in enhancing milk harvesting processing and preservation, this will not only improve the plane of nutrition of the individuals but will also boost the state and nation's GDP

   iii. The training and adoption of modern milk processing and preservation techniques for small holder households will reduce postharvest losses in milk at household level, reduce milk contamination and increase total yield per annum

iv. Develop standard operating procedures for milk handling and processing

2. Institutional Support:

   i. Strengthen extension services focusing on dairy production and shelf life to minise post-harvest losses in the dairy sector
   ii. Facilitate formation of dairy farmer cooperatives
   iii. Production of farmer guide manual booklets for distribution by extension agents and farmers
   iv. Improving access to credit facilities for dairy farmers both from the government and NGOs in the formal and informal sector
   v. Establish quality control mechanisms for milk and milk products

3. Infrastructure Development:

   i. Improve rural road networks to facilitate milk transportation
   ii. Develop solar powered cold chain facilities in major milk-producing areas
   iii. Establish modern milk processing facilities
   iv. Create dedicated marketplaces for dairy products

4. Capacity Building:

   i. Provide training on modern dairy farming practices
   ii. Educate farmers on proper animal health management
   iii. Organize workshops for step down of trainings to farmers on milk hygiene and quality control
   iv. Develop entrepreneurship skills among dairy farmers

5. Policy Interventions:

i. Develop specific policies supporting smallholder dairy development

ii. Create regulatory framework for milk quality standards

iii. Establish price support mechanisms for dairy products

iv. Provide incentives for dairy sector modernization

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APPENDIX

DAIRY BASELINE STUDY QUESTIONNAIRE

(Target Respondents: Members of Milk Producers)

MODULES:
Module A: General Information

Module B: Household Characteristics, Availability and Use of Labour

Module C: Socio-economic Parameters

Module D: Production

Module E: Milk Production

Module F: Marketing of Milk and Milk Products

Module G: Animal Nutrition, Health, Housing and Management

Module H: Extension & Credit

A. GENERAL INFORMATION

1. Date of Interview _____________ (Day/Month/Year.
2. Questionnaire no. _____________
4. Name of Farmer __________________
5. Age of farmer ________ (Years)
6. Village _______________________
7. District ________________________
8. LGA _________________
9. Is respondent head of household? ______ (Y/N)
10. Sex: ________
11. Education: 1 = No formal 2 = Koranic 3. = Primary 4 = Secondary 5 = Tertiary
11. Number of Wives _____ Number of children ___ Number of dependants ___________
12. Do you belong to any farmers' organization e.g. co-operative society, dairy development association? ________ (Y/N)
13. For how long? ____________ (years)
14. List benefits derived

____

____

B HOUSEHOLD CHARACTERISTICS, AVAILABILITY AND USE OF LABOUR

15. Type of household (encircle as applicable):
    (1) Male head (monogamous),
    (2) Male headed (polygamous),
    (3) Female headed (husband absent),

(4) Female headed (widowed),
(5) Female headed (divorced),
(6) Female headed (single),
(7) male headed (single),
(8) male headed (divorced),
(9) male headed (widowed).

16. Demographics of households

a) Number of household members ____________________

b) Distribution of household members by age groups

Age group	Male	Female
≥60		
50 -59		
40 - 49		
30 - 39		
20-29		
10-19		
1-9		
≤1		

C. SOCIO-ECONOMIC PARAMETERS

17. How many of the following items does the respondent have?

Items	Number Owned
Radio	
Bicycle	
Motorcycle	
Vehicle	
Zinc House	
Others (Specify)	

18. Do you have access to the following amenities (circle appropriately)

Schools	Yes	No
Hospitals	Yes	No
Recreational centres	Yes	No
Electricity	Yes	No
Others (Specify)	Yes	No

D PRODUCTION

18. Classification of producers:

1 = Specialized dairy farmer (dairy is main source of income)
2 = Crop – Livestock farmer
3 = Small/landless dairy farmer (little or no crop land)

19. Dairy cattle (female) size and composition

Livestock type (No.)	Bunaji		Rahaji		Sokoto Gudali		Others	
	Dry	Milking	Dry	Milking	Dry	Milking	Dry	Milking
Cows								

20. Other classes of cattle owned

Type/	No.	Other Livestock species	No.
Bulls (3 years and above)		Sheep	
Heifers (1-3 years)		Goats	
Bulls (1-3)		Poultry	
Male calves		Camels	
Female calves (0-1 year)		Donkeys	
		Horses	

21. **Farm Characteristics**

FARM PLOT	SIZE (ha)	CURRENT STATUS (1=cropped, 0= fallow)	No. of years Fallow	Crop Grown (1=sorghum, 2= millet, 3=Maize, 4= Cowpea, 5= groundnuts 6= Others	Forage Grown (Specify)	Distance From home-stead (km)
A						
B						
C						
D						
E						
F						

E. MILK PRODUCTION

22. Seasons of Milk Production

	Wet Season		Dry Season	
	Lit/day	No. of wet/lactating cows	Lit/day	No. of wet cows
Bunaji				
Rahaji				
Sokoto Gudali				
Others (specify)				

23. Season for high calving rate (a) Dry season _____ (b) Rainy Season ________

24. On a typical day how long does each of these household members allocate to the following activities (hrs):

Household members	ACTIVITY						
	Herding/ grazing	Milking	Milk Processing	Milk Marketing	Supplementary Feeding	Cut & carry Feeding	Clearing of pens/holding placing
Household head							
Adult female							
Children 1<16 yrs							
Hired male labour							
Hired female labour							

25. Processing and Disposal of milk and milk products average per day/herd in each season

Item	**Product (kg)**	**Wet Season**	**Dry Season**
MILK	Total Produced		
	Total Consumed by family		
	Total sold as fresh		
	Others specify		
SOUR MILK	Total produced		
	Total consumed by family		
	Total sold		
SOFT CHEEESE	Total produced		
	Total consumed by family		
	Total sold		
YOGHURT	Total produced		
	Total consumed by family		
	Total sold		
BUTTER	Total produced		
	Total consumed by family		

	Total sold		
OTHER (Specify)	Total produced		
	Total consumed by family		
	Total sold		

F. MARKETING OF MILK AND MILK PRODUCTS

26. Who sales the milk and its products ___________________,

how often _______________

Where does he/she sale these _______________ and

how far is the place _______________Km

27. How far is the milk collection point from your homestead? _____________________ Km

Section for head of household if involved in marketing of dairy products.

28. Which of the following outlets do you use? (Multiple answers are acceptable). 1= farm gate, 2=collection point 3=urban/per-urban markets 4=other (Specify).

29. What influences your use of the above outlets? (Multiple answers allowed).

Outlet	Reasons for choice of outlet						
	Proximity	Immediate Cash payment	Cash payment in advance	Revenue goes to Head of Household directly	Revenue goes to Adult Females in household directly	Offer better prices	Steady market
Farm gate							
Collection point							
Urban/Peri Urban (UPU) market							
Other (specify)							

30. Price of milk per litre (N) dry season__________ Wet season_________________

31. What do you use the revenue from milk sales for _____________________

32. Who does the milking _______________and what does he/she uses in milking ______________

33. What do you use in processing the milk __________________________

34. What are the main problem in the following areas concerning the marketing of dairy products? Please specify the product for which the problem is mentioned.

Type of problem	Product Associated with the problem

G. ANIMAL NUTRITION, HEALTH, HOUSING AND MANAGEMENT

Housing and Management

35. Where do you keep your dairy animals at night? 0= outside without protection, 1=in a coral, 2=in a barn, 3=in a stable made from wood and other local materials, 4=in a "modern, stable, 5=in the living room with the household.

36. Do you keep your dairy cattle and other livestock together? ________ (Y/N)

37. If yes are your dairy cows on zero grazing? _________________ Y/N.

38. Within your dairy herd, do you also separate dry from milking animals? _________ (Y/N)

39. How many times a day do you water your milking cows:

in the dry season? _______________

in the rainy season? ______________

40. Distance of source of water for dairy animals ____________ (km).

41. Feeding: Do you give supplementary feeds to your animals during?

i) Dry Season ________ ii) Raining Season ___________ if yes how often during

i) Dry Season ________ ii) Raining Season ___________

42. **Feeding:** Expenditure on Supplementary feeds

Feed type		Quantity purchased during the last rainy season	Cost of feed during the last rainy season	Quantity purchased during the last rainy season	Cost of feed during the last rainy season
Agro-Industry By-product	Cotton seed cake				
	Groundnut seed				
	Cotton seed				
	Cereal bran				
	Dry brewer's grains				
	Wet brewer's grains				
	Molasses				
Crop residues	Cereal straw and stovers				
	Groundnut hay				
	Cowpea hay				
Grains					
Minerals and Supplements					
Salt					
Other (specify)					

43. **Animal Health:** Important animal health problems and expenditure on veterinary drugs and treatment (Please the diseases in descending order of importance i.e 1=most important).

Health problem	Number of dairy Animals affected	Ranking of disease	Expenditure on drugs	Payment for treatment
Trypanosomiasis				
Helminthiasis				
Ticks and other Ectoparasites				
Respiratory/Pneumonia				
Diarrhoea				
Mastitis				
Skin problems				
Reproductive problems				
Foot rot/feet problems				

44. Number of Calves that died during: (a) Dry season________ (b) Rainy season __________

45. Number of Adult cows that died:

(a) Dry season___________

(b) Rainy season __________

H. EXTENSION & CREDIT

Extension

46. Do you have access to livestock extension services? _____________ (Y/N)

47. Who provides extension services here?

    a) Government,

    b) NGO,

    c) Other (specify)

48. How many times did you get their services last year from sources listed above?

    a) Government _________

    b) NGO __________

    c) Other sources __________

49. Are these advises you received beneficial to your needs? Grade using the following grades:

    1 = poor

    2 = fair

    3 = good

50. **Access to Credit facilities:**

Have you taken any credit for purpose of financing your dairy activities within the last 12 months?

a) Yes
b) No

If, Yes, give the Amount of credit received last year for your dairy enterprise.

Source	For Production	For Processing	For Marketing
Formal			
Informal			
Co-op society			
Relatives/friends			
NGO			
Other (specify)			

COW – CALF PRODUCTIVITY DATA SHEET (TDS IA)

Background Information on Cow Reproductive Performance

NAME OF ENUMERATOR ………………………………

DATE ....

NAME OF FARMER ………………………….. ASSOCIATION ………………………….

VILLAGE ………………… AREA COUNCIL ………………………….

LACTATING COWS PROFILE	1	2	3	4	5	6	7	8	9	10
Age of Cow (months)										
Age at first calving (month)										
No. of calving to date										
Date of first calving										
Date of last calving										
Qty of milk supplied/milking: Dry season (lit)										
Qty of milk supplied/milking: Raining season (lit)										
Disease										
When first noticed (date)										
When first treated (date)										
Treated by (F, LH, VA, DVM)										
Type of drug (eg. Antibiotic, dewormer, local herb)										
Source of drug										
Cost of treatment (N)										
Health Status cow (W, NIM, IMP, REC) **										
Health Status of Calves										

* F = Farmer, LH = Local Herbalist, VA = Vet. Assistant, DVM = Vet. Surgeon ** W = Worse, NIM = Not Improving, IMP = Improving, REC = Recovered