KNOWLEDGE, ATTITUDES, AND PRACTICES OF DAIRY FARM PERSONNEL IN KWAZULU-NATAL: UNPACKING MILK QUALITY, HYGIENE PRACTICES AND MILK PRODUCTION

By

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PREFACE

The research contained in this dissertation was completed by the candidate while based in the Discipline of Agricultural Science, Sub-discipline of Animal Science, School of Agriculture and Science, of the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Pietermaritzburg Campus, South Africa. This research was conducted between May 2024 and December 2025. The dissertation contains different chapters in manuscript style; hence, there might be some repetition. This work has not been submitted in any form to another university, and the findings provided are the result of the research, with the exception of instances in which the work of others is acknowledged in the text. This research was supervised by DR Ntuthuko Raphael Mkhize and co-supervised by DR Lelethu Mdoda.

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Date: 24/06/2026

DECLARATION

I, Mduduzi Base present a formal declaration that:

- This dissertation and its findings are originally my own work, except as stated otherwise with acknowledgement.
- The present dissertation has not undergone submission of any form for university degree examination.
- The images, data, graphs, or any other type of information presentation in this dissertation are originally of my work, and will be acknowledged if otherwise.
- The writings of this dissertation are originally my work, unless stated otherwise with acknowledgements. Information quoted and re-written will be attributed to the source with references.
- Quotation marks with references are used where wording of the source has been used
- Where there is any form of publication, my involvement is noted.
- Any material of this dissertation presented at conferences and journals for publication is my contribution.
- Any graphic information used directly as sourced will be acknowledged in references.

ABSTRACT

The dairy sector is shown to have great importance in rural livelihoods and the economy in South Africa. However, maintaining high levels of milk quality, productivity, and profitability remains a challenge due to factors related to milk hygiene management, farm personnel competencies, and biological determinants of milk production. This study evaluated the knowledge, attitudes, and practices (KAP) of dairy farm personnel on milk hygiene, assessed the economic feasibility of implementing milk quality and hygiene interventions, and investigated the effects of parity and lactation phase on milk yield and composition in dairy cows in KwaZulu-Natal (KZN). Data were collected through structured questionnaires administered to dairy farm personnel and dairy farmers, as well as production and milk composition records obtained from cows participating in the Agricultural Research Council's National Milk Recording and Improvement Scheme. Descriptive statistics, Tobit regression analysis, cost-benefit analysis, and appropriate statistical procedures were used to analyse the data. The results showed that dairy farm personnel generally possessed adequate knowledge and positive attitudes toward milk hygiene, with high awareness of somatic cell count, total bacterial count, and mastitis management. However, gaps were identified in the implementation of hygiene practices, particularly regarding formal training, record-keeping, and structured herd management. Education, household income, access to extension services, age, farming experience, and farmer organisation membership significantly influenced KAP outcomes. Economic analysis revealed that dairy farming was financially viable, with an average Benefit-Cost Ratio (BCR) of 3.92 and a Return on Investment (ROI) of 292.18%, although profitability varied considerably among farms due to differences in management efficiency, hygiene practices, and resource utilisation. Furthermore, parity and lactation phase significantly influenced milk yield and composition traits. Milk yield was highest during early to mid-lactation and among cows in their second and third parities, while milk fat and protein increased during late lactation. Lactose content declined with advancing lactation, whereas somatic cell count increased in late lactation and older cows. The findings demonstrate that milk quality and dairy farm profitability are influenced by a combination of human, economic, and biological factors. Strengthening farmer training, improving access to extension services, promoting effective hygiene management, and considering parity and lactation-stage effects in herd management strategies can enhance milk quality, productivity, and the long-term sustainability of dairy farming systems in KZN.

Keywords: dairy farming, milk hygiene, knowledge-attitudes-practices, cost-benefit analysis, milk quality, somatic cell count, parity, lactation stage, milk composition

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TABLE OF CONTENTS

PREFACE ..... **i**
DECLARATION ..... **ii**
ABSTRACT ..... **iii**
ACKNOWLEDGMENTS ..... **iv**
TABLE OF CONTENTS ..... **v**
LIST OF TABLES ..... **ix**
LIST OF FIGURES ..... **x**
LIST OF ACRONYMS ..... **i**
CHAPTER 1: **1**
Introduction **1**
1.1 Background of the study 1
1.2 Problem statement 4
1.3 Justification 5
1.4 Objectives 7
1.5 Outline of dissertation 7
References 9
CHAPTER 2: **14**
Literature review **14**
2.1 Introduction of the chapter 14
2.2 Overview of the South African dairy industry 15
2.3 The dairy industry in KwaZulu-Natal 15
2.4 Dairy farm profitability 16
2.5 Importance of milk quality and production efficiency 18
2.6 Milk composition 19
2.6.1 Definition and Components of Milk Composition 19
2.6.2 Protein 20
2.6.3 Fat 21
2.6.4 Lactose 21
2.6.5 Somatic Cell Count 21
2.7 Factors affecting milk composition and yield 22
2.7.1 Breed 23
2.7.2 Season 23

2.7.3 Lactation Phases 23
2.7.4 Parity 24
2.8 Hygiene and its role in maintaining milk quality 25
2.9 Knowledge of dairy farm personnel 26
2.9.1 Knowledge of hygiene practices in milk production 26
2.9.2 Socioeconomic and Cultural Factors Influencing hygiene 27
2.10 Attitudes of dairy farm personnel 27
2.10.1 Perceptions toward milk quality and composition 27
2.10.2 Attitudes Toward Hygiene and Milking Practices 28
2.11 Link between milk composition, SCC, and dairy farm management 29
2.12 Barriers to improving milk quality and hygiene 31
2.12.1 Resource and Infrastructure Limitations 31
2.13 Strategies to enhance knowledge, attitudes, and practices 32
2.13.1 Training and Capacity-Building Initiatives 32
2.13.2 Extension and Advisory Services 33
2.14 Conclusion 34
References 36

CHAPTER 3: 60

Evaluating the determinants of knowledge, attitudes, and practices of dairy farm personnel 60

3.1 Abstract 60
3.2 Introduction 61
3.3 Theoretical framework 64
3.4 Materials and Methods 66
3.4.1 Study Site 66
3.4.2 Sampling 66
3.4.3 Data Collection 68
3.4.4 Data Analysis 69
3.4.5 Descriptive Statistics 69
3.4.6 Tobit Regression Model 71
3.4.7 Description of Variables 72
3.5 Results and Discussion 74
3.5.1 Socio-demographic profile 74

3.5.2 Percentage distribution of dairy farm personnel's Knowledge, Attitudes, and Practices (KAP) on milk hygiene in KwaZulu-Natal Province....76
3.5.3 Determinants of knowledge of milk hygiene practices....79
3.5.4 Determinants of attitudes toward milk hygiene practices....82
3.5.5 Determinants of practices of milk hygiene....86
3.6 Conclusion and recommendations....90
References....92

CHAPTER 4:....120

Assessing the economic feasibility and potential benefits of implementing interventions to improve milk quality and hygiene....120

Abstract....120
4.1 Introduction....121
4.2 Theoretical framework....123
4.3 Methods and Materials....125
4.3.1 Study site....125
4.3.2 Sampling....125
4.3.3 Data collection....127
4.3.4 Data Analysis....128
4.3.5 Cost-Benefit Analysis....128
4.3.6 Description of Variables....130
4.4 Results and discussion....132
4.4.1 Socio-Demographic Characteristics of Dairy Farmers....132
4.4.2 Dairy Production System Characteristics....134
4.4.3 Cost Structure of Dairy Production....135
4.4.4 Revenue and Benefit Structure....137
4.4.5 Cost-Benefit Analysis Results....138
4.5 Conclusion and recommendations....140
References....142

CHAPTER 5:....150

Effect of parity and lactation phases on milk composition and yield in dairy cows in KwaZulu-Natal....150

5.1 Abstract....150
5.2 Introduction....151
5.3 Materials and Methods....153

5.3.1 Study site 153
5.3.2 Sampling procedure 153
5.3.3 Data collection 153
5.3.4 Data editing 154
5.3.5 Statistical Analysis 155
5.4 Results and Discussion 156
5.5 Conclusion and recommendations 162
References 164

CHAPTER 6: 171
Conclusion and recommendations 171
6.1 Introduction 171
6.2 Summary 171
6.3 Conclusion 172
6.4 Recommendations 173
6.5 Limitations of the study 173
6.6 Future areas of research 174

APPENDICES 175
Appendix A: Questionnaire 175
Appendix B: Ethical Clearance Certificate 185
Appendix C: Gatekeeper's letter 186
Appendix D: Informed Consent letter 187
Appendix E: Turnitin Report 190

LIST OF TABLES

Table 2.1 The number of producers of milk per province in 2024. 15

Table 3.1 Assessment of the Knowledge, Attitudes and Practices of dairy farm personnel on milk quality. 70

Table 3.2 Variables for analysing dairy farm personnel's KAPs on milk quality and hygiene. 73

Table 3.3 Descriptive Statistics of Demographic and Socio-Economic Characteristics 75

Table 3.4 Percentage distribution of dairy farm personnel's knowledge of milk hygiene in KwaZulu-Natal Province, South Africa 76

Table 3.5 Percentage distribution of dairy farm personnel's attitudes toward milk hygiene in KwaZulu-Natal Province, South Africa 78

Table 3.6 Percentage distribution of dairy farm personnel's milk hygiene practices in KwaZulu-Natal Province, South Africa. 79

Table 3.7 Tobit Regression Results - Determinants of Knowledge 80

Table 3.8 Tobit Regression Results - Determinants of Attitudes 83

Table 3.9 Tobit Regression Results - Determinants of Practices 87

Table 4.1 Variables for analysing dairy farmers' economic feasibility for targeted interventions 130

Table 4.2 Socio-demographic profile of respondents 132

Table 4.3 Production system characteristics 134

Table 4.4 Monthly cost structure 137

Table 4.5 Monthly dairy revenue components 138

Table 4.6 Economic feasibility indicators 139

Table 5.1 Effect of parity on of milk fat, protein, lactose and SCC. 156

Table 5.2 Effect of lactation phases on milk fat, protein, lactose and SCC 159

LIST OF FIGURES

Figure 2.1 The decline of the number of dairy producers in KwaZulu-Natal 16

Figure 2.2 Composition of milk in percentage 20

Figure 2.3 Schematic diagram of the flow of factors affecting milk Composition and profitability. 30

Figure 5.1 Effect of parity and lactation phases on milk yield.. 161

LIST OF ACRONYMS

ANOVA:	Analysis of Variance
ARC:	Agricultural Research Council
BCR:	Benefit-Cost Ratio
CBA:	Cost-Benefit Analysis
DAFF:	Department of Agriculture, Fisheries and Forestry
FAO:	Food and Agriculture Organisation
FMD:	Foot and Mouth Disease
GDP:	Global Dairy Platform
GDP:	Gross Domestic Product
IFCN:	The International Farm Comparison Network
INTERGIS:	Registration and Genetic Information System
KAP:	Knowledge-Attitudes and Practices
KZN:	KwaZulu-Natal
NAMC:	National Agricultural Marketing Council
NMRIS:	National Milk Recording and Improvement Scheme
ROI:	Return on Investment
SAA:	Sub-Saharan Africa
SCC:	Somatic Cell Count
SPSS:	Statistical Package for the Social Sciences
STATS SA:	Statistics South Africa
USDA:	United States Department of Agriculture
WPR:	World Population Review

CHAPTER 1:

Introduction

1.1 Background of the study

Globally, agriculture is a vital component of employment, nutrition, and the economy as a whole. In Africa, agriculture shows its contribution through supporting livelihoods and stimulating economic growth. According to the Food and Agriculture Organisation of the United Nations (OECD/FAO, 2025), the value of Africa's agricultural industry increased from approximately ZAR 2.7 trillion in 2000 to ZAR 7.4 trillion in 2023, representing a growth of 169% over the period. This substantial expansion reflects the sector's growing contribution to economic development and poverty alleviation (Merem et al., 2022). In South Africa, agriculture is a strategic sector of the economy, contributing approximately ZAR 222 billion in 2024 and creating more than 25 000 jobs between 2023 and 2024 (National Agricultural Marketing Council [NAMC], 2025; Statistics South Africa [Stats SA], 2025). These contributions highlight the importance of agricultural industries in supporting economic growth, employment creation, and sustainable livelihoods.

Among the various agricultural industries, the contribution of dairy farming cannot be overstated. The role of both commercial and emerging farming enterprises makes it South Africa’s fourth-largest sector in agriculture (United States Department of Agriculture [USDA], 2025). South Africa maintains approximately 1.2 million dairy cows, with an average herd size of 435 cows per farm, making it the country with the second-largest average dairy herd size globally (Milk SA, 2022). The industry provides employment for approximately 65,000 people and supports numerous households through direct and indirect economic activities (Department of Agriculture, Forestry, and Fisheries [DAFF], 2023). Consequently, the dairy sector contributes substantially to food security, rural development, and national economic growth (Banda et al., 2021).

The South African dairy industry comprises diverse production systems, including commercial, smallholder, and subsistence farming operations. Commercial dairy farms utilise advanced technologies and intensive management practices to maximise productivity and efficiency, contributing approximately 2.8 billion litres of milk annually from a national production of 3.3 billion litres (Milk SA, 2024). In contrast, smallholder and emerging dairy farms often operate under resource-constrained conditions characterised by limited access to capital, technology, extension services, and formal markets (Fan and Rue, 2020). These challenges frequently result

in lower productivity and reduced competitiveness. Nevertheless, emerging dairy farms remain important contributors to rural livelihoods and local economic development, particularly in provinces such as KwaZulu-Natal.

The primary product of dairy farming is milk, which serves nutrients important for humans (Ahmed et al., 2020). Therefore, it is the responsibility of the dairy farmers to ensure that the milk produced meets the standards for consumer safety. Milk produced is dependent on factors such as animal health, environmental conditions, and farm practices (Nyokabi et al., 2021). These factors can result in microbial contamination, reduced milk quality, and increased risks to consumer health (Ahmedsham et al., 2018). Consequently, maintaining high standards of hygiene throughout the milk production chain is a critical requirement for sustainable dairy production. The responsibility for implementing these hygiene standards largely rests with dairy farm personnel. Farm personnel perform essential activities related to milk production, including animal management, milking, milk handling, cleaning of equipment, and milk storage (Nyokabi et al., 2021). The standard of milk produced on dairy farms are influenced by their daily management procedures, attitudes toward adhering to prescribed standards, and awareness of milk the standard of hygiene concepts. Effective knowledge enables personnel to identify contamination risks and implement appropriate preventive measures, while positive attitudes promote adherence to hygiene protocols and quality standards (Castellini et al., 2023). Conversely, inadequate knowledge, poor attitudes, and inappropriate practices may contribute to increased contamination, elevated somatic cell counts, reduced milk quality, and economic losses to farmers (Henchion et al., 2022). Despite the recognised importance of farm personnel in maintaining milk quality, studies indicate that significant knowledge and practice gaps persist, particularly among smallholder and emerging dairy farming systems in Africa (Chilambula, 2025).

In addition to farm management practices, the biological state of the animal determines the milk quality and production performance. Milk composition is commonly evaluated using parameters such as milk fat, protein, lactose, and somatic cell count (SCC), which are indicators of nutritional value, udder health, and overall milk quality (Olatoye et al., 2018). These parameters are influenced by several factors, including genetics, nutrition, environmental conditions, disease status, parity, and stage of lactation (Kaskous, 2021). Parity refers to the number of times a cow has calved and is known to influence milk production efficiency and milk composition due to physiological changes associated with age and mammary gland development. Similarly, milk yield and composition vary throughout the lactation cycle,

reflecting changes in metabolic and hormonal activity. Understanding the influence of parity and lactation stage on milk yield and composition is therefore essential for optimising herd management practices and improving production efficiency within emerging dairy systems.

Indicators for the quality assessment of milk also include SCC. Elevated SCC levels are often associated with mastitis, which has a significant economic impact on the global dairy business (Ruegg and Wolfe, 2018). Mastitis contributes to altered milk composition and yield, thereby creating a direct link between farm personnel practices, animal health, and milk quality outcomes. Therefore, improving farm personnel knowledge and hygiene practices may contribute significantly to reducing SCC levels and improving milk quality. The implications of milk quality extend beyond animal health and food safety to include farm profitability and economic sustainability. Poor-quality milk often results in reduced market value, milk rejection, lower quality premiums, increased veterinary expenses, and production losses associated with disease and reduced productivity (Ruegg and Wolfe, 2018). Conversely, investments in training, hygiene management, mastitis prevention, and milk quality monitoring can improve production efficiency and economic performance. However, implementing such interventions requires financial investment, making it important to evaluate whether the expected benefits justify the associated costs.

Every province in South Africa produces milk, but KwaZulu-Natal is one of the most significant (Xulu and Naidoo, 2023). However, issues with milk quality, production efficiency, and farm management techniques still impair KZN province's emerging dairy producers. Obstacles in the KAPs of dairy farm personnel have been found in earlier research, which may have a detrimental impact on milk quality and hygienic standards (Nyokabi et al., 2021). Additionally, little is known about how parity and lactation phase affect milk composition and yield in newly established dairy herds in the province. Furthermore, the economic viability and possible advantages of interventions aimed at enhancing milk quality and hygiene have not received much attention. In order to better understand the effects of parity and lactation phases on milk composition and milk yield in emerging dairy herds, as well as the possible advantages and economic viability of implementing interventions to improve milk quality and hygiene, this study will evaluate the KAPs of dairy farm personnel in KZN. It is expected that the results of this study would offer evidence-based suggestions for raising production efficiency, strengthening the economic viability of new dairy farming businesses in KZN, and improving milk quality.

1.2 Problem statement

Achieving and maintaining acceptable standards of milk quality and hygiene remains a persistent challenge, particularly within emerging dairy farming systems. The production of high-quality milk depends largely on the effectiveness of farm management practices, which are implemented primarily by dairy farm personnel. These personnel are responsible for critical activities, including milking, milk handling, equipment sanitation, animal health monitoring, and disease management (Ahmed et al., 2020; Nyokabi et al., 2021). Consequently, deficiencies in KAP related to milk hygiene and quality management can increase the risk of microbial contamination, elevate SCC, compromise milk quality, and reduce farm productivity and profitability (Kumssa, 2018).

Although previous studies have identified deficits in the KAP of African dairy farm personnel and other developing regions, existing research has largely focused on describing hygiene behaviours and management practices without adequately examining their implications for milk quality and production outcomes (Nyokabi et al., 2021; Sewunet et al., 2024; Chilambula, 2025). In KZN, where dairy farming contributes significantly to rural livelihoods and agricultural development, limited information exists regarding the current status of dairy farm personnel KAP and its influence on milk quality indicators (Mahlobo, 2016; Xulu and Naidoo, 2023). This knowledge gap restricts the development of targeted interventions capable of improving milk quality and production efficiency within emerging dairy farming systems.

Beyond management-related factors, milk quality and productivity are also influenced by biological characteristics of the dairy cow (Antanaitis et al., 2021). Milk parameters are known to vary according to parity and stage of lactation due to physiological and metabolic changes occurring throughout the production cycle (Sokoliuk et al., 2022; Aleli, 2024). Despite the importance of these factors, there remains limited empirical evidence on how parity and lactation phases influence milk composition and yield in emerging dairy herds under the environmental and management conditions of KZN. Most available studies have been conducted in commercial production systems or in countries with different production environments, limiting their applicability to emerging dairy farmers within the province (Chisowa, 2023; Washaya and Cheruwa, 2025). Consequently, producers, extension practitioners, and policymakers lack locally relevant information required to optimise herd management strategies and improve milk quality and productivity.

The challenges associated with milk quality and productivity also have important economic implications (Azooz et al., 2020; Fiorillo and Amico, 2024). Emerging dairy farmers continue to operate under conditions characterised by low production efficiency, inconsistent milk quality, rising production costs, limited access to quality inputs, and restricted market opportunities (Reinecke et al., 2024). To address these constraints, interventions such as improved hygiene practices, personnel training, enhanced disease control measures, and better management systems have frequently been recommended (Berge and Baars, 2020; Nyokabi et al., 2021; Ahmed et al., 2022). However, while the technical benefits of such interventions are widely acknowledged, little evidence exists regarding their economic feasibility and potential returns within emerging dairy farming systems in KZN (Xulu and Naidoo, 2023; Masha et al., 2026). Specifically, there is limited understanding of whether improvements in milk quality and productivity generate sufficient economic benefits to justify the costs associated with implementing these interventions.

Therefore, this study seeks to: (1) assess the current KAPs of dairy farm personnel in KZN; (2) evaluate the effects of parity and lactation phases on milk composition and milk yield in emerging dairy herds; and (3) assess the economic feasibility and potential benefits of interventions aimed at improving milk quality and hygiene.

1.3 Justification

There are still a lot of unanswered questions on how dairy farm workers' KAPs affect milk quality and cleanliness outcomes in KZN, despite the significance of factors impacting milk production. In order to improve farm management practices, lower the risk of milk contamination, and raise milk quality standards, it is necessary to produce evidence that can assist the creation of focused interventions (Xulu and Naidoo, 2023). This study's contribution is its evaluation of dairy farm personnel' knowledge, attitudes, and practices regarding milk quality and hygiene. Workers on dairy farms are directly in charge of tasks including milking, handling animals, cleaning equipment, and storing milk, they all have a direct impact on milk and consumer safety (Nyokabi et al., 2021). The creation of training programs, extension services, and dairy management methods will benefit greatly from an evaluation of gaps in personnel knowledge and management practices (Rovai et al., 2016). This is especially crucial in KwaZulu-Natal, where inadequate hygiene practices have been linked to lower farm output, higher illness prevalence, and poor milk quality (Xulu and Naidoo, 2023). The study has the potential to increase milk quality, boost customer trust in dairy goods, and improve the general profitability of dairy businesses by filling up these gaps (Popescu and Angel, 2019).

This study's examination of how parity and lactation phases affect milk composition and output in developing dairy herds is its second contribution. Important indicators of milk quality, udder health, and production performance include fat, protein, lactose, and SCC (Mukasafari et al., 2025). There is little data on dairy production systems in sub-Saharan Africa (SSA) and KZN, despite the fact that these parameters are known to differ among parity groups and lactation stages (Paraffin et al., 2018; Xulu and Naidoo, 2023). Most earlier studies have been conducted in commercial dairy enterprises abroad or in production environments that are very different from those encountered by emerging farmers (Elhassan et al., 2015; Yu et al., 2022; Chisowa, 2023). Because of this, management choices in developing dairy herds are frequently centred on general knowledge that might not accurately reflect regional circumstances (Niles et al., 2019). In emerging dairy farming systems, better herd management, more informed breeding and culling decisions, and increased productivity will result from producing locally relevant knowledge on the relationship between parity, lactation stage, milk composition, and milk yield.

The third contribution of this study is its assessment of the economic feasibility and potential benefits of interventions aimed at improving milk quality and hygiene. While previous studies have demonstrated the technical benefits of improved hygiene practices and milk quality management (Habtamu et al., 2018; Nyokabi et al., 2021), limited attention has been given to the economic implications of implementing such interventions. This creates uncertainty regarding whether the costs associated with training, improved hygiene protocols, disease prevention measures, and milk quality monitoring are justified by the resulting improvements in milk quality, productivity, and farm income. By applying an economic evaluation framework, this study provides evidence on the costs and benefits associated with improving milk quality and hygiene, thereby supporting informed decision-making by farmers, extension practitioners, industry stakeholders, and policymakers.

Collectively, this study is significant because it integrates human, biological, and economic dimensions of dairy production within a single analytical framework. Unlike previous studies that have focused primarily on farm personnel perceptions or technical production factors in isolation (Paraffin et al., 2018), this research examines how management practices influence milk quality, evaluates biological determinants of milk composition and yield, and assesses the economic viability of improvement strategies. This integrated approach will provide a more comprehensive understanding of the factors affecting dairy farm performance and sustainability in KZN. The findings of this study contribute to scientific knowledge, improve

dairy management practices, inform extension and training programmes, and support evidence-based policy development. Furthermore, the results assist dairy farmers in making informed management and investment decisions that enhance milk quality, increase productivity, improve profitability, and strengthen the long-term sustainability of the dairy sector in KZN and similar production environments.

1.4 Objectives

The main objective of this study is to investigate the management, economic, and biological factors influencing milk quality and dairy production in KwaZulu-Natal, focusing on the knowledge, attitudes, and practices of dairy farm personnel, the economic feasibility of milk quality and hygiene interventions, and the effects of parity and lactation phase on milk composition and yield.

The specific objectives are as follows:

I. Evaluate the existing KAPs of dairy farm personnel.
II. Assess the economic feasibility and potential benefits of implementing interventions to improve milk quality and hygiene.
III. Evaluate the effects of parity and lactation phases on milk composition and milk yield in emerging dairy herds in KwaZulu-Natal.

The following hypotheses were formulated:

I. Dairy farm workers in KwaZulu-Natal do not possess adequate knowledge, attitudes and practices regarding milk quality and hygiene.
II. Interventions to improve milk quality and hygiene are economically feasible and result in large increases in farm profitability in KwaZulu-Natal.
III. Lactation stage and parity significantly influence milk composition and yield in dairy cows. Milk fat, protein, and SCC are expected to increase, while lactose and milk yield are expected to decrease as lactation progresses. Furthermore, parity is anticipated to affect milk composition and yield, with variations occurring across successive lactations.

1.5 Outline of dissertation

This dissertation is presented in seven chapters, with Chapters 3, 4, and 5 formatted as standalone research papers that directly address the study objectives.

This dissertation is presented in seven chapters, with Chapters 3, 4, and 5 structured as research papers that directly address the study objectives.

Chapter 1 entails the research problem, rationale, goals, hypotheses, theoretical framework, and basic dissertation structure, which also serves as the study's background and general introduction.

Chapter 2 presents a comprehensive review of the literature relating to dairy farm personnel's KAPs, milk quality and hygiene, factors influencing milk composition and yield, and the economic implications of interventions aimed at improving dairy farm performance.

Chapter 3, presented as the first standalone paper, evaluates the existing KAPs of dairy farm personnel in KZN.

Chapter 4, presented as the second standalone paper, assesses the economic feasibility and potential benefits of implementing interventions to improve milk quality and hygiene through a cost-benefit analysis framework.

Chapter 5, presented as the third standalone paper, investigates the effects of parity and lactation phases on milk composition parameters, including fat, protein, lactose, and SCC, as well as milk yield in emerging dairy herds in KZN.

Chapter 6 integrates and discusses the findings from the three research papers within the broader context of dairy production, milk quality management, productivity, and profitability.

Finally, Chapter 7 presents the overall conclusions and recommendations of the study, highlighting the implications of the findings for dairy farmers, extension practitioners, policymakers, and future research.

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CHAPTER 2:

Literature review

2.1 Introduction of the chapter

South Africa is home to about 12.1 million of the expected 1.6 billion cattle worldwide, according to the World Population Review (WPR, 2026). The large population demonstrates how important livestock farming is to world nutrition, especially in the dairy industry (Tona, 2021). A wide variety of production techniques, such as smallholder farms, communal farming, and large-scale commercial operations, define the dairy industry throughout the continent (Fariña et al., 2021). Africa has a sizable cattle population, but milk output per cow is still low by international standards because of issues like poor-quality feed, subpar veterinary care, and bad weather (Merem et al., 2022).

In South Africa, the production of milk is a significant component of the agricultural sector, making a substantial contribution to both economic growth and food security (Molomo, 2022). Refocusing economic sectors on job creation is imperative given the rising unemployment rate, especially among young people. Throughout its vast value chain, the dairy industry has been acknowledged as a major force behind the creation of jobs (Kyule and Nguli, 2020). Dairy farming, one of the biggest agricultural subsectors, contributes R25 million to the country's GDP, but its full potential to generate jobs is still underutilised (USDA, 2025). Strengthening the link between youth employment and the dairy industry is crucial for fostering economic development and reducing unemployment (Yeboah and Flynn, 2021). Milk production is a labour-intensive industry that provides various employment opportunities across several phases of the manufacturing process. One of the most common jobs created in the sector is that of farm labourers, who play a vital role in daily dairy operations (Bojovic and McGregor, 2023). Many of these workers enter the industry with little or no prior training, yet they perform essential tasks such as feeding animals, milking cows using machines or by hand, and monitoring the health and well-being of cattle for signs of illness or injury (Kyule and Nguli, 2020). Milk production is a labour-intensive industry that provides various employment opportunities across several phases of the manufacturing process (Kemitare et al., 2021). Producers are facing the challenge of meeting growing consumer needs while ensuring sustainability in the industry (Boland and Hill, 2020). Despite the rising demand for milk, small-scale dairy farmers, who make up the majority of global producers, often struggle due to weak market positions and vulnerability to economic fluctuations (USDA, 2025).

2.2 Overview of the South African dairy industry

There are about 882 registered dairy farmers in South Africa who produce milk, with an average herd size of 797 cows per dairy farm (Milk SA, 2024). Smaller-scale, up-and-coming dairy farms coexist with a well-developed commercial industry in South Africa (Mathinya et al., 2024).

Table 0.1 The number of producers of milk per province in 2024 (Milk SA, 2024).

Province	**2024**
Western Cape	299
Eastern Cape	164
Northern Cape	3
KwaZulu-Natal	182
Free State	91
North West	57
Gauteng	46
Mpumalanga	35
Limpopo	5
Total	**882**

Table 2.1 displays the distribution of South African producers by province. In terms of milk production, the Western Cape, KwaZulu-Natal, and Eastern Cape are the top three provinces in South Africa. However, the provinces' milk production has decreased over the last ten years. Mkhabela (2011) claims that the adoption of the "pasture-based" feeding approach is to blame for the decline in dairy farms. Coastal provinces prosper in this regard because of their ideal soils, mild temperatures, and sufficient rainfall, which promote the growth of high-quality pastures.

2.3 The dairy industry in KwaZulu-Natal

Many people are employed as farm workers, and milk production is a vital part of South Africa's agricultural economy (Diniso and Jaja, 2021). One of the most important dairy-

producing provinces in the nation, KwaZulu-Natal produces more than a million litres of milk per month, accounting for 25% of the nation's total milk production (Masha, 2025). Because of its soil, climate, and rainfall, the province of KZN is ideal for dairy production (Mahlobo, 2016). The high-altitude and coastal regions in the province have demonstrated the highest levels of dairy production activity (Mkhabela, 2011).

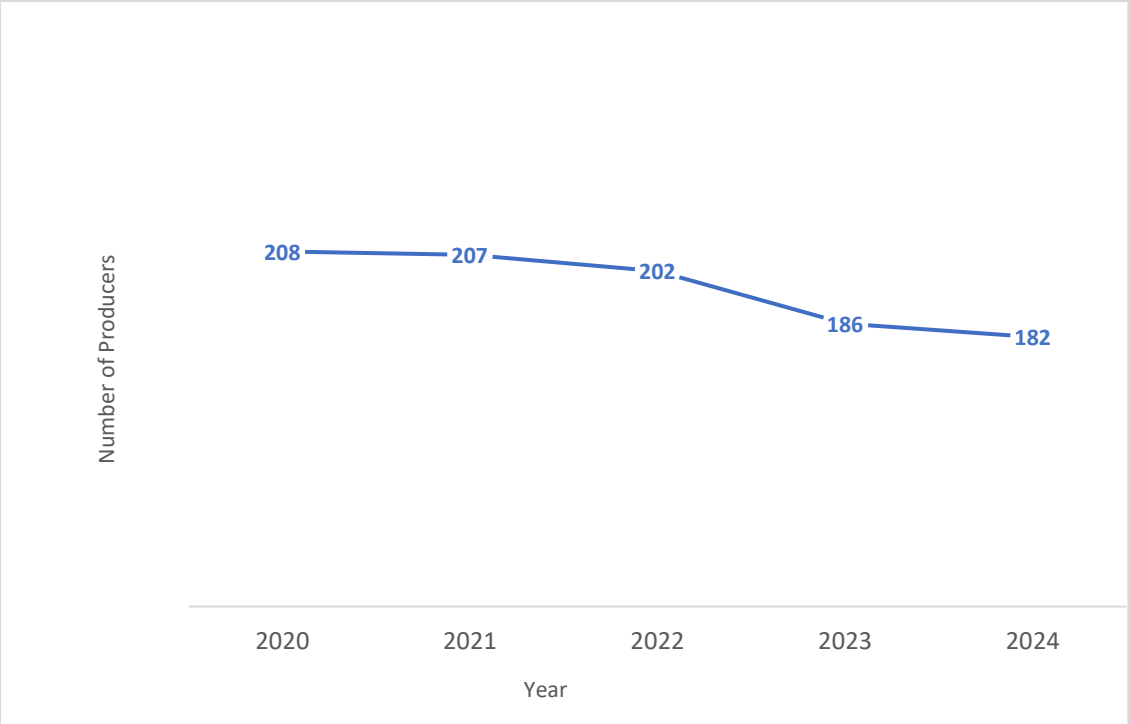

Figure 0.1 The decline of the number of dairy producers in KwaZulu-Natal, 2020-2024 (Milk SA, 2024)

Figure 2.1 demonstrates the decline in the number of dairy milk producers in KwaZulu-Natal throughout the years. In 2010, the KZN province had about 381 dairy milk producers. This number has been shown to decline over the years, with the number standing at 182 dairy milk producers in 2024 (Milk SA, 2024). Despite the decline being small, the consistency throughout the years is worthy of note. This shows a decline of over 50% in the previous 15 years.

2.4 Dairy farm profitability

Research has established the importance of farm profitability, with Atzori et al. (2013) and Bravo-Ureta et al. (2021) linking farm profitability to input-output efficiency, which shows

that profitability is not just a matter of cost value, but also the importance of how resources such as labour, infrastructure and feed are managed and converted into returns. Recent literature by Ragkos et al. (2021) and Sarinca et al. (2021) further emphasises the importance of farm input management as feed accounts for the largest portion of costs in dairy farming, followed by labour wages. The consistency of earlier and recent literature shows the importance of farm management and the distribution of costs in farm profitability.

A large part of the literature has identified farm size as the most impactful factors in farm profitability (Mareth et al., 2019; Náglová and Rudinskaya, 2021; Čobanović et al., 2021; Chetroiu et al., 2022), with findings concluding that farms of larger scale benefit the most due to the ability of higher production output, which enable them to invest in advanced infrastructure and modern automated technologies. This suggests a justification for the high labour costs in smaller dairy farms, where a large number of specialised labourers are required to adequately manage the milk production and farm-related practices. Furthermore, Baltenweck et al. (2025) further state that farmers receive penalties due to inadequate milk standards. This justifies the low income from smaller farms, which may be a result of poor labour practices. Studies have reported milk composition to have an impact on farm profitability, showing that milk with a high fat and protein content leads to higher profit margins (Hanrahan et al., 2018). Moreover, a recent study by Mitrosz et al. (2024) further supports this claim stating that farms with better milk composition and milk yield receive incentives. Furthermore, poor milk composition and low yields are associated with lower profitability. This further emphasises the importance of hygiene practices by dairy farmers to increase profitability.

International studies have highlighted a shift by dairy farms to larger scale, which is driven by access to the market (McDonald, 2014). However, Hassan (2019) argues that despite being small-scale, with an efficient management system, access to market and proper utilisation of available resources, smaller farms can achieve profitability. This suggests uncertainty about the effect of farm size on profitability but raises the importance of management in dairy production and profitability. In contrast, the impact of pastures grazing has been credited with profitability in dairy farming, with grazing length directly improving the quality and yield of milk, thus improving the profitability (Ramsbottom et al., 2015; Hanrahan et al., 2018). However, the use of additional feed for supplementation is negatively associated with profitability. This justifies the profitability of dairy farms with larger land size for pasture

grazing. This suggests that focusing on pasture grazing rather than supplemented feed would boost farm profitability by reducing feed costs.

In South Africa, studies have identified Feed, Veterinary costs, labour wages, electricity and fluctuating milk prices as factors that affect dairy farm profitability (Tanyanyiwa et al., 2017; Mokoena et al., 2023; Masha, 2025). The effect of electricity and fluctuating milk prices shows the geographical and economic differences that farmers in South Africa operate under in comparison to dairy farmers around the world. This suggests that the South African dairy industry is shaped around an economy-driven market with policy involvement.

2.5 Importance of milk quality and production efficiency

Milk quality can take various definitions; However, studies have attributed milk quality to define milk free from bacterial and microbial contamination while maintaining good milk composition (Martin et al., 2023; Baltenweck et al., 2025). On the other hand, some studies define milk from two perspectives, one being the farmer's perspective, involving bacterial contamination, and the other being consumer perspectives, which involve sensory assessment of the milk and dietary preferences (Castellini et al., 2023; Samad et al., 2024). Despite the differences in definitions, literature has established the importance of milk quality for farmers and consumers.

Milk quality is important for both farmers and consumers as the quality determines the profitability of the dairy farm, and also supplies important nutrients and minerals to the human diet (Popescu, A. and Angel, E., 2019; Rizzo et al., 2020). Studies emphasise the importance of quality monitoring by the government in countries to ensure consumer safety (Park et al., 2013; Ahmedsham et al., 2018). Consequently, dairy farmers have been put under immense pressure to make sure that milk produced is of an adequate standard to meet consumer needs (Habtamu et al., 2018; Luna-Guevara et al., 2019). This development is in a beneficial direction to consumer health and dairy farm sustainability as it ensures consumer safety but also urges farmers to produce quality milk, which enhances milk sales and profitability. However, in countries like South Africa, these regulations are not enforced as studies report inadequate milk production practices being employed by dairy farmers (Xulu and Naidoo, 2023).

Milk quality is often associated with management practices in the dairy farm, emphasising that production efficiency leads to better milk quality and increases economic outcomes (Kavithaa et al., 2020; Ferrazza et al., 2020; Nyokabi et al., 2021; Chilambula, 2025). The influence of production efficiency is further emphasised in literature (Pérez Urdiales et al., 2016; Hansen et

al., 2019), suggesting that training on the adoption of modern technology and the use of automated milking machines yields better milk quality; therefore, production efficiency is achieved. Earlier research discovered that increased milking frequency increases production efficiency (Wall and McFadden, 2008; Khanal et al., 2010). Current research has also emphasised feed efficiency, lengthy grazing periods, modern infrastructure and training initiatives for production efficiency (Craig et al., 2022; Hassen et al., 2022). However, production efficiency is often linked to larger investment costs, which puts smaller dairy farms at a disadvantage. Larger farms, therefore, benefit more in the market due to their ability to invest in modern infrastructure, thereby increasing milk sales. Given the limited availability of research on the country's regions, this raises concerns about the status of South African dairy farms and the possible advantages of making these investments.

2.6 Milk composition

2.6.1 Definition and Components of Milk Composition

Earlier studies defined milk quality according to sensory assessment, like taste, smell, colour, blood stains and SCC (Rasmussen, 2002; Sim et al., 2003). However, recent literature proves this claim to be outdated as they define milk according to its compositional characteristics, which include fat, protein, lactose and SCC (Lambrini et al., 2021; Jain et al., 2022). The value of milk composition is further highlighted by research since it affects the milk's capacity to be processed into dairy products (Achaw and Danso-Boateng, 2021; Martin et al., 2023). This shows the importance of the assessment of each compositional characteristic and its role in milk quality and human nutrition.

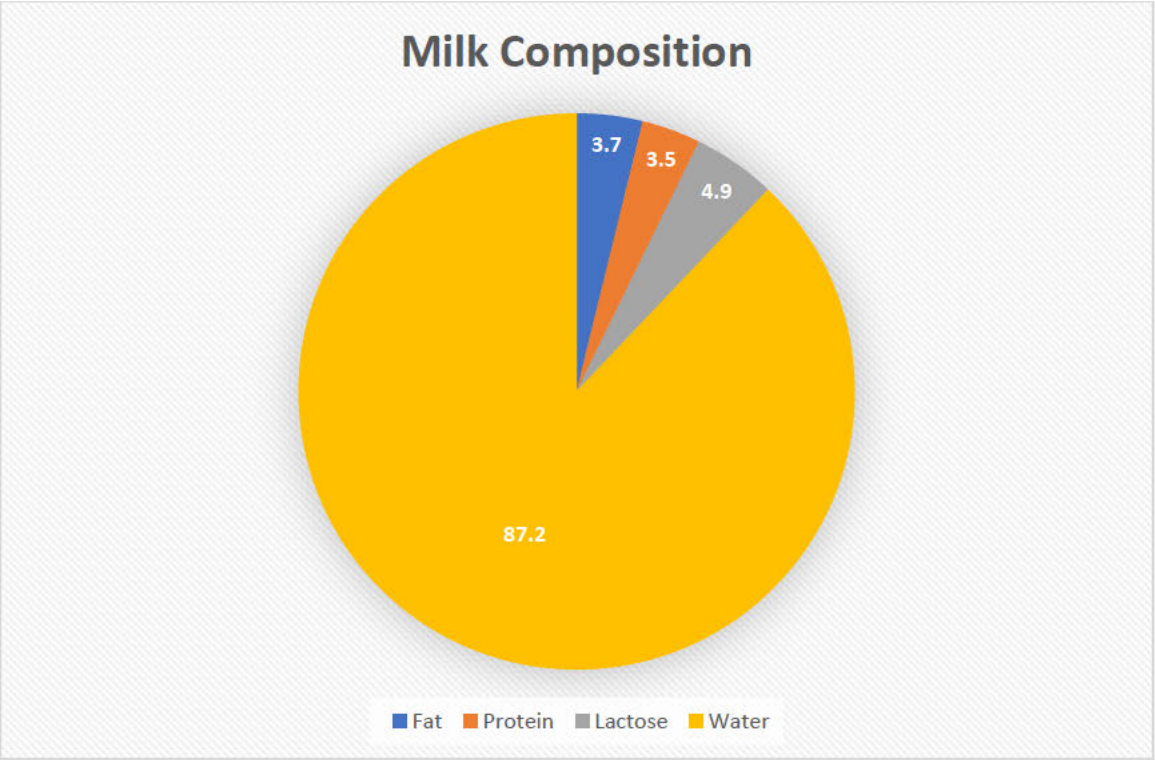

Figure 0.2 Composition of milk in percentage (Guetouache et al., 2014)

Figure 2.2 shows the average milk composition of a dairy cow. Milk is made up of mainly water and a lesser percentage of solids (Lambrini et al., 2021). Despite its lesser percentage, the role of milk solids should not be underestimated as studies have highlighted their importance in the nutritional value and pricing of milk (Elbagermi et al., 2020; Arjuna et al., 2020). Many global studies have explored factors influencing milk composition, including feeding systems, breed, management, and health status (Nickerson, 1995; Schwendel et al., 2015; Chen et al., 2024).

2.6.2 Protein

According to studies, milk's proteins are significant because they include every amino acid required for human growth that the body is unable to produce (Kim and Lee, 2021; Alkaisy et al., 2023). The protein in milk can be found in different forms, which have different tasks in the composition of milk, with studies often associating casein with cheese production and whey with sports supplements and infant milk formulation (Balivo et al., 2024; Salek et al., 2024). However, for processing, the milk solids are required to be a certain percentage for quality by-products, with the average percentage for protein reportedly being 3.5% (Fox et al., 2015; Mediwaththe et al., 2024).

2.6.3 Fat

Milk contains a significant amount of fat that is mostly used in the production of butter due to its density from the triglycerides, which make it an important source of nutrition for humans (Mu et al., 2021; Mohan et al., 2022). Fat is further important in the human diet due to its ability to produce vitamins A, D, E and K when consumed in normal amounts (Stevens, 2021). However, some researchers argue that while milk fat is important in the human diet, an excessive portion can be harmful and produce unwanted flavour and smell (Guetouache et al., 2014; Sakha and Ahmadi, 2024). Reducing fat content in milk requires additional processing, which can be costly to the processors; however, studies have determined the ideal percentage of fat in milk to be around 4% (Alirezalu et al., 2020; Lambrini et al., 2021).

2.6.4 Lactose

It is impossible to overestimate the significance of lactose as a component of milk. Previous research highlighted lactose's contribution to milk's taste by supplying sugars. In the human diet, lactose is a significant source of carbohydrates, particularly for infants whose digestive systems are unable to accommodate many types of nutrients (Adam et al., 2004; Hettinga, 2019). However, recent research has increased awareness of lactose's potential to harm people and induce illnesses, including cancer (Catanzaro et al., 2021; Katoch et al., 2022; Li et al., 2023). It has also been documented that lactose affects milk production (Fox et al., 1998; Portnoy et al., 2021; Costa et al., 2019). Due to its impact on udder health, lactose has become well-known throughout the world. Research has shown a connection between lactose and SCC, which also affects mastitis and udder health (Sharif et al., 2007; Hanuš et al., 2010; Alessio et al., 2021). On the other hand, 4.7% milk is regarded as normal (Vaskova and Buckova, 2016).

2.6.5 Somatic Cell Count

According to Talukder and Ahmed (2017) and Sun et al. (2023), somatic cells are naturally occurring white blood cells that line the cow's mammary gland and shield it from infections. Because of this, SCC has been recognised in the literature as a marker of intramammary infection. Because SCC affects milk's fat, protein, and lactose content in a technical and nutritional way, milk collectors have reportedly implemented a quality-based payment system in which a high level of SCC is penalised and may lead to the milk being thrown out, while a low level of SCC is rewarded with a higher price (Magro et al., 2023; Rowe et al., 2024; Baltenweck et al., 2025).

Due to global concerns about milk safety, research has focused on developing thresholds aimed at raising awareness for dairy farmers and processors to produce milk to the accepted standard for human consumption. Literature from Talukder and Ahmed (2017) reported that milk is in the range of consumption safety, and the SCC level must be approximately 2×10^5 cells/mL. Conversely, milk that exceeds a threshold of 4×10^5 cells/mL is considered unsafe for human consumption. Consistently, Norman et al. (2000) further state that adoption of these thresholds leads to improved milk quality and consumer confidence. However, these thresholds have been reported by studies to vary globally, with suggestions that thresholds should be based on location, season and calving cycle (Sharma et al., 2011; Zecconi et al., 2020; Dal Prà et al., 2022). This lack of adherence to SCC thresholds raises worries, especially at smaller dairy farms, over the hygiene and standard of milk produced.

2.7 Factors affecting milk composition and yield

The production of milk is interconnected with various management and environmental factors. Studies have investigated these influences, concluding that a leading contributor to milk contamination is the lack of knowledge and inadequate practices employed by the dairy farm milkers (Sraïri et al., 2006; Nyokabi et al., 2021; Kunes et al., 2021). On the other hand, some studies have attributed milk contamination to poor environmental conditions during milking, such as inadequate cleaning of milking equipment, use of cold water when cleaning and use of unclean water to disinfect the equipment (Pandey and Voskuil, 2011; Ruegg, 2017). These studies, despite investigating different aspects of milk contamination, tend to agree with each other as a poor milking environment is a result of inadequate practices by farm personnel.

Other studies have identified animal health as a key player in milk production, associating poor milk composition and yield with diseases like mastitis (Halasa et al., 2007; Neculai-Valeanu and Ariton, 2022). Mastitis, which is an udder health disease that is a result of contamination of the udder, is most commonly linked with a high SCC. Research has associated low levels of SCC with lower incidences of mastitis (Talukder and Ahmed, 2017; Fernandes et al., 2021). This shows that proper management and disease prevention can reduce udder health issues, thus maintaining quality milk production.

However, a few studies have reported the effect of biological factors affecting milk composition, identifying parity, lactation phases and breed as factors influencing milk quality (Tančin et al., 2020; Sabek et al., 2021; Aleli, 2024). In contrast, these studies, despite investigating different aspects, emphasise the importance of milk production. This proves

research is moving in the correct direction, as even in Africa, including South Africa, studies have determined inadequate practices employed by dairy farm personnel (Nyokabi et al., 2021; Xulu and Naidoo, 2023). It is important to look at each of the factors that influence milk composition and how they predict the milk quality.

2.7.1 Breed

Literature has identified the use of a variety of breeds used in the dairy industry, such as Jersey, Holstein, Ayrshire, and Brown Swiss, among others (Rodríguez-Bermúdez et al., 2019; Opoola et al., 2022). These breeds, being commonly used, offer different production qualities in terms of milk production (Gantner et al., 2015; Kebede, 2018; Gorelik et al., 2021). A majority of studies have reported Jersey and Holstein cattle to be the two most popular breeds in the dairy industry worldwide due to their superiority in both milk composition and yield (Lim et al., 2020; Khan, 2020; Olthof et al., 2023). The role of breed in milk production is well understood, with the majority of the population of farmers preferring Holstein. This indicates that farmers prioritise milk yield over higher milk fat and protein since Jersey herds produce lower yields and higher milk solids, which are important in the processing of milk by-products.

2.7.2 Season

TThere is evidence that season affects milk output. According to studies, milk solids fluctuate throughout the seasonal year, peaking in the winter and falling in the summer (Kabil et al., 2015; Li et al., 2019). This variation can be explained by the summer's high temperatures, which could interfere with the udder's ability to produce milk. Some research, however, indicated that seasonal variation had no impact on milk production, which contradicts this occurrence (Lin et al., 2017; Ramadani et al., 2024). This implies that the populations under study differ geographically and environmentally.

2.7.3 Lactation Phases

The lactation cycle has been systematically separated into phases, and it has been demonstrated that milk production varies throughout. The lactation cycle was previously separated into early and late lactation (Lehtolainen and al., 2003; Castillo et al., 2005). This has been shown to be out of date by current research, which reports that milk production follows distinct trajectories that are best explained by the three lactation periods of early, mid, and late lactation (Mol et al., 2018; Sabek et al., 2021). Research has reported the different phases of lactation to have a significant impact on the components of milk and yield, further emphasising the dilution effect where milk yield is high but milk solids are relatively low (Van der Fels-Klerx and Camenzuli,

2016; Antanaitis et al., 2021; Soyyılmaz et al., 2021; Connolly et al., 2023; Chen et al., 2024). The contradiction in the number of lactation phases shows the development of research in bridging gaps in the knowledge of the trajectories of milk throughout the lactation cycle.

However, similar studies conducted have recorded no significant effect of lactation phases on milk composition (M abd-el naser et al., 2014; Sehested et al., 2019). Even though limited, these studies show the need for further establishment of the effect of lactation phases in the literature. Most studies have been conducted in Europe and other continents (Čobanović et al., 2021; Verd et al., 2023; Connolly et al., 2023). Africa has only recently paid attention to milk composition with studies reported in Rwanda, Tanzania, and South Africa (Idamokoro et al., 2017; Mukasafari et al., 2025).

2.7.4 Parity

Parity is a term that has been used generatively in the dairy industry. However, in earlier studies, parity has been used to investigate its contribution to culling in the dairy industry with links to dystocia in multiparous cows (Seegers et al., 1998; Bonneville-Hébert et al., 2011). Dairy problems and diseases such as ketosis and hypocalcaemia have been found to be associated with parity (Vanholder et al., 2015; Neves et al., 2017). Farmers have developed culling tactics to prevent production losses thanks to the discovery of the connection between parity and diseases in cattle. However, recent studies have contradicted this theory, attributing the occurrence of hypocalcemia and ketosis to inadequate feeding (Arechiga-Flores et al., 2022; Alabdallah, 2023). This indicates the huge role of farmers in managing health in the dairy farm. However, it also presents uncertainty in the role of parity in the dairy industry.

The focus of current research has switched to examining how primiparous and multiparous cows produce different amounts of milk (Chisowa, 2023; Ridhowi et al., 2025). Multiparous cows have been linked in multiple studies to an increased prevalence of mastitis and SCC (Senha et al., 2021; Barbosa et al., 2023). Further research has reported challenges in milk production due to exposure to extreme temperatures, leading to stress, which may disrupt the intramammary function and result in udder problems (Cinar et al., 2015; Neculai-Valeanu and Ariton, 2022). This has been consistent with studies associating age with susceptibility to udder health issues. However, some studies indicate multiparous cows have better milk yield in comparison to primiparous cows (Marumo et al., 2022; Berry and Downing, 2025). This suggests differences in effect on milk qualities; furthermore, studies focused on determining the effect of parity on each parameter separately. However, an integrated approach would yield

valuable results in identifying how the different milk parameters, including yield, respond to advancing parities. In Africa, recent attention has been paid to the importance of understanding these relationships, with studies highlighting that the establishment of these relationships in the African environment would yield better milk quality and productivity (Kaskous, 2021; Dauda and Ebegbulem, 2023; Washaya and Cheruwa, 2025).

2.8 Hygiene and its role in maintaining milk quality

Hygiene has been shown to be one of the key elements in dairy production that affects milk quality and profitability. Studies have associated inadequate hygiene with reduced milk quality and shelf life due to poor hygiene, introducing contaminating agents into the milk (Zigo et al., 2021; Nyokabi et al., 2021). This puts a workload on dairy farmers to ensure a clean environment, as studies have identified the milking environment, milking equipment, feed sources and unclean water as the main sources for udder infections and milk contamination (Ranasinghe et al., 2021; Gupta et al., 2024). The broad spectrum of contaminants proves to be almost impossible to prevent for dairy farmers; however, dairy farmers should aim to minimise the risks of contamination, as the contaminated milk can cause foodborne diseases. Milk, being the main source of nutrients for infants, the importance of safe milk cannot be overemphasised.

Improved milk quality and reduced levels of contamination have been linked to good cleanliness. Studies have reported that training yields adherence to hygiene standards, resulting in lower SCC (Goksoy et al., 2021; Mihajlović et al., 2023). The support of extension services has also been shown to yield better hygiene standards (Nyokabi et al., 2021). The lack of awareness of proper hygiene standards should be of concern to consumers. Even with the advanced technologies and machinery, since personnel are responsible for their operations, they are required to abide by the correct standards to ensure clean equipment and machinery.

In contrast, maintaining hygiene standards leads to a chain of benefits; it builds a suitable stress-free environment for cattle, which in turn improves milk composition and minimises milk contamination (Ledo et al., 2019; Kaskous, 2021). Secondly, hygiene standards lower SCC levels in milk, which improves the milk price and bonuses and further improves profitability (Mondini et al., 2023). And lastly, hygiene standards improve consumer confidence in milk. increasing consumption (Zhang et al., 2024). Despite these established benefits of hygiene practices, the adoption is proven to be a challenge for dairy farmers, particularly in South Africa (Molomo, 2022; Xulu and Naidoo, 2023). A study by Masha

(2025) further established that loadshedding has an effect on practices in dairy farming in KwaZulu-Natal.

2.9 Knowledge of dairy farm personnel

2.9.1 Knowledge of hygiene practices in milk production

Recent studies present mixed findings on whether farmers have knowledge of the concept of milk quality. Research has shown that many farmers possess a general awareness of the importance of cleanliness, udder health, and proper milking procedures in producing good-quality milk (Nyokabi et al., 2021; Andersson et al., 2025). Earlier research by Ellis et al. (2007) and Swai and Schoonman (2011) revealed that many farmers believed the leading causes of contamination were environmental factors and udder-related diseases, such as mastitis. These farmers felt confident that their own farm practices were not contributing to the problem. Farmers showed strong trust in their routine milking practices and hygiene measures, stating that these were adequate for maintaining good milk quality.

According to a study conducted in Ethiopia by Amenu et al. (2017), mastitis affects a large number of animals, with cattle accounting for almost 60% of cases. Many members of the community falsely think that mastitis is brought on by the "evil eye," and they frequently treat mastitis using traditional methods. Controlling the prevalent mastitis in dairy cattle is made more difficult by this misconception or ignorance. This thus adds to the ignorance and unethical behaviour of dairy farm personnel with regard to milk quality. These beliefs are challenged by more recent research, which discovered that poor hygiene during milk storage and transportation, rather than solely environmental or animal health factors, was the primary cause of milk contamination (Fusco et al., 2020; Haldar et al., 2022). This suggests that contamination can occur after milking, especially when milk is not stored at the right temperature or transported in clean, sealed containers. Additionally, Paraffin et al. (2018) pointed out that many farmers might not be aware of additional potential sources of contamination, like contaminated water used during cleaning procedures, unclean milking equipment, and inadequate handwashing.

These findings indicate a gap between what farmers believe and what is actually happening on the ground. The lack of awareness and knowledge of all potential contamination sources means that many farmers may unknowingly be compromising milk safety and quality (Nyokabi et al., 2021). Therefore, it is crucial to investigate and record the actual milking practices used by dairy farmers. This will help identify weaknesses in the current system and create opportunities

for targeted training and interventions to improve milk hygiene and overall dairy productivity. A deeper understanding of these day-to-day practices is essential for developing practical, context-specific solutions (Junior et al., 2015).

2.9.2 Socioeconomic and Cultural Factors Influencing hygiene

Every farmer has an obligation to implement hygienic standards in order to guarantee high-quality milk. Studies that have looked at the adoption of hygienic practices on dairy farms over the years have found that aspects like education, training, and extension services have an impact (Norton and Alwang, 2020; Nyokabi et al., 2021; Antwi-Agyei and Stringer, 2021; Chouhan et al., 2023). However, some studies have also found these factors to have no significant influence on hygiene adoption (Triveni et al., 2018; Usadadiya et al., 2023). Due to differences in farm size, farms may experience different outcomes from these factors. However, it is still believed that the KAPs of dairy farmers are built around these factors.

Different socioeconomic factors may affect smallholder and commercial farmers. Studies report that smallholders often fail to adhere to hygiene standards due to a lack of education on the importance of their role in ensuring milk quality. Smallholder farmers prefer using low-cost materials, such as plastic containers, to store milk; however, this increases the risk of contamination (Can and Altuğ, 2014; Krpalkova et al., 2016; Bava et al., 2017; Bereda et al., 2018; Diniso and Jaja, 2021). The income received by dairy farmers is a motivation for farmers to adhere to hygiene standards. When income is low, farmers tend to cut down on production costs to maintain profit, thus compromising milk quality. Studies show that farmers do not take days off during illness (Xulu and Naidoo, 2023). Working with illness is driven by the desire to avoid income loss; however, the risk of milk contamination is greater.

This lack of knowledge is also evident in the treatment of diseases, where farmers ignore the withdrawal period for cattle to reduce economic losses (Bosc et al., 2018; Nyokabi et al., 2021). Milk rejected due to antibiotic residues results in additional losses.

2.10 Attitudes of dairy farm personnel

2.10.1 Perceptions toward milk quality and composition

Milk quality is often assessed scientifically, taking factors like SCC and milk solids content into account; however, studies have reported that farmers rely on sensory assessment of milk, which can be done by colour inspection, smelling and tasting the milk (Craighead et al., 2021; Castellini et al., 2023). Many variables, such as practical experience, traditional beliefs, a lack of scientific knowledge, and resource constraints, contribute to the dependence on these

antiquated methods. Additionally, depending too much on such a foundation may result in misunderstandings and lower-quality milk.

This misconception is further emphasised by Paraffin et al. (2018), where farmers prioritise breed as the determining factor of quality milk, with the belief that Holstein and Jersey cattle possess' resistance to udder-related issues. While genetics do affect the composition of milk, it is ignorant to base milk quality on just one factor, while factors such as environment, nutrition and management practices are equally important. Furthermore, studies report that farmers who have an understanding of the effect of parity, nutrition, hygiene and lactation phases tend to have improved milk quality (Goksoy et al., 2021; Fadillah et al., 2023; Burtscher et al., 2023). The reliance of farmers on outdated sensory techniques raises concern about the milk being produced and suggests a lack of awareness of the modern techniques for determining milk quality.

2.10.2 Attitudes Toward Hygiene and Milking Practices

Farmers' attitudes towards milking hygiene are very important in determining milk quality. Studies have investigated the impact of attitudes towards adopting hygiene practices, reporting that positive attitudes lead to better milking hygiene and improved milk quality (Múnera-Bedoya et al., 2017; Nyokabi et al., 2021). Exposure to training and workshop programmes has been linked to improved hygiene through learning about environmental factors that affect milk quality (Baul et al., 2013; Mihajlović et al., 2023). The role of extension services and intervention programmes would therefore prove to be beneficial in the dairy industry to improve farmers' attitudes and motivation towards milk hygiene.

However, some studies have determined negative attitudes of dairy farmers towards milk hygiene (Bechini et al., 2020; Nyokabi et al., 2021). Farmers with negative attitudes believe that their hygiene practices are adequate for milk quality and there is no need for improvements, even rejecting participation in training programmes to improve their hygiene. The negative attitudes are further evident in a study by Cox (2017). The lack of awareness is evident, and interventions are needed. A few studies have investigated the determinants of farmers' attitudes towards hygiene globally (Korale-Gedara et al., 2023; Chilambula, 2025; Emmanuel et al., 2025). A study by Xulu and Naidoo (2023) reported inadequate hygiene practices by dairy farmers in South Africa. Determining the barriers in dairy farming is important to develop evidence-based interventions (Bechini et al., 2020; Stokes et al., 2022)

2.11 Link between milk composition, SCC, and dairy farm management

Studies frequently show that SCC is an indicator of mastitis and udder-related problems, making it helpful in the management of udder health and milk quality (Liu et al., 2023). Due to poor farming practices, a number of studies linked a high SCC to decreased nutritional content and market value (El-Tahawy and El-Far, 2010; Kul et al., 2019). Since the majority of milk contamination is said to occur on farms, literature has identified farmers as the cornerstone of milk quality (Lemma et al., 2018; Owusu-Kwarteng et al., 2020). Further research highlights the importance of farmers' attitudes and expertise in ensuring that the milking environment is free of impurities such feed, water, and even the milking equipment (Viegas et al., 2020; Hohmann et al., 2020; Nyokabi et al., 2021). The level of SCC would decrease if the dairy farm used appropriate procedures, which would result in fewer cases of mastitis and higher-quality milk. According to studies, better dairy farm techniques, like cleaning the udder both before and after milking, reduce the amount of microbiological contamination in milk (De Silva et al., 2016; Gaikwad and Ghule, 2025). Figure 2.3 further illustrates the relationship between the farmer's KAPs, milk quality, and dairy farm profitability.

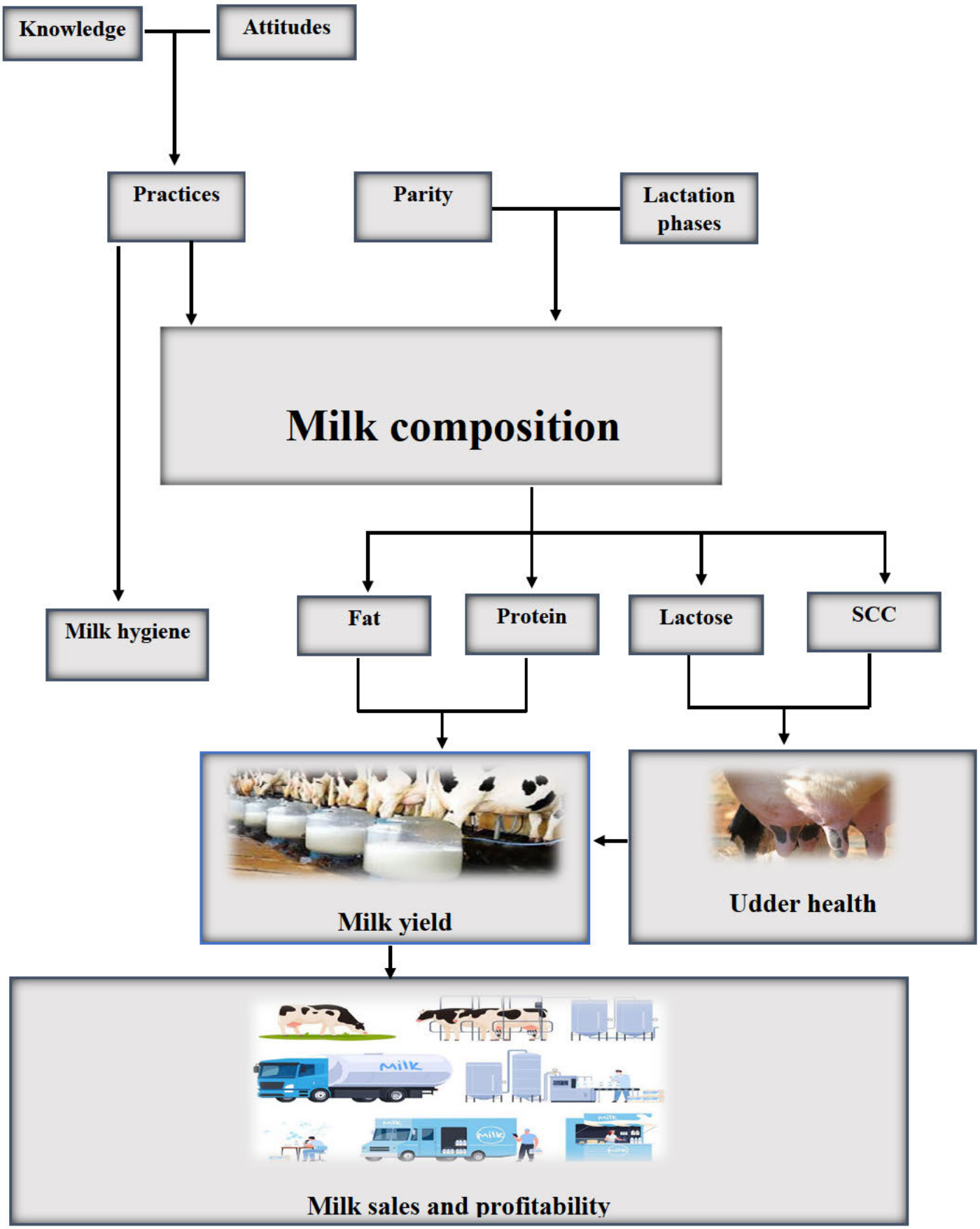

Figure 0.3 Schematic diagram of the flow of factors affecting milk Composition and profitability.

2.12 Barriers to improving milk quality and hygiene

Despite reports that the Sub-Saharan African region's growing population and dietary preferences are driving up demand for milk and its dairy products (Kapaj and Deci, 2017; Adesogan and Dahl, 2020), some studies note that issues like high prices and refrigeration costs are preventing proper milk production (Tricarico et al., 2020; Merem et al., 2022; Kiambi et al., 2022). The dairy sector is under a lot of pressure to produce high-quality milk, yet supply chain advancement is hampered by infrastructure and economic obstacles.

By creating policies, rules, and regulations for producers to follow, the government may help ensure food safety for the public. However, milk safety is jeopardised if these rules and regulations are not enforced (Ayvaz‐Çavdaroğlu et al., 2021; Akkaya et al., 2021). The management of dairy businesses has apparently been impacted by the Foot and Mouth Disease (FMD) outbreak, which has caused limitations and biosecurity measures to disrupt the dairy industry (Chumsang et al., 2025). Managing milk hygiene appears to be multifaceted since numerous elements need to be considered. Numerous parameters that guarantee milk quality have been explored in the literature, but the conflicting results point to variations in farm management and performance.

Management practices and lack of knowledge are among the most frequently investigated constraints in the dairy farming industry, with smallholder farming often recognised as the victim of a lack of awareness of hygiene practices to enhance milk quality (Nyokabi et al., 2021; Xulu and Naidoo, 2023). However, as knowledge plays a big role in hygiene, it cannot solely determine milk quality outcomes. Studies have reported that economic and resource constraints inhibit farmers' ability to preserve milk quality (Hansen, 2015; Jafri et al., 2024; Masha, 2025). A closer look at these factors should provide insight into their range of effects.

2.12.1 Resource and Infrastructure Limitations

Resources such as feed are often reported as among the factors limiting dairy farming practices, particularly among smallholder dairy farmers. Due to smallholder dairy farmers' inability to provide sufficient feed to maintain high performance in cattle, milk composition and yield are compromised (Mäkinen, 2013; Njarui et al., 2016). This is further supported by studies showing that limited grazing land reduces animal nutrition (Guadu and Abebaw, 2016). This shows the structural perspective rather than the farm management deficiencies that may affect the profitability of the dairy farm.

Since dairy farming is usually located in regions far from urban cities and busy areas, they are usually associated with poor roads. Studies have identified poor road networks to disrupt the access to the farms by extension officers and veterinary support (Fiorillo and Amico, 2024). Since milk is perishable, prolonged storage in farm facilities may result in deterioration and financial losses for the dairy farm (Jafri et al., 2024; Shandilya et al., 2025). Consistent research also highlights how poor roads impede the movement of milk from dairy farms to facilities for processing.

In South Africa, the combination of poor road networks and electricity issues, such as load shedding reported by Masha (2025), may prove detrimental to the economy. Since many dairy farmers are reported to be in small-scale and located in rural settlements in Africa (Quddus, 2018; Nyokabi et al., 2021; Xulu and Naidoo, 2023), this limits investment into these industries and benefits larger-scale farms with more developed road networks and other resources. As a result, smaller farmers face difficulties in producing milk that complies with hygiene standards. Studies report that smallholder farmers have limited access to credit (MacDonald and Newton, 2014; Giller et al., 2021; Kiarie, 2025). This limits smaller farms' ability to invest in advanced technologies and improve road networks, which further widens the gap between smaller and larger farms. Literature emphasises the effect of these resource constraints and their interaction, with Molomo (2022) identifying these constraints as inhibiting the commercialisation of many dairy farms.

2.13 Strategies to enhance knowledge, attitudes, and practices

2.13.1 Training and Capacity-Building Initiatives

It is commonly acknowledged that training and capacity-building programs are crucial tactics for enhancing the skills, attitudes, and behaviours of dairy farm personnel (Nyokabi et al., 2021). Employees' proficiency in implementing best practices greatly increases when they receive organised, ongoing training, according to numerous studies (Hossain, 2017; Tarekegne et al., 2024). According to a study by Roy et al. (2013), farm workers who took part in focused training programs had a better grasp of contemporary production techniques and were more likely to embrace cutting-edge, hygienic practices. Such training not only enhanced technical knowledge but also encouraged behavioural changes necessary for maintaining product quality and ensuring consumer health (Arowosegbe et al., 2024). Similarly, Noor and Dola (2011) highlighted the importance of peer-to-peer learning, reporting that knowledge sharing among personnel plays a crucial role in reinforcing and sustaining good practices. Their findings further revealed that training initiatives do more than improve operational efficiency; they also

reduce production costs by minimising mistakes, enhancing disease prevention, and promoting timely interventions, similar to findings by Mnukwa et al. (2025). The combination of improved efficiency and increased output ultimately makes production more cost-effective, particularly for smallholder and emerging farmers who often face resource constraints (Kövesdi et al., 2025). Beyond technical skills, capacity-building programmes also play a role in shaping positive attitudes towards hygiene, biosecurity, and routine animal health monitoring (Keba et al., 2025). Studies emphasise that personnel who undergo continuous training tend to demonstrate a stronger appreciation of the link between their daily practices and milk safety outcomes (Nyokabi et al., 2021; Rodriguez et al., 2025). Effective training programmes therefore integrate practical demonstrations, on-farm mentorship, and follow-up support to ensure that knowledge is not only acquired but also applied consistently.

Modern training approaches encourage the use of visual aids, mobile-based learning tools, and hands-on sessions to address challenges posed by varying literacy levels among personnel (Ordu, 2021). When combined with supportive supervision and regular refresher courses, these strategies contribute to sustained improvements in milk hygiene, reduced somatic cell counts, and better overall farm performance (Mihajlović et al., 2022).

2.13.2 Extension and Advisory Services

For training initiatives to be effective, dairy farmers and farm personnel must remain informed about current practices and technological advancements (Nyokabi et al., 2021). In this sense, extension and advisory services are essential for transferring the knowledge and skills required to enhance dairy production systems, especially in areas with few opportunities for formal agricultural education and training (Lukuyu et al., 2012; Chilambula, 2025). Extension services greatly enhance the KAPs of dairy farmers by giving them access to current information on disease prevention, animal health, herd management, and milk production (Kabir and Talukder, 1999; Gölge et al., 2009; Nyokabi et al., 2021; Abhishek, 2022). Good extension systems make it easier for producers to learn best management methods from agricultural specialists, which improves milk quality, production, and the long-term viability of dairy businesses (Agwu et al., 2023).

The importance of extension support is particularly evident in farming communities where literacy levels are low, and access to technical information is limited. Under such circumstances, dairy farm personnel often depend heavily on government-led extension programmes to acquire practical knowledge and develop competencies required for efficient

farm management (Karbasioun et al., 2008; Rana et al., 2025). Structured training programmes, workshops, and on-farm demonstrations provide valuable opportunities for personnel to improve their understanding of milking hygiene, mastitis prevention, udder health management, record-keeping, feeding practices, and animal welfare (Adamsone-Fiskovica and Grivins, 2022). These interventions not only increase awareness of recommended practices but also enhance the ability of farmers to apply them effectively in their daily operations (Coman et al, 2020). According to Vázquez-López and Marey-Perez (2021), extension officers should support farmers throughout the technology adoption process by providing technical guidance and practical training. Exposure to technologies such as automated milking systems, mastitis detection tools, and hygiene monitoring devices can improve milk quality, reduce contamination risks, and minimise production losses (Bekuma and Galmessa, 2018). Consequently, the integration of technological innovations into dairy production systems can contribute substantially to improved farm performance and profitability.

Access to financial resources is essential for improving dairy farmers' ability to apply best management practices, in addition to extension help (Habtamu et al., 2018). According to a study by Jafri et al. (2024), investments in cutting-edge milking machinery, technologies for testing milk, and suitable facilities for storing milk greatly enhance milk quality and lower the danger of contamination. Smallholder dairy farmers, however, are unable to purchase this technology due to financial limitations (Duguma, 2022). According to Njarui et al. (2016), government-sponsored credit schemes, subsidies, grants, and cheap loan programs can thus enable technical advancements and enhance farm infrastructure. The advantages are increased when training and financial assistance are coupled, leading to higher standards of hygiene, increased production efficiency, and better milk quality results (Chen et al., 2023). Nonetheless, research conducted in South Africa has revealed shortcomings in the efficiency of the extension services provided to farmers and has recommended an assessment of the services (Mncina and Agholor, 2021; Mokgomo et al., 2022).

2.14 Conclusion

The literature shows that milk composition and farm personnel KAPs play a major role in determining productivity and profitability; however, significant gaps exist in evidence specific to emerging dairy farming systems in KZN. Although global studies confirm that lactation stage and parity influence milk components and SCC, little research has examined these effects within South Africa’s smallholder and emerging dairy sectors, where production environments and management practices differ from commercial operations. Similarly, while KAP of dairy

personnel are known to affect milk hygiene and udder health, most studies are from North Africa and Europe, leaving a limited understanding of how education, experience, training, and resource availability shape KAP in diverse KZN dairy farms. Furthermore, despite profitability being essential for farm sustainability, there is minimal research on how herd size, labour structure, and limited resources affect economic performance in KZN. These gaps underscore the need for a comprehensive study evaluating the impact of lactation phases and quantity on milk quality and yield, KAP levels and their causes among dairy workers, and profitability across various dairy farms in the province.

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CHAPTER 3:

Evaluating the determinants of knowledge, attitudes, and practices of dairy farm personnel

3.1 Abstract

Milk production is important with the growing demand by consumers worldwide. However, if dairy personnel's knowledge and practices are inadequate, milk quality and safety are compromised. This study assessed the factors influencing dairy farm personnel's KAPs regarding milk hygiene in KZN. Fifty-nine personnel from various dairy farms participated in the survey. Structured questionnaires were used to gather information about sociodemographic traits, attitudes toward milk safety, knowledge of milk hygiene, and on-farm practices. A Tobit regression model was used to determine the determinants of KAPs, while descriptive statistics were used to describe respondent characteristics and KAP levels. The results revealed that respondents had a mean age of 44.25 years and relatively high levels of formal education (mean = 13.83 years), but limited dairy-specific experience (mean = 7.35 years). A high proportion of respondents demonstrated awareness of key milk quality indicators such as somatic cell count (80%), total bacterial count (72%), and mastitis detection (65%). Attitudes toward milk hygiene were generally positive, with the majority acknowledging responsibility for milk safety (90%) and the importance of regulatory compliance (90%). However, despite this awareness, gaps were observed in the implementation of critical hygiene practices, particularly in relation to formal training (12% always), record keeping, and structured herd management. The Tobit regression analysis indicated that education ($p = 0.003$), household income ($p= 0.075$), extension service access ($p=0.009$) were significant determinants of attitudes. Additionally, age ($p= 0.010$) and farming experience ($p < 0.001$), and farmer organisation membership influenced knowledge and practices respectively. The study concludes that although dairy farm personnel possess adequate knowledge and positive attitudes toward milk hygiene, the translation of this knowledge into consistent practice is constrained by limited training and extension support. Promoting improved management practices through training is essential to enhance milk hygiene and overall dairy productivity in dairy systems.

Keywords: Milk hygiene; Knowledge, attitudes, and practices; Dairy farm personnel; somatic cell count; mastitis.

3.2 Introduction

The dairy industry is essential to the advancement of rural living standards, agriculture, and food availability worldwide. The dairy industry produced about 950 tonnes of milk in 2023, up 1.3% from 2022, according to the Food and Agriculture Organisation (FAO, 2024). Additionally, the dairy industry supports livelihoods by generating more than 250,000 jobs (Hill, 2024). Dairy production has become a crucial subsector for improving nutrition and promoting equitable economic growth as the demand for foods derived from animals continues to rise due to expanding populations, urbanisation, and income expansion (Leggesse et al., 2023). However, structural inefficiencies, a lack of technological adoption, and poor human capital development continue to limit dairy output in many African nations (Tadele et al., 2025; Fiorillo and Amico, 2024). While significant attention has been directed toward improving genetics, feed resources, and infrastructure, comparatively less emphasis has been placed on the knowledge base, attitudes, and day-to-day practices of farm personnel who are directly responsible for herd management and milk hygiene (Nyokabi et al., 2021). Therefore, it is essential to comprehend the human behavioural aspect of dairy production in order to enhance industry performance and sustainability.

In the African context, the dairy industry is characterised by a dualistic structure comprising commercial large-scale farms and smallholder systems operating under varying levels of resource endowment (Molomo, 2022). However, productivity gaps remain substantial when benchmarked against global standards (Nyokabi et al., 2021; Leggesse et al., 2023; Tadele et al., 2025). These gaps are not only attributed to inadequate technical knowledge, weak compliance with standard operating procedures, and negative or indifferent attitudes toward best management practices (Kilima et al., 2024). Empirical evidence across sub-Saharan Africa indicates that deficiencies in training, extension access, and workplace supervision often translate into poor milking hygiene, suboptimal disease control, and reduced milk quality, thereby undermining farm profitability and public health outcomes (Ledo, 2020). Milk is the Singular source of nutrients for infants, compromised milk therefore; poses a risk to their health (Scholz-Ahrens et al., 2020).

Within South Africa, the dairy sector is one of the most organised and commercially advanced in the region, contributing significantly to agricultural GDP with a gross of R25 billion in 2023 and employing over 100 000 workers within the dairy chain (FAO, 2024). According to Statistics South Africa (Stats SA, 2025), the agricultural sector's share of South Africa's GDP was 17,4% for 2025. Provinces such as KwaZulu-Natal, Western Cape, and Eastern Cape serve

as major milk-producing hubs, supported by relatively sophisticated value chains and established processing industries (Milk SA. 2024). Despite these structural advantages, the industry is under increasing pressure from factors such as growing input costs, climate variability, strict food safety regulations, and overwhelming concerns about sustainable environmental practices and animal rights (Jafri et al., 2024). The number of dairy farmers decreased from 1,365 in 2018 to 882 in 2024 (Milk SA, 2024). In this evolving landscape, the competence and behavioural orientation of dairy farm personnel become central determinants of operational efficiency, product quality, and regulatory compliance.

KwaZulu-Natal, in particular, occupies a strategic position within South Africa's dairy economy (Xulu and Naidoo, 2023). The province has a total of 182 dairy farmers (Milk SA, 2024), hosting a mix of large commercial enterprises and emerging black-owned dairy farms supported through land reform and agrarian transformation programmes (Masha, 2025). However, disparities in managerial capacity, workforce skills, and training access persist across farm typologies. Dairy farm personnel ranging from herd managers and supervisors to milkers and general workers play a critical role in translating farm policies into daily operational practices. Their knowledge of animal health protocols, mastitis control, feed management, and milking procedures directly influences herd productivity and milk safety standards (Mills, 2020).

The concept of KAP has been extensively used in studies on agricultural extension and public health to assess behavioural drivers influencing outcomes (Liao et al., 2022). Knowledge refers to the level of understanding individuals possess regarding specific technical issues; attitudes capture beliefs, perceptions, and motivational dispositions; while practices reflect observable behaviours and routine actions (Wang et al., 2023). In the dairy context, inadequate knowledge about disease transmission, antimicrobial use, or hygienic milking procedures may coexist with complacent attitudes, ultimately resulting in poor farm-level practices (Nyokabi et al., 2021). Conversely, well-informed and positively oriented personnel are more likely to adopt and sustain recommended innovations. Despite its analytical relevance, limited research in South Africa has systematically examined KAP dynamics among dairy farm personnel, particularly within the context of commercial and semi-commercial operations in KZN.

Emerging evidence suggests that human capital constraints remain a binding limitation in South Africa's agricultural transformation agenda (Molomo, 2022). Many farm workers possess limited formal education and receive minimal structured training after employment

(O'Donoghue and Heanue, 2018). Language barriers, high labour turnover, and weak incentive systems further complicate the effective implementation of standard operating procedures. In dairy production systems, where precision, hygiene, and timely interventions are essential, gaps in knowledge and negative work attitudes can have cascading effects on milk yield, somatic cell counts, antibiotic residues, and overall herd health (Amenu et al., 2020; Nyokabi et al., 2021). These challenges not only reduce farm profitability but may also compromise consumer trust and export competitiveness.

Furthermore, South Africa's regulatory framework governing food safety, animal health, and labour standards is becoming increasingly stringent in alignment with global norms (Mphaga et al., 2024). Compliance with biosecurity measures, responsible antimicrobial stewardship, and animal welfare protocols requires not only infrastructure but also competent and motivated personnel. Yet there is insufficient empirical understanding of the socio-economic, institutional, and farm-level factors that shape the KAPs of dairy farm personnel in KZN (Xulu and Naidoo, 2023). Determinants such as education level, training exposure, work experience, remuneration structures, supervision intensity, farm size, and access to extension services may significantly influence behavioural outcomes (Bechini et al., 2020), but these relationships remain underexplored in the provincial context.

Against this backdrop, the problem confronting the dairy sector in KZN is not solely technological or infrastructural; it is fundamentally behavioural and institutional (Masha, 2025). While investments have been made in improved breeds, feeding systems, and milking technologies, less attention has been devoted to systematically evaluating the human factors that determine whether these investments translate into improved productivity and quality outcomes. The absence of rigorous empirical evidence on the determinants of KAPs among dairy farm personnel creates a policy and managerial blind spot (Nyokabi et al., 2021). Without such evidence, training programmes may be poorly targeted, extension interventions inadequately designed, and farm-level management strategies misaligned with workforce realities. This study therefore evaluated the determinants of the KAPs of dairy farm personnel in KZN, South Africa, with the aim of generating context-specific insights to inform evidence-based interventions that strengthen productivity, sustainability, and compliance within the provincial dairy sector.

3.3 Theoretical framework

The Knowledge-Attitude-Practice model, which was developed from Bhandura and Walter's (1977) learning theory and Rogger's (1995) theory of diffusion and innovation, provides the strongest foundation for this study. This model offers an appropriate framework for assessing the KAPs' determinants (Zarei et al., 2024). In behavioural, agricultural, veterinary, and public health research, the KAP model is frequently utilised to investigate how people's knowledge affects their feelings or perceptions, which in turn influence their actions (Liao et al., 2022). The model assumes a sequential relationship in which knowledge forms the cognitive basis for attitudes, while attitudes influence the adoption of specific practices or behaviours (Chilambula, 2025).

The KAP model is particularly relevant in the field of dairy farming because farm personnel's everyday actions during milking and animal handling procedures have a significant impact on the standards and hygiene of milk (Nyokabi et al., 2021). Farm workers are directly involved in activities such as udder preparation, milking hygiene, equipment sanitation, milk storage, mastitis detection, and general herd management. Their ability to perform these tasks effectively depends not only on their technical knowledge but also on their attitudes toward milk quality, animal health, hygiene protocols, and the importance of compliance with recommended practices (Bafanda et al., 2018). These cognitive and behavioural dimensions ultimately affect the practices they implement on-farm, which may in turn influence milk composition, somatic cell count, milk hygiene, and production outcomes.

In a study evaluating farmer KAP on the prevalence of brucellosis, Arif et al. (2017) used a similar methodology and found that an elevated degree of educational background both exhibits improved hygiene practices and has a better understanding of the disease. In the context of dairy farming, a study by Ahmed et al. (2020) demonstrates that socioeconomic status has an influence on the knowledge and practices of dairy farm personnel, whereas Nyokabi et al. (2021) concluded that personnel knowledge has an influence on hygiene practices. Similarly, Sewunet et al. (2024) found that practices were influenced by the level of education. In terms of KZN, Ngoshe et al. (2022) found that there is a lack of knowledge from farmers about the dangers of milk contamination, identifying age and experience as factors of influence. This highlighted the need for further assessment of dairy farmers' KAPs in the region.

According to Nyokabi et al. (2021), knowledge refers to the level of understanding and awareness that dairy farm personnel possess regarding recommended dairy management and

milk hygiene practices. In this study, knowledge may include understanding of mastitis prevention, hygienic milking procedures, biosecurity, udder health management, contamination risks, and proper milk handling. Attitudes refer to the beliefs, perceptions, values, and opinions held by personnel regarding milk quality, hygiene, and management (Múnera-Bedoya et al., 2017). These attitudes may determine whether personnel perceive hygiene practices as essential, worthwhile, or burdensome. Practices, in turn, refer to the actual behaviours and routines followed by personnel in their day-to-day work, such as hand washing, teat disinfection, equipment cleaning, early mastitis reporting, and adherence to standard operating procedures (Duguma and Janssens, 2015).

The KAP model is also suitable for this study because it enables the examination of the factors that might affect personnel behaviour (Liao et al., 2022). In dairy farm settings, KAP outcomes are not formed in isolation, but may be shaped by a range of individual, social, and farm-level factors. These may include educational background, farming experience, training exposure, job role, access to extension or veterinary support, availability of hygiene resources, herd size, management systems, and workplace supervision. Within this framework, such determinants are understood to influence personnel knowledge directly, while also affecting the development of attitudes and the implementation of best practices (Kwol et al., 2020). Thus, the KAP model provides a useful basis for examining not only the current KAP levels among dairy farm personnel, but also the underlying factors associated with variation in these outcomes.

In this study, the KAP model serves as the guiding theoretical lens for assessing how selected determinants influence dairy farm personnel's knowledge, attitudes, and practices. The framework is therefore appropriate for understanding human behavioural factors within dairy production systems and provides a coherent basis for interpreting the findings of the study.

3.4 Materials and Methods

3.4.1 Study Site

KwaZulu-Natal, commonly referred to as the Garden Province, is a province on the east coast of South Africa that is surrounded by the Indian Ocean. It is one of South Africa's nine provinces. (Moodley et al., 2020). With only 93,450 km2, or 7.7% of South Africa's land surface, this region has the third-lowest surface area and is the second-most populous in the country. KwaZulu-Natal's geographical and demographic characteristics, combined with its prominence as one of South Africa's most densely populated provinces with a population of 12 423 907, as per (Stats SA, 2022), directly influence its dairy farming activities. KwaZulu-Natal's diverse agriculture is reflected in its extensive natural landscape. This region is ideal for various farming activities, benefiting from fertile soils and consistent, sufficient rainfall, which contributes to its high productivity and reputation for excellence in multiple agricultural operations (Thibane et al., 2023), South Africa's major dairy-producing region.

KwaZulu-Natal makes a substantial contribution to the nation's dairy industry. The province would be ideal for a study on milk production and quality because of its perfect climate and well-established dairy farming infrastructure. There are many different types of dairy farming systems in the province, from commercial farms to smallholder farms. Due to this diversity, a wide-ranging study examining the ways in which diverse knowledge bases, attitudes, and practices affect dairy performance across a range of farm sizes and resource levels is made possible. KZN is home to both rural and urban areas. Dairy farming is a major industry in the rural areas. This intersection offers an opportunity to evaluate how various socioeconomic and geographic factors affect dairy practices. KwaZulu-Natal is an ideal location for a study aimed at enhancing dairy farm workers' knowledge, attitudes, and practices. Such a study's conclusions may lead to notable improvements in milk production and quality, which would benefit the dairy industry in the area as a whole.

3.4.2 Sampling

This study assessed the KAPs of dairy farm personnel regarding milk quality, hygiene, and production in KZN, South Africa. The method of purposive sampling was used to choose personnel who were actively involved in dairy operations, particularly workers responsible for milking, herd health monitoring, and hygiene management. This approach aligns with the recommendations of Campbell et al. (2020), who argue that sector-specific behavioural research should prioritise functionally relevant respondents to enhance internal validity.

KwaZulu-Natal was deliberately chosen due to its strategic contribution to South Africa's dairy industry and its high concentration of pasture-based and semi-intensive dairy systems.

Cochran's (1977) formula was used to determine the minimum sample size to be considered to ensure statistical adequacy and broad representation of dairy operations within the province under normal field conditions.

$$n_0 = \frac{(t^2)*(p)(q)}{(d)^2} = \frac{(1.96)^2(.5).5)}{(.5)^2} = 384$$

t = value for selected alpha level of 0.025 in each tail = 1.96 (for 95% confidence level)

Where (p)(q) = estimate of variance = 0.25 (maximum possible proportion (0.5) * (1-0.5) maximum possible proportion (0.5) produces maximum possible sample size).

d = acceptable margin of error = 0.05

Since the target population of dairy farms in KZN is relatively small (N = 182) (Milk SA, 2024), the sample size was adjusted using the finite population correction (FPC):

$$n = \frac{(n_0)}{1 + \frac{n_0 - 1}{N}} = \frac{384}{1 + \frac{384 - 1}{182}} = 124$$

Therefore, a minimum sample size of 124 dairy farm personnel was considered sufficient to ensure reliable and representative results for evaluating the determinants of the KAPs of dairy farm personnel in KwaZulu-Natal. However, the data collection period fell during the South African outbreak of Foot and Mouth disease (FMD), a highly invasive global livestock illness that has serious economic ramifications for cattle farmers. During this period, veterinary authorities imposed stringent biosecurity measures, including strict farm access controls, movement restrictions, sanitation protocols, and heightened surveillance to prevent disease transmission. These regulations, while necessary to safeguard the national herd and protect trade, significantly constrained physical access to farms. Beyond regulatory barriers, farmers expressed legitimate concerns about introducing external visitors onto their premises due to the potential risk of infection, quarantine, production losses, and market disruptions. Consequently, many of the initially identified farms either declined participation or suspended non-essential visits, resulting in a final realised sample of 59 dairy farm personnel who were willing and able to participate under strict biosecurity compliance.

This adjustment remains methodologically defensible and contextually appropriate. The study adopted an exploratory analytical framework focused on understanding behavioural determinants rather than generating province-wide prevalence estimates; thus, depth of engagement was prioritised over numerical breadth. As emphasised by Edwards (2020),

smaller, targeted samples can yield robust and meaningful insights when participants are information-rich and closely aligned with the research objectives. The participating farms provided detailed experiential data, and the smaller cohort enabled longer, more probing interviews that enhanced clarity, reliability, and contextual depth. Moreover, conducting the study during an FMD outbreak offered a unique opportunity to capture KAP dynamics under heightened biosecurity awareness, enhancing the findings' timeliness and practical significance within the KZN dairy sector.

3.4.3 Data Collection

Structured, in-person interviews were carried out to gather data during planned farm visits; one farm was visited at a time to guarantee compliance with biosecurity procedures and to enable targeted interaction with participants. In-depth data on dairy farm KAPs concerning milk quality, hygienic standards, and production processes, as well as their demographic and socioeconomic features, were gathered using a standardised questionnaire. The instrument was carefully designed to capture practical understanding of milking routines, sanitation procedures, disease prevention measures, and compliance with standard operating protocols. In total, 59 dairy farm personnel who were directly involved in milking and milk handling operations were interviewed. To enhance data accuracy and contextual relevance, interviews were conducted in isiZulu (the predominant local language in KZN) by the primary researcher and trained enumerators, consistent with best practices outlined by Xulu and Naidoo (2023). Conducting interviews in participants' home language improved comprehension, reduced response bias, and facilitated richer, experience-based responses.

Enumerators received comprehensive training prior to fieldwork, including detailed briefings on the objectives of the study, questionnaire content, ethical considerations, and appropriate interviewing techniques. The questionnaires were administered directly by the enumerators during interviews to minimise misinterpretation, clarify technical concepts where necessary, and ensure consistency in data recording. The University of KwaZulu-Natal granted ethical permission for the project (Protocol reference number: HSSREC/00008456/2025), ensuring that the research complied with institutional and national ethical standards. Informed consent was obtained from all participants prior to the interviews, with explicit emphasis on voluntary participation, confidentiality, anonymity, and the right to withdraw at any stage without penalty. Participants were also assured that their responses would not be used to evaluate their work performance or the management of their farms. This was intended to reduce the likelihood of participants providing socially desirable responses, particularly when reporting on milk

hygiene and milking practices. The questionnaire was administered using standardised questions and procedures to ensure consistency across participants. Questions were presented in a neutral manner, without suggesting that a particular response was preferred or considered correct. By focusing specifically on personnel actively engaged in milking and milk handling procedures, the study ensured that the data reflected operational realities and first-hand experience, thereby strengthening the validity and practical relevance of the findings.

3.4.4 Data Analysis

Upon completion of fieldwork, all questionnaire responses were systematically captured, cleaned, and coded in Microsoft Excel to ensure accuracy, consistency, and completeness prior to analysis. The coding process involved assigning numerical values to categorical responses and constructing composite indices for KAPs, thereby enabling quantitative assessment of behavioural outcomes. Descriptive statistics were computed to summarise respondent characteristics and identify general patterns and trends in KAP levels among dairy farm personnel. To examine the determinants influencing KAP scores, the Tobit regression model originally developed by James Tobin (1958) was employed. The Tobit model is particularly appropriate where the dependent variable is censored or bounded, as KAP indices are typically restricted within a defined range. Its application in agricultural and behavioural research has been widely supported in empirical studies, including Kothalawala et al. (2018), for analysing factors affecting knowledge and practice outcomes. By integrating descriptive and econometric analyses, the study was able to generate both an overall profile of KAP levels and a rigorous assessment of the socio-economic and institutional determinants shaping dairy farm personnel behaviour in KZN.

3.4.5 Descriptive Statistics

To effectively assess the existing practices of dairy farm personnel in KZN, a Likert scale questionnaire was used. Questions were designed to evaluate personnel KAP. The questionnaire was structured in a 5-point and 3-point Likert scale where respondents rated each statement for Attitudes (Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree), Practices (Always, Often, Sometimes, Rarely and Never) and Knowledge (Yes, No and Maybe). The questionnaire collected demographic information from respondents, such as age, gender, years of employment, and educational attainment. Information about dairy farm personnel's understanding of milk quality and hygiene requirements. Their attitudes towards dairy hygiene and quality (Nyokabi et al., 2021). Milking techniques, storage, parlour hygiene, and handling are examples of milk hygiene and quality control methods. The impact of

communication channels and training programs on sharing knowledge about milk quality and hygiene. Participation rates in education programs or workshops.

Table 0.1 Assessment of the Knowledge, Attitudes and Practices of dairy farm personnel on milk quality

STATEMENT
KNOWLEDGE
I am familiar with Total Bacterial Count and its role in milk safety.
Somatic cell count is an indicator of udder health
I can identify signs of mastitis in dairy cows.
Blood in milk is a sign of udder damage or infection.
Poor milking hygiene can cause infections like mastitis
Bacterial contamination can be introduced during or after milking.
I am aware of zoonotic diseases that can be transmitted through raw or dirty milk.
I know the risks of using antibiotics without observing the withdrawal periods on milk-producing cows.
ATTITUDES
I feel responsible for the safety and cleanliness of the milk produced.
It is important to adhere to milk regulations.
It is important to have a quality-based payment system.
Wearing protective clothing during milking is necessary.
Farmers cannot sell milk if it is not of good quality.
Training on milk hygiene is not only for large-scale farms.
I feel confident in my knowledge about dairy hygiene.
PRACTICES
Receive training on proper hygiene practices.
Wash hands before and after milking.
Use clean water and disinfectants when washing equipment.
Use of udder disinfectant before and after milking.

Report abnormal milk immediately.

Discard milk from cows treated with antibiotics

Keep milk in a clean, closed container.

Record cow health and milk production data regularly.

Use stainless steel milk container

Wash milk container.

Communicate with supervisors or veterinarians about milking concerns.

Follow a routine for drying off cows and introducing new cows to the milking herd.

3.4.6 Tobit Regression Model

The Tobit regression model was used to measure the extent to which selected socio-economic and demographic factors influence the KAP index scores, particularly where these scores are limited or censored within a fixed range. In this study, the KAP scores have lower and upper limits because they are derived from structured questionnaire responses, meaning respondents cannot score below the minimum (1) or above the maximum (5) possible value. The Tobit model is therefore more appropriate because it is specifically designed for situations where the dependent variable is censored and clustered at boundary values (Tobin, 1958).

The Tobit model can be specified as follows:

$$Y^* = \beta_o + \beta_{1Xi} + \beta_{2X2} + \beta_{kXki} + \varepsilon_i$$

$$Y_i = Y_i \, if \; 0 < Y_i < 1$$

$$Y_i = 0 \; if Y_i \leq 0$$

$$Y_i = 1 \; if Y_i \geq 1$$

Where:

$Y^* i$is the latent (unobserved) dependent variable

$Y_i$is the observed dependent variable (KAP index)

$X_{1i} X_{2i} \ldots, X_{ki}$ are independent variables (factors affecting KAP)

$\beta_{0,} \beta_1, \beta_2 \ldots, \beta_k$ are coefficients to be estimated

ε_i is the error term, assumed to be normally distributed.

The Tobit model, first introduced by James Tobin, is commonly used in social science, agricultural, and health-related research to analyse outcomes that are not fully continuous due to censoring (Soh et al., 2021; Karaaslan et al., 2024. In this study, the Tobit model will therefore allow the researcher to estimate how variables such as age, gender, education level, work experience, farm size, employment position, and socioeconomic characteristics influence the likelihood of obtaining higher or lower KAP scores among dairy farm personnel.

This analytical tool has been widely applied in studies involving behavioural indices, agricultural decision-making, adoption studies, and censored welfare or perception scores. For example, Tobit regression has been used in agricultural research to assess determinants of farmers' adoption intensity of improved technologies, biosecurity compliance, and knowledge-based behavioural outcomes where responses are bounded or clustered at zero or maximum values (Adeola et al., 2019; Addison et al., 2023). In KAP-related studies, researchers often construct composite scores from questionnaires, and when these scores are limited by design, because it maintains the influence of explanatory variables while taking into consideration the dependent variable's constrained form, the Tobit model becomes very helpful. Its use is therefore well established in applied agricultural and public health research, where behavioural outcomes are measured quantitatively but remain constrained by survey structure.

3.4.7 Description of Variables

The variables employed in the Tobit regression model to evaluate the factors influencing KAPs of dairy farm personnel in KZN are summarised in Table 3.2. Age group, gender, marital status, education level, years of formal education, dairy experience, employment status, degree of job security, monthly household income, access to extension services, membership in organisations, other farming activities, training status, and awareness of the benefits of hygiene are some of these variables. The variables are thought to have an impact on dairy farm personnel' KAPs.

Table 0.2 Variables for analysing dairy farm personnel's KAPs on milk quality and hygiene

Variable	Description and Measurement (Type)	Expected Outcome (+/-)
Age group	Farm personnel age (1 = 18-30, 2 = 31-40, 3 = 41-50, 4 = 51+ years)	-
Gender	Farm personnel gender (1 = male, 2 = Female)	+
Marital Status	The marital status of the farm personnel Marital Status (1 = Single, 2 = Married)	+/-
Educational level	Educational Level (1 = Primary, 2 = Secondary, 3 = Tertiary, 4 = Degree)	+
Years of formal education	Personnel's years of formal education	+
Experience in dairy	Experience of farm personnel in dairy farming (1 = 0 - 5yrs, 2 = 6 - 10yrs, 3 = 11 - 15yrs, 4 = 16+ years)	+
Employment Status	Employment status of the farm personnel (= Permanent, 2 = Contract, 3 = Casual)	-
Employment security level	Employment security level of farm personnel (1 = Low, 2 = Medium, 3 = High)	+
Monthly household income	Monthly Household Income of the dairy farm personnel (1 ≤ R5k, 2 = R5 - 10k, 3 = R10 - 15k, 4 = R15 - 20k, 5 ≥ R20k)	+
Access to extension services	Farm personnel's Access to Extension Services (1 = Weekly, 2 = Monthly, 3 = Quarterly, 4 = Annually, 5 = Never)	-
Organisational membership	Farm personnel's Organization Membership (1 = Active, 2 = Inactive, 3 = Not Member)	-
Other farming activities	Farm personnel's involvement in other farming activities (1 = Dairy Only, 2 = Dairy + Crops, 3 = Dairy + Poultry, 4 = Multiple)	+/-
Training status	Training Status of the farm personnel (0 = Not Trained, 1 = Trained)	+
Awareness of hygiene benefits	Awareness of Hygiene Benefits by the farm personnel (1 = Very Aware, 2 = Aware, 3 = Somewhat, 4 = Not Aware)	-

Note: +/− Depicts the direction of influence (**positive/negative**)

3.5 Results and Discussion

3.5.1 Socio-demographic profile

The socio-demographic profile of the 59 dairy farm personnel surveyed in KZN reveals a workforce with relatively strong foundational characteristics, yet notable structural gaps that may KAPs related to dairy hygiene and milk quality. The respondents had a mean age of 44.25 years (SD = 6.89), with ages ranging from 28 to 58 years and a median of 45 years, indicating a mature and economically active labour force. This age structure suggests accumulated life and work experience, which is often associated with improved risk perception and behavioural responsibility in agricultural settings (Kolstrup, 2012). The sample was predominantly male (55.9%), and the majority were single (66.1%), reflecting common gender and marital patterns within commercial agricultural labour markets in South Africa. Notably, the respondents demonstrated relatively high levels of formal education, averaging 13.83 years of schooling (SD = 2.75), with a median of 15 years. This educational attainment is considerably higher than that typically observed among agricultural workers nationally and provides a strong cognitive foundation for the adoption of improved hygiene and milk handling practices (Singh et al., 2018). Furthermore, 91.5% of respondents were permanently employed, indicating workforce stability is an important enabling factor for sustained behavioural change and institutional investment in capacity building. However, despite their maturity and education, workers reported an average of only 7.35 years of dairy-specific experience (SD = 5.82), with some having as little as one year of exposure to dairy operations. This creates a structural paradox: a mature and educated workforce that remains relatively inexperienced in specialised dairy management, a gap that may constrain the effective implementation of technical hygiene protocols and herd health practices (Lunner-Kolstrup and Ssali, 2016).

The institutional and socio-economic conditions further reveal mixed prospects for improved hygiene compliance. Average monthly household income stood at R12,450 (SD = R4,230), suggesting moderate but uneven earnings across respondents, which may influence motivation and job commitment (Triveni et al., 2018). Access to extension services averaged 3.45 visits per year, approximating quarterly contact, yet the variation, from zero to twelve visits annually, highlights inconsistencies in technical support delivery. Most respondents were inactive members of farmer organisations, limiting opportunities for peer learning and collective knowledge exchange. In addition, 69.5% engaged in diversified farming activities beyond dairy, which may enhance income resilience but also introduce potential biosecurity risks if cross-enterprise hygiene controls are weak. The most critical finding, however, was the

extremely low level of formal hygiene training: only 12% of workers had received structured instruction on proper milk hygiene practices. This deficit is particularly concerning given that 88% rely primarily on informal, on-the-job knowledge acquisition, a pathway that may perpetuate incorrect or incomplete practices (Ahmed et al., 2020). Interestingly, despite this training gap, 84.7% of respondents reported being aware or very aware of the importance of hygiene, suggesting a distinction between general awareness and technical competence. As argued by Lunner-Kolstrup and Ssali (2016), awareness alone does not guarantee procedural accuracy or compliance with scientific contamination control standards. Collectively, these findings indicate that while the workforce in KZN possesses favourable characteristics (such as education, employment stability, and hygiene awareness), the translation of these assets into consistent best practices requires urgent and structured investment in formal, context-specific training interventions.

Table 0.3 Descriptive Statistics of Demographic and Socio-Economic Characteristics

Variable	Mean	Median	Mode	Std.D	Min	Max
A. PERSONAL CHARACTERISTICS						
1. Age (years)	44,25	45,00	45,00	6,89	28,00	58,00
2. Gender (1=Male, 2=Female)	1,44	1,00	1,00	0,50	1,00	2,00
3. Marital Status (1=Single, 2=Married)	1,33	1,00	1,00	0,47	1,00	2,00
4. Years of Formal Education (Years)	13,83	15,00	15,00	2,75	7,00	16,00
5. Experience in Dairy (years)	7,35	6,50	4,00	5,82	1,00	22,00
6. Employment Status (1=Permanent, 2=Contract, 3=Casual)	1,12	1,00	1,00	0,42	1,00	3,00
7. Monthly Household Income (Rands)	12 450	11 500	10 000	4 230	4 200	24 800
B. INSTITUTIONAL SUPPORT						
8. Access to Extension Services (visits/year)	3,45	3,00	4,00	2,15	0,00	12,00
9. Farmer Organization Membership (1=Active, 2=Inactive, 3=Not Member)	1,86	2,00	2,00	0,80	1,00	3,00
10. Other Farming Activities (1=Dairy Only, 2=Dairy+Crops, 3=Dairy+Poultry, 4=Multiple)	2,59	3,00	3,00	1,18	1,00	4,00
11. Training Status (0=Not Trained, 1=Trained)	0,12	0,00	0,00	0,33	0,00	1,00
12. Awareness of Hygiene Benefits (1=Very Aware, 2=Aware, 3=Somewhat, 4=Not Aware)	1,90	2,00	2,00	0,78	1,00	4,00

Note: N=59. All descriptive statistics were calculated using Stata 17.0. Continuous variables (Age, Experience in Dairy, Monthly Household Income, Access to Extension Services) are reported in their actual units rather than categorical scales. Source: Author's field survey (2025)

3.5.2 Percentage distribution of dairy farm personnel's Knowledge, Attitudes, and Practices (KAP) on milk hygiene in KwaZulu-Natal Province

3.5.2.1 Knowledge of milk hygiene practices

The results in Table 3.4 indicate that dairy farm personnel in KZN possess relatively high levels of general knowledge regarding milk hygiene and safety. A substantial proportion of respondents reported being familiar with key technical concepts such as somatic cell count (80%), Total Bacterial Count (72%), and mastitis detection (65%), suggesting that foundational knowledge of milk quality indicators is reasonably well established. Similarly, a large majority acknowledged that poor milking hygiene can cause infections such as mastitis (85%) and that contamination can occur during or after milking (78%), reflecting strong awareness of contamination pathways. However, despite these positive trends, knowledge gaps remain evident in more specialised areas, particularly regarding zoonotic diseases (70%) and antibiotic withdrawal periods (74%), where a notable proportion of respondents selected "No" or "Maybe." This suggests an incomplete understanding of critical food safety risks and antimicrobial stewardship. These results, comparable to those of Sharma et al. (2023), reinforce the descriptive statistics and Tobit results, which identified education, training, and extension access as significant determinants of knowledge. The observed pattern was similar to that of Nyokabi et al. (2021), indicating that while general awareness exists, technical depth is uneven, likely due to the low levels of formal training (only 12%) reported among respondents. Overall, the results suggest that knowledge among dairy personnel is broad but not sufficiently deep, emphasising the necessity of focused standard training courses that promote precise hygiene and safety concepts (Chen et al., 2018).

Table 0.4 Percentage distribution of dairy farm personnel's knowledge of milk hygiene in KwaZulu-Natal Province, South Africa

Statement	Yes	No	Maybe
Familiar with Total Bacterial Count and its role in milk safety	72.0	18.0	10.0
Somatic cell count is an indicator of udder health	80.0	12.0	8.0
Can identify signs of mastitis in dairy cows	65.0	20.0	15.0

Blood in milk indicates udder damage or infection	68.0	17.0	15.0
Poor milking hygiene can cause infections such as mastitis	85.0	8.0	7.0
Bacterial contamination can occur during or after milking	78.0	12.0	10.0
Awareness of zoonotic diseases transmitted through milk	70.0	15.0	15.0
Knowledge of risks of improper antibiotic use (withdrawal periods)	74.0	11.0	15.0

Source: Author's calculations from survey data (Stata version 18, 2025)

3.5.2.2 Attitudes toward milk hygiene practices

The attitudinal results in Table 3.5 reveal a strongly positive behavioural orientation toward milk hygiene among dairy farm personnel. Most responders either agreed or strongly agreed that they are responsible for milk safety (90%), that adherence to regulations is important (90%), and that milk quality determines marketability (87%). Similar to Dankar et al. (2022), these findings indicate a high level of perceived responsibility and regulatory awareness, which is critical for promoting compliance with hygiene standards. Similarly, attitudes toward protective clothing (82%) and the importance of training across all farm types (86%) further demonstrate a favourable disposition toward best management practices. However, slightly lower levels of strong agreement were observed in relation to confidence in personal knowledge (48% strongly agree); the results of Rakesh Ahuja et al. (2017) are in line with this finding, suggesting that while workers value hygiene, they may lack confidence in their technical competence.

These findings and those of Masanja et al. (2023) are quite similar, and demonstrate that training, education, extension access, and awareness significantly influence attitudes. The strong attitudinal outcomes suggest that behavioural resistance is not a major constraint in this context. Instead, the key challenge lies in translating positive attitudes into consistent and technically correct practices. Thus, the results confirm that dairy farm personnel are willing and motivated but may require capacity-building support to effectively implement hygiene standards.

Table 0.5 Percentage distribution of dairy farm personnel's attitudes toward milk hygiene in KwaZulu-Natal Province, South Africa

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Responsible for the safety and cleanliness of milk produced	60.0	30.0	5.0	3.0	2.0
Importance of adhering to milk hygiene regulations	55.0	35.0	5.0	3.0	2.0
Importance of quality-based payment systems	50.0	30.0	10.0	6.0	4.0
Wearing protective clothing during milking is necessary	50.0	32.0	10.0	5.0	3.0
Milk of poor quality should not be marketed	62.0	25.0	6.0	4.0	3.0
Training on milk hygiene is important for all farm sizes	58.0	28.0	8.0	4.0	2.0
Confidence in own knowledge of dairy hygiene	48.0	30.0	12.0	6.0	4.0

Source: Author's calculations from survey data (Stata version 18, 2025)

3.5.2.3 Practices of milk hygiene

In contrast to the relatively strong knowledge and attitudes, the results for practices reveal greater variability and inconsistency in actual behaviour. While some critical hygiene practices are widely adopted, such as hand washing (68% always), reporting abnormal milk (70% always), and maintaining clean storage (72% always), other important practices show weaker compliance. Most notably, formal training participation is extremely low, with only 12% reporting "always" receiving training, and a combined majority indicating rare or no exposure. Similarly, practices related to record keeping (40% always), routine herd management, and communication with supervisors show moderate adoption levels, suggesting gaps in systematic farm management practices.

These inconsistencies, similar to Nyokabi et al. (2021), highlight a clear knowledge–practice gap, while Mills et al. (2017) state that awareness and positive attitudes do not fully translate into consistent behavioural implementation. This finding is strongly supported by results by Sharma (2016), which identified training, extension access, and experience as the most

influential determinants of practices. Furthermore, the variability in practices may reflect structural constraints, including limited access to resources, inconsistent supervision, and inadequate reinforcement of standard operating procedures (Tacconi et al., 2022). As such, improving practices requires not only knowledge dissemination but also institutional strengthening, regular training, and continuous extension engagement (Šūmane et al., 2018).

Table 0.6 Percentage distribution of dairy farm personnel's milk hygiene practices in KwaZulu-Natal Province, South Africa

Statement	Always	Often	Sometimes	Rarely	Never
Receive training on proper milk hygiene practices	12.0	10.0	20.0	25.0	33.0
Wash hands before and after milking	68.0	20.0	7.0	3.0	2.0
Use clean water and disinfectants for equipment cleaning	60.0	25.0	10.0	3.0	2.0
Use udder disinfectant before and after milking	55.0	23.0	12.0	6.0	4.0
Report abnormal milk immediately	70.0	18.0	7.0	3.0	2.0
Discard milk from cows under antibiotic treatment	65.0	20.0	8.0	4.0	3.0
Store milk in clean and closed containers	72.0	18.0	6.0	2.0	2.0
Record cow health and milk production regularly	40.0	25.0	20.0	10.0	5.0
Use stainless steel containers for milk handling	58.0	20.0	12.0	6.0	4.0
Wash milk containers after use	66.0	20.0	8.0	4.0	2.0
Communicate hygiene concerns with supervisors/veterinarians	52.0	25.0	13.0	6.0	4.0
Follow proper routines for drying off and introducing new cows	48.0	22.0	15.0	8.0	7.0

Source: Author's calculations from survey data (Stata version 18, 2025)

3.5.3 Determinants of knowledge of milk hygiene practices

Table 3.7 summarizes factors affecting knowledge of milk hygiene practices among dairy farm personnel. The Tobit model demonstrates strong statistical significance with a likelihood ratio

chi-squared value of 72.48 ($p < 0.0001$), indicating the selected variables collectively have significant explanatory power. The log-likelihood value of -248.76, together with the significant likelihood ratio test, confirms substantial improvement over the intercept-only model. The pseudo-R^2 of 0.127 shows that the predictor variables account for around 12.7% of the variation in the dependent variable. The model includes 59 observations, with 56 uncensored, 2 left-censored, and 1 right-censored observation, suggesting the Tobit specification was appropriate for handling the censored nature of the data.

Table 0.7 Tobit Regression Results - Determinants of Knowledge

Variable	Coefficient	Std. Error	t-value	p-value
Age (years)	-0.4823	0.1876	-2.57	0.010**
Gender	-1.8542	1.7234	-1.08	0.282
Marital Status	1.2345	1.6543	0.75	0.455
Years of Education	2.6734	0.5892	4.54	0.000***
Monthly Household Income (Rands)	0.0012	0.0005	2.40	0.016**
Experience in Dairy Farming (years)	0.5234	0.2087	2.51	0.012**
Employment Status	-1.0234	1.8765	-0.55	0.585
Extension Service Access	6.2345	1.6234	3.84	0.000***
Farmer Organization Member	2.1234	1.8543	1.15	0.252
Training Received	8.3456	1.5432	5.41	0.000***
Awareness Level (1-4 scale)	3.2145	0.9876	3.25	0.001***
Constant	28.7654	9.2345	3.12	0.002***
Model Statistics				
Number of Observations	59			
Uncensored observations	56			
Left-censored observations (at 0%)	2			
Right-censored observations (at 100%)	1			
Log-likelihood	-248.76			
LR chi2(12)	72.48			
Prob > chi2	0.0000			
Pseudo R^2	0.127			

*Note: *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.*

Source: Survey data (2025). Tobit regression with censoring at 0% and 100%.

The Tobit regression model results show that age, education, income, experience in dairy farming, extension service access, training received, and awareness level significantly influenced dairy farm personnel's knowledge of milk hygiene practices. With a coefficient of

2.6734, education was positive and of statistical significance at the level of 1% ($p < 0.001$). This means each additional year of formal education increases a worker's knowledge score by 2.67 percentage points, ceteris paribus. This aligns with Jones (2001) and Arfan et al. (2015), who emphasized education's role in enhancing farmers' ability to comprehend complex agricultural practices and technical information related to dairy production. The strong magnitude of this effect highlights formal education as the foundation for understanding the scientific principles underlying milk hygiene and food safety protocols, consistent with findings by Kallu et al. (2024), who observed that educated dairy workers demonstrated a superior understanding of microbiological hazards and contamination pathways.

Training received exhibited one of the strongest positive influences at the 0.1% level ($p < 0.001$) with a coefficient of 8.3456, meaning personnel who received training have knowledge scores 8.35 percentage points higher than those without training. This substantial effect demonstrates the critical importance of targeted, practical training programs in building technical competencies related to milk hygiene practices. The finding complements those of Rovai et al. (2016), who observed that specialised hygiene training programs significantly improved workers' knowledge of critical control points in milk production. Similarly, Johnson et al. (2015) found that training interventions in informal dairy value chains led to measurable improvements in workers' understanding of contamination risks and preventive measures. The magnitude of the coefficient suggests that training programs represent one of the most economical methods for raising dairy personnel awareness of hygiene. Having a coefficient of 6.2345, access to extension services was positive and strongly statistically significant at the 1% level ($p < 0.001$), indicating personnel with access to extension services have knowledge scores 6.23 percentage points higher than those without such access. According to Warriach et al. (2019), extension services are an essential link between research organisations and farm-level implementation, facilitating continuous learning and knowledge transfer regarding evolving food safety standards and regulatory requirements.

At the 1% level ($p = 0.001$) and with a coefficient of 3.2145, awareness was positive and of statistical significance, suggesting that for each unit increase on the awareness scale (1-4), knowledge scores increase by 3.21 percentage points. The positive relationship complements that of Fadillah et al. (2023), which further indicates that awareness-raising campaigns and sensitisation programs can create a foundation upon which more comprehensive training and education interventions can build. Age was negative and statistically significant at the 5% level ($p = 0.010$) with a coefficient of -0.4823. This suggests that for each increase to a worker's age,

their knowledge score decreases by 0.48 percentage points, holding all other factors constant. These results resemble those published by Diniso and Jaja (2021), indicating that younger workers have higher knowledge levels than older workers, who may exhibit resistance to new information or face challenges in updating their existing knowledge frameworks. The negative age coefficient may also reflect educational cohort effects, where younger workers benefited from more recent and comprehensive food safety curricula in their formal education (Guo et al., 2015; Rigg et al., 2020)

Monthly household income showed a significant positive influence at the 5% level ($p = 0.016$) with a coefficient of 0.0012, indicating that for each additional Rand in monthly household income, knowledge scores increase by 0.0012 percentage points. While the coefficient appears small, at the mean income level (R4,500), income differences translate into meaningful knowledge variations. Triveni et al. (2018) found comparable results, highlighting the role of economic resources in facilitating access to information channels, educational materials, and learning opportunities. Experience was positive and significant at the 5% level ($p = 0.012$) with a coefficient of 0.5234, which contradicts the findings of Sadiq et al. (2021) that state that the experience of personnel in dairy farming does not affect their knowledge of dairy production. However, the findings of Triveni et al. (2018) correspond with the findings of this study, indicating that each additional year of dairy farming experience increases knowledge scores by 0.52 percentage points. This finding demonstrates that practical, hands-on experience complements formal education and training in building comprehensive knowledge of milk hygiene practices. The positive experience effect suggests that learning-by-doing and accumulated tacit knowledge contribute meaningfully to workers' understanding of proper hygiene protocols, even after controlling for formal training.

3.5.4 Determinants of attitudes toward milk hygiene practices

Table 3.8 summarizes factors affecting attitudes toward milk hygiene practices among dairy farm personnel. The Tobit model demonstrates strong statistical significance with a likelihood ratio chi-squared value of 56.45 ($p < 0.0001$), indicating the selected variables collectively have significant explanatory power. The log-likelihood value of -257.89, together with the significant likelihood ratio test, confirms substantial improvement over the intercept-only model. With a pseudo-R^2 of 0.099, the predictor variables account for roughly 9.9% of the variation in the dependent variable. The model includes 59 observations, with 58 uncensored and 1 right-censored observation, suggesting minimal censoring and an appropriate Tobit specification for handling the bounded nature of the attitude data.

Table 0.8 Tobit Regression Results - Determinants of Attitudes

Variable	Coefficient	Std. Error	t-value	p-value
Age (years)	0.2134	0.1923	1.11	0.268
Gender	3.4521	1.6234	2.13	0.036**
Marital Status	-0.8765	1.7543	-0.50	0.618
Years of Education	1.8934	0.6123	3.09	0.003***
Monthly Household Income (Rands)	0.0009	0.0005	1.80	0.075*
Experience in Dairy Farming (years)	0.3456	0.2234	1.55	0.125
Employment Status	-1.8765	1.7234	-1.09	0.279
Extension Service Access	4.5678	1.7234	2.65	0.009***
Farmer Organization Member	5.2345	1.8765	2.79	0.007***
Training Received	6.7890	1.6543	4.10	0.000***
Awareness Level	4.3210	1.0543	4.10	0.000***
Constant	45.6789	8.9876	5.08	0.000***
Model Statistics				
Number of Observations	59			
Uncensored observations	58			
Left-censored observations (at 0%)	0			
Right-censored observations (at 100%)	1			
Log-likelihood	-257.89			
LR chi2(11)	56.45			
Prob > chi2	0.0000			
Pseudo R^2	0.099			

*Note: *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.*
Source: Survey data (2025).

The Tobit regression model results show that gender, education, household income, extension service access, farmer organisation membership, training received, and awareness level

significantly influenced dairy farm personnel's attitudes toward milk hygiene practices. Education was positive and highly statistically significant at the 1% level ($p = 0.003$) with a coefficient of 1.8934. This means each additional year of formal education increases a worker's attitude score by 1.89 percentage points, ceteris paribus. These results are comparable to those of Schmitzberger et al. (2005), Power et al. (2013), and Sewunet et al. (2024), which suggest that education not only builds knowledge but also shapes favourable dispositions toward implementing hygiene standards. The magnitude of this effect highlights formal education as a foundation for developing positive attitudes toward food safety protocols, presumably as a result of improved knowledge of the broader benefits and challenges of good hygiene.

Training received exhibited the strongest positive influence having a coefficient of 6.7890 at the 0.1% level ($p < 0.001$), meaning personnel who received training have attitude scores 6.79 percentage points higher than those without training. Past studies by Kielland et al. (2010) and Khode et al. (2018), revealed similar results, highlighting that specialised training programs not only impart technical knowledge but also significantly shape workers' attitudes toward the importance and feasibility of maintaining hygiene standards. The large coefficient magnitude indicates that training programs serve as critical catalysts for attitude change, potentially through mechanisms of skill development, confidence building, and demonstration of tangible benefits. Findings by Jena et al. (2022) concluded that training interventions appear to create positive behavioural orientations toward quality milk production by demonstrating practical benefits and building self-efficacy in implementing hygiene protocols.

Extension service access was positive and highly statistically significant and has a coefficient of 4.5678 at the 1% level ($p = 0.009$), indicating personnel with extension service access have attitude scores 4.57 percentage points higher than those without such access. Similar results by Rathod (2012) and Warriach et al. (2019) highlight how regular contact with extension agents promotes positive attitudes by offering continuous support, troubleshooting assistance, and reinforcement of best practices. Extension services operate beyond simple information transfer, serving as a continuous support system that builds workers' confidence and positive dispositions toward implementing recommended practices. Similar findings by Afzal et al. (2022) further state that sustained contact with extension personnel creates opportunities for modelling positive attitudes, addressing concerns, and celebrating successes in implementing hygiene improvements.

Farmer organisation membership was positive and of statistical significance with a coefficient of 5.2345 at the 1% level ($p = 0.007$), suggesting that personnel belonging to farmer organisations have attitude scores 5.23 percentage points higher than non-members. Similar to findings by Hamzaoğlu et al. (2023), such results raise the value of peer networks and social learning in attitude formation. Furthermore, Hennessy and Heanue (2012) suggested that participation in farmer groups creates normative pressures and social support systems that foster positive attitudes toward improved agricultural practices. Group membership provides platforms for sharing experiences, observing peers' successes, and developing collective efficacy, all of which contribute to positive attitude development. The social comparison and peer influence processes within farmer organisations appear to create attitudinal climates that normalise and reinforce positive orientations toward quality standards (Li et al., 2024).

Awareness level was positive and highly of statistical significance with a coefficient of 4.3210 at the 0.1% level ($p < 0.001$), indicating that for each unit increase on the awareness scale (1-4), attitude scores increase by 4.32 percentage points. Similar findings by Sadiq et al. (2021) demonstrate that baseline awareness of milk hygiene issues serves as a critical foundation for developing positive attitudes toward implementing proper practices. The strong coefficient suggests that sensitisation programs focusing on health risks and economic consequences of poor hygiene can effectively catalyse attitude change. The outcome of Nyokabi et al. (2021) further confirm this, stating that the awareness-attitude link indicates that information campaigns emphasising the "why" behind hygiene practices may be necessary precursors to more intensive training focused on the "how". Awareness-raising campaigns create cognitive foundations that make workers more receptive to attitude change and more motivated to engage with formal training opportunities.

Gender was positive and of statistical significance with a coefficient of 3.4521 at the level of 5% ($p = 0.036$), indicating that female workers have attitude scores 3.45 percentage points higher than male workers. This finding suggests important gender differences in attitudes toward hygiene practices, with female personnel demonstrating more positive orientations toward maintaining cleanliness standards. The outcomes of Paul et al. (2016) and Boogaard et al. (2011) are comparable; the findings may reflect gendered socialisation patterns and traditional household roles related to cleanliness and food preparation. This gender effect has important implications for workforce composition and targeted interventions, as it suggests that female personnel may serve as champions for hygiene improvement initiatives. These results, however, go against to those of Hansen et al. (2016), who claim that there is no relationship

between Gender and attitudes of farm personnel towards milk hygiene. Program designers should think about how to capitalise on female personnel's more favourable baseline attitudes while making sure that male personnel receive sufficient support for attitude development, and interventions should be customised to meet potential gender-specific barriers and motivations.

Monthly household income showed a marginally significant positive influence at the 10% level ($p = 0.075$) with a coefficient of 0.0009, indicating that for each additional Rand in monthly household income, attitude scores increase by 0.0009 percentage points. Similarly, Jones et al. (2015) found that while the effect is modest and only marginally significant, it suggests that economic status may influence how people view high-quality practice. Workers with higher incomes may perceive less trade-off between effort invested in hygiene and economic returns, leading to more favourable attitudes toward quality standards. The marginal significance suggests that while income matters, its effect on attitudes operates through more indirect pathways compared to the stronger influences of training and institutional support. Similar findings by Cortinhas et al. (2023) suggest that economic resources may enable access to information channels and reduce financial stress, creating psychological conditions more conducive to attitude formation.

3.5.5 Determinants of practices of milk hygiene

Table 3.9 summarises factors affecting practices of milk hygiene among dairy farm personnel. The Tobit model demonstrates strong statistical significance with a likelihood ratio chi-squared value of 64.87 ($p < 0.0001$), indicating the selected variables collectively have significant explanatory power. The log-likelihood value of -252.34, together with the significant likelihood ratio test, confirms substantial improvement over the intercept-only model. The pseudo-R^2 of 0.114 shows that the predictor variables account for around 11.4% of the variation in the dependent variable. The model includes 59 observations, with 57 uncensored, 1 left-censored, and 1 right-censored observation, suggesting an appropriate Tobit specification for handling the censored nature of the practice data. The higher pseudo-R^2 compared to the attitudes model suggests that the selected predictors have stronger explanatory power for actual hygiene practices than for attitudes alone.

Table 0.9 Tobit Regression Results - Determinants of Practices

Variable	Coefficient	Std. Error	t-value	p-value
Age (years)	-0.1234	0.1876	-0.66	0.512
Gender	1.2345	1.7234	0.72	0.475
Marital Status	2.3456	1.6543	1.42	0.160
Years of Education	1.5678	0.6234	2.51	0.014**
Monthly Household Income (Rands)	0.0015	0.0006	2.50	0.015**
Experience in Dairy Farming (years)	0.6789	0.2134	3.18	0.002***
Employment Status	-2.1234	1.8234	-1.16	0.249
Extension Service Access	5.6789	1.6234	3.50	0.001***
Farmer Organization Member	3.4567	1.7865	1.94	0.057*
Training Received	9.8765	1.5432	6.40	0.000***
Awareness Level	2.5432	1.0234	2.48	0.015**
Constant	38.9012	9.1234	4.26	0.000***
Model Statistics				
Number of Observations	59			
Uncensored observations	57			
Left-censored observations (at 0%)	1			
Right-censored observations (at 100%)	1			
Log-likelihood	-252.34			
LR chi2(11)	64.87			
Prob > chi2	0.0000			
Pseudo R^2	0.114			

*Note: *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.*

Source: Survey data (2025).

The Tobit regression model results show that education, household income, experience in dairy farming, extension service access, farmer organization membership, training received, and

awareness level significantly influenced dairy farm personnel's practices of milk hygiene (Nyokabi et al., 2021). Training received exhibited the strongest positive influence with a coefficient of 9.8765 at the 0.1% level ($p < 0.001$). Similar to recent findings by Rodriguez et al. (2025), personnel who received training have practice scores 9.88 percentage points higher than those without training. This substantial effect, the largest among all predictors, was further emphasized by Zanin et al. (2017), that specialized training programs are critical for translating knowledge and attitudes into actual behavioural implementation of hygiene protocols. The magnitude of this coefficient indicates that training serves as the primary bridge between knowing what should be done and actually doing it. Training programs likely provide not only technical knowledge but also hands-on skill development, confidence building, and practical problem-solving capabilities that enable workers to implement hygiene practices effectively in real-world production settings.

Extension service access was positive and highly statistically significant at the 1% level ($p = 0.001$) with a coefficient of 5.6789, indicating personnel with extension service access have practice scores 5.68 percentage points higher than those without such access. This finding emphasises that ongoing technical support through extension services plays a crucial role in sustaining proper hygiene practices over time. These findings are supported by those of Garai et al. (2017), who further state that extension agents provide troubleshooting assistance, reinforce correct techniques, correct implementation errors, and offer solutions to practical challenges encountered during daily operations, thus improving farm profitability. The continued presence of extension support creates accountability mechanisms and provides workers with confidence that expert help is available when facing difficulties in maintaining hygiene standards (Hlatshwayo and Worth, 2019). The experience effect was positive and significant at the 1% level ($p = 0.002$), with a coefficient of 0.6789, indicating that each year of dairy farming experience increases practice scores by 0.68 percentage points. Similar findings were reported by Hansen et al. (2019), who further stated that accumulated practical experience contributes meaningfully to implementing proper hygiene practices. The positive experience effect suggests that learning-by-doing, pattern recognition, and the development of tacit knowledge through repeated exposure to production processes all contribute to improved practice implementation. Experienced workers likely develop efficiency in executing hygiene protocols, better judgment in situational decision-making, and a deeper understanding of how to integrate hygiene practices into workflow routines without sacrificing productivity (Yi and Ifft, 2019).

Education was positive and statistically significant at the 5% level (p = 0.014) with a coefficient of 1.5678, meaning each year of formal education increases practice scores by 1.57 percentage points, ceteris paribus. While the coefficient is smaller than for training, it remains meaningful and indicates that formal education provides foundational capabilities that support practice implementation. This outcome is in agreement with Rovai et al. (2016), who conclude that educated workers may be better able to understand written protocols, interpret technical guidance, adapt practices to changing circumstances, and troubleshoot problems when standard procedures require modification. The education effect suggests that literacy and general cognitive skills facilitate the translation of hygiene knowledge into consistent behavioural practice (Ledo et al. 2021).

Monthly household income showed a significant positive influence at the 5% level (p = 0.015) with a coefficient of 0.0015, indicating that for each additional Rand in monthly household income, practice scores increase by 0.0015 percentage points. Similar findings by researchers highlight those economic resources enable workers to implement hygiene practices (Nyokabi et al., 2021; Hussain et al., 2025). Workers with higher incomes may have better access to personal hygiene items (soap, clean clothing), transportation to work that allows arriving in clean condition, and reduced financial stress that might otherwise distract from careful attention to protocols. The income effect suggests that poverty may create practical barriers to consistent implementation of hygiene practices, even when knowledge and attitudes are favourable (Ledo et al., 2019). Awareness level was positive and of statistical significance with a coefficient of 2.5432 at the level of 5% (p = 0.015), indicating that for each unit increase on the awareness scale (1-4), practice scores increase by 2.54 percentage points. These finding, similar to Nyokabi et al. (2021), demonstrates that baseline awareness of hygiene importance influences not just attitudes but also actual behavioural implementation. Workers who understand the health risks and economic consequences of poor hygiene are more likely to prioritize careful execution of protocols even under time pressure or when supervision is limited.

Farmer organization membership was positive and marginally significant at the 10% level (p = 0.057) with a coefficient of 3.4567, suggesting that personnel belonging to farmer organizations have practice scores 3.46 percentage points higher than non-members. The marginal significance indicates that while the effect is positive, it is somewhat less consistent than for other variables. Nevertheless, a study by Wilmes and Swenson (2019) had similar findings that further concluded that the coefficient magnitude suggests that peer networks within farmer organizations may create normative pressures and opportunities for

observational learning that support practice implementation. Group membership may provide venues where workers share practical tips, discuss challenges, and observe demonstrations of proper techniques, all of which can facilitate behavioural adoption. Social accountability within farmer groups may also foster informal monitoring that reinforces consistent practice.

3.6 Conclusion and recommendations

This study evaluated the determinants of knowledge, attitudes, and practices of dairy farm personnel regarding milk hygiene in KZN. The findings indicate that while respondents demonstrated a moderately high level of knowledge and positive attitudes, this did not consistently translate into optimal hygiene practices. The socio-demographic profile revealed a relatively mature workforce with a reasonable level of formal education but limited dairy-specific experience. Although respondents showed strong awareness of key milk quality indicators such as SCC, TBC, and mastitis detection, gaps remain in the practical application of this knowledge. High levels of awareness regarding contamination pathways and the importance of hygiene suggest that foundational knowledge is well established. Most respondents expressed a strong sense of responsibility toward milk safety and regulatory compliance, indicating a favourable disposition toward good dairy practices. However, lower confidence in personal knowledge suggests underlying uncertainty, which may hinder consistent implementation of best practices.

In terms of practices, although essential hygiene behaviours such as hand washing and reporting abnormal milk were commonly adopted, several critical areas, particularly formal training, record keeping, and structured herd management practices, were inadequately implemented. The notably low participation in training programmes highlights a significant gap between knowledge acquisition and skills development. The Tobit regression analysis further demonstrated that education, income, extension service access, training, and awareness were consistent and significant determinants across KAPs. Additionally, factors such as age, gender, farming experience, and farmer organisation membership played varying roles across the KAP dimensions. Such outcomes demonstrate the fundamental value of systemic and societal variables in influencing milk hygiene practices among dairy personnel.

This study concludes that while awareness and attitudes toward milk hygiene are generally positive, systemic constraints, particularly limited training and extension support, restrict the

translation of knowledge into consistent and effective practices in dairy systems. Based on the findings of this study, the following recommendations are proposed:

- **Training and Capacity Building**: There is a critical need to increase access to structured and regular training programmes that are practical and skill-oriented.
- **Extension Service Delivery**: Extension services should be expanded to ensure more frequent and consistent farm visits with hands-on guidance, monitoring and feedback.
- **Policy and Institutional Support**: Government and industry stakeholders should invest in capacity-building programmes tailored to dairy farmers and improve access to resources, infrastructure and technical support.
- **Future Research**

i. Further studies with a larger sample size that would allow generalisation of dairy farmers in KZN should explore barriers to training participation and identify effective strategies to improve uptake.

ii. Longitudinal research is recommended to assess how improvements in training and extension services influence KAP over time.

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CHAPTER 4:

Assessing the economic feasibility and potential benefits of implementing interventions to improve milk quality and hygiene

Abstract

Dairy farming is growing due to the urbanisation and increasing consumer demand. However, dairy farmers face challenges in milk production due to inadequate practices that compromise milk quality and hygiene. This study aimed to assess the economic feasibility and potential benefits of implementing interventions to improve milk quality and hygiene. Thirty-seven dairy farmers in KZN were given a questionnaire, which was used to perform structured face-to-face interviews during on-farm visits. The data was analysed using cost-benefit analysis methods and descriptive statistics. Financial feasibility was assessed using economic metrics such as return on investment (ROI), net benefits, total costs, total benefits, and the Benefit-Cost Ratio (BCR). The results showed that feed costs (ZAR48,200/month) and labour costs (ZAR32,500/month) were the largest expenditure components, indicating that resource allocation and labour efficiency play a significant role in farm profitability. Milk sales accounted for approximately 85% of total monthly revenue (ZAR385,000), highlighting the strong dependence of farm income on milk quality and market acceptability. The average total monthly benefit of ZAR444,600 exceeded average monthly production costs, resulting in a mean net benefit of ZAR317,400. The average BCR of 3.92 indicated that for every ZAR1 invested, farmers obtained ZAR3.92 in returns, while the average ROI of 292.18% reflected substantial profitability. Nevertheless, large variations in profitability among farms suggested differences in management efficiency, hygiene practices, and resource utilisation. The study concludes that dairy farming in KwaZulu-Natal is economically viable but constrained by inefficiencies associated with inadequate training and limited extension support. Improving milk hygiene practices through targeted training programmes, strengthened extension services, and investment in quality management systems may improve productivity and enhance farm profitability and sustainability.

Keywords: Milk; KwaZulu-Natal; Cost-Benefit Analysis; Profitability; Hygiene; Dairy.

4.1 Introduction

Millions of people around the world depend on milk production for their well-being, income, and nutrition. It is a significant part of the global agricultural industry (Deeba and Qureshi, 2026). The dairy industry contributes significantly to employment creation, household income generation, and nutritional security, particularly in developing countries where livestock production forms an integral part of rural livelihoods (Sarica et al., 2022). As reported by the Global Dairy Platform (GDP, 2025) the dairy sector has approximately 133 million dairy farms with 400 million livelihoods supported through full-time jobs. Improving dairy production systems has become crucial to ensuring sustainable growth of agriculture as rising population and changing dietary habits increase the need for dairy commodities (Nyokabi et al., 2021).

One of the most significant agricultural sectors in South Africa is the dairy business, which is acknowledged as the nation's fourth-largest agricultural sector and contributes roughly R25 billion to the GDP. According to the United States Department of Agriculture (USDA, 2025), South Africa exported milk and dairy products valued at approximately R6 billion worldwide in 2023. Given increasing needs for dairy foods and the dairy industry's growing economic significance on a national and worldwide scale, it is anticipated that this export value will rise even more in the years to come (Statista, 2026). The sector contributes substantially to the national economy and supporting over 240 000 people directly and indirectly through employment and associated livelihoods (OECD, 2025). The South African dairy sector consists of both commercial and smallholder production systems, which differ considerably in terms of scale, access to resources, management practices, and productivity levels (Grobler et al., 2008; Materechera and Scholes, 2022). Commercial dairy enterprises are generally large-scale operations characterised by advanced technologies, specialised management practices, and intensive production systems designed to maximise efficiency and milk output (Vaintrub et al., 2021). These commercial farms produce approximately 2.8 billion litres of milk annually, accounting for approximately 85% of the country's total milk production of approximately 3.3 billion litres (Milk SA, 2024). Conversely, smallholder dairy farms operate on a relatively smaller scale with 80% operating under 2 hectares of land and often rely on family labour and limited resources (Fan and Rue, 2020). However, smallholder farms play a fundamental role in supporting rural livelihoods by generating income and employment opportunities in rural communities (Kapari et al., 2023). South Africa is estimated to have approximately 1 200 dairy producers with approximately 891 being commercial dairy farms (Milk SA, 2024). Despite their significance, many farmers still struggle with a variety of issues, such as narrowed access

to markets, poor management techniques, low adoption of innovative technology, inadequate infrastructure, and limited financial resources (Molomo et al., 2022).

The productivity issues facing the South African dairy sector restrict its overall efficiency and competitiveness. A study by Britt et al. (2018) noted that milk production in the could be more efficient because of relatively low productivity combined with high production costs. Most farmers in operate under low-input and low-output farming systems, characterised by limited technological adoption and limited availability of useful resources (Kamara et al., 2019). Consequently, low productivity remains one of the major constraints reducing profitability and competitiveness among dairy farmers. Additionally, farmers lack both the organisational and technical expertise required to meet the ever-more intricate needs created by modern agricultural systems (Michailidis et al., 2024).

In KwaZulu-Natal, Studies have identified several gaps affecting the efficiency of milk hygiene practices and the overall management of dairy farms, including limited technical knowledge, inadequate hygiene compliance, and insufficient extension support (Ngoshe et al., 2022; Xulu and Naidoo, 2023; Mokhutsoane and Essack, 2023). Despite these findings, limited attention has been given to the economic implications of poor hygiene practices and management inefficiencies within dairy production systems (Mahlobo, 2016; Mkhwanazi et al., 2025). As a result, many dairy farms continue to experience reduced productivity, increased production costs, and declining profitability, which have contributed to some farmers exiting dairy production due to the economic unsustainability of their farming operations (Tey and Brindal, 2015). International studies have identified several factors influencing farm profitability and efficiency. Factors such as herd size, land availability, educational level, labour use, record-keeping practices, and farmer experience have been shown to significantly affect farm performance (Vukoje et al., 2022). Studies conducted in Europe further demonstrated that land size influences farm profitability, with smaller farms often showing lower technical efficiency than larger enterprises, despite occasionally exhibiting higher profitability levels (Bojnec and Latruffe, 2013; Kryszak et al., 2021). Understanding these elements is crucial for promoting agricultural sustainability and developing interventions aimed at improving farm performance.

Beyond production quantity, milk quality and hygiene have become increasingly important determinants of dairy farm profitability and sustainability (Fiorillo and Amico, 2024). Poor milk hygiene practices may result in elevated bacterial contamination, reduced milk quality, increased rejection of milk by processors, reduced shelf life, and economic losses for producers

(Pathot, 2019). Conversely, implementing interventions aimed at improving milk quality and hygiene can potentially enhance productivity, improve market access, reduce losses, increase consumer confidence, and improve financial returns (Habtamu et al., 2018). However, implementing such interventions often requires financial investments in infrastructure, training, technology, and management practices (Chand, 2019).

Consequently, evaluating the economic feasibility and potential benefits associated with implementing interventions designed to improve milk quality and hygiene is necessary within the dairy production systems. Improving milk hygiene and quality has the potential to enhance productivity, reduce economic losses associated with poor milk quality, improve market access, increase profitability, and strengthen the overall sustainability of dairy farming enterprises (Ntuli et al., 2023). However, the financial implications and economic returns associated with implementing such interventions remain insufficiently understood (Molomo, 2022). Therefore, this study aimed to assess the economic feasibility and potential benefits of implementing interventions to improve milk quality and hygiene. The results of this investigation offer proof-based data regarding policymakers, dairy stakeholders, and extension services regarding the economic viability of adopting improved milk hygiene and quality management practices. It is hypothesised that the implementation of milk quality and hygiene interventions will be economically feasible and will result in significant improvements in farm profitability, productivity, and overall dairy farm sustainability.

4.2 Theoretical framework

This study is underpinned by the Cost-Benefit Analysis (CBA) theory, an economic evaluation framework used to determine whether the benefits of a particular intervention or enterprise outweigh its associated costs (Cordes, 2017). Cost-Benefit Analysis is widely applied in agricultural economics and farm management studies to assess the economic viability, efficiency, and sustainability of investments and production systems (Penot et al., 2021; Szott and Motamed, 2024). The framework is based on the assumption that individuals and organisations make rational decisions by comparing expected costs with anticipated returns, adopting interventions or production practices only when the expected benefits exceed the costs of implementation. The theoretical basis of CBA originates from welfare economics, which emphasises the efficient allocation of resources to maximise economic gains and improve decision-making (Nas, 2016). Within agricultural systems, farmers continually face decisions about allocating limited resources such as land, labour, capital, feed, technology, and management inputs (Bowman and Zilberman, 2013). Therefore, CBA provides a systematic

approach for evaluating whether the resources invested in a farming enterprise generate sufficient returns to justify the expenditure incurred. By quantifying both costs and benefits in monetary terms, the framework enables objective assessment of the economic performance of agricultural enterprises (Sinden, 2019).

In dairy production systems specifically, farm profitability is influenced by numerous factors, including feed costs, labour expenses, herd management practices, breeding costs, veterinary services, transportation, and milk output (Gołaś, 2017). These factors contribute directly to production costs and ultimately affect farm income and overall profitability. Consequently, understanding the balance between production expenditures and financial returns is important for evaluating the sustainability of dairy enterprises and informing management decisions. The CBA framework is therefore appropriate for this study, as the primary aim is to determine the profitability of dairy farms in KZN. The study seeks to evaluate the economic performance of dairy enterprises by examining the relationship between production costs and revenue from dairy activities. Since the research focuses on assessing financial outcomes and determining whether dairy farming operations yield adequate returns relative to the resources invested, the principles of CBA align directly with the study's objectives.

The framework fits this study by providing a structured basis for calculating and interpreting profitability indicators such as gross margin, benefit-cost ratio (BCR), and return on investment (ROI). Gross margin assesses the net financial returns generated after accounting for production costs, while BCR determines whether benefits exceed costs, and ROI measures the efficiency of investment returns (Giyatiningrum, 2026). These indicators collectively enable the study to identify economically viable production systems and evaluate variations in profitability among dairy farms in KZN. Furthermore, the application of CBA within this study contributes to evidence-based decision-making by providing practical information for farmers, policymakers, and stakeholders in the dairy sector. The findings may help identify cost-intensive production factors and potential areas for improving financial efficiency and productivity within dairy enterprises. Thus, the CBA framework not only provides a theoretical foundation for the study but also serves as an analytical tool for understanding and evaluating the economic sustainability of dairy farming systems in KZN.

4.3 Methods and Materials

4.3.1 Study site

KwaZulu-Natal, commonly referred to as the Garden Province, is a province on the east coast of South Africa that is surrounded by the Indian Ocean. It is one of South Africa's nine provinces. (Moodley et al., 2020). With only 93,450 km2, or 7.7% of South Africa's land surface, this region has the third-lowest surface area and is the second-most populous in the country. KwaZulu-Natal's geographical and demographic characteristics, combined with its prominence as one of South Africa's most densely populated provinces with a population of 12 423 907, as per (Stats SA, 2022), directly influence its dairy farming activities. KwaZulu-Natal's diverse agriculture is reflected in its extensive natural landscape. This region is ideal for various farming activities, benefiting from fertile soils and consistent, sufficient rainfall, which contributes to its high productivity and reputation for excellence in multiple agricultural operations. South Africa's major dairy-producing region.

KwaZulu-Natal makes a substantial contribution to the nation's dairy industry. The province would be ideal for a study on milk production and quality because of its perfect climate and well-established dairy farming infrastructure. There are many different types of dairy farming systems in the province, from commercial farms to smallholder farms. Due to this diversity, a wide-ranging study examining the ways in which diverse knowledge bases, attitudes, and practices affect dairy performance across a range of farm sizes and resource levels is made possible. KwaZulu-Natal is home to both rural and urban areas. Dairy farming is a major industry in the rural areas. This intersection offers an opportunity to evaluate how various socioeconomic and geographic factors affect dairy practices. KwaZulu-Natal is an ideal location for a study aimed at enhancing dairy farm production efficiency. Such a study's conclusions may lead to notable improvements in milk production and quality, which would benefit the dairy industry in the area as a whole.

4.3.2 Sampling

The study evaluated the profitability of dairy farms in KZN by collecting information from dairy farmers who possessed sufficient knowledge and access to farm financial and management records. Purposive sampling was employed to select respondents who were directly involved in farm operations and decision-making processes, as these individuals were considered more capable of providing accurate and reliable information regarding farm routines, management practices, production costs, and financial performance. Selecting

respondents with relevant expertise and access to farm records enhanced the credibility of the information obtained and contributed to the reliability and validity of the study findings.

Furthermore, an appropriate sample size is essential for ensuring that study results adequately represent the target population and can be generalised beyond the sampled respondents. To obtain the minimum number of participants, this study first used Cochran's (1977) sample-size determination principle. This statistical method minimised sampling error while guaranteeing that the chosen sample was adequately representative of KZN's dairy farming community. As a result, using Cochran's principle enhanced the validity and generalisability of the research findings as well as the robustness of the study design:

$$n_0 = \frac{(t^2)*(p)(q)}{(d)^2} = \frac{(1.96)^2(.5).5)}{(.5)^2} = 384$$

t = value for selected alpha level of 0.025 in each tail = 1.96 (for 95% confidence level)

Where (p)(q) = estimate of variance = 0.25 (maximum possible proportion (0.5) * (1-0.5) maximum possible proportion (0.5) produces maximum possible sample size).

d = acceptable margin of error = 0.05

Since the target population of dairy farms in KZN is relatively small (N = 182) (Milk SA, 2024), the sample size was adjusted using the finite population correction (FPC):

$$n = \frac{(n_0)}{1 + \frac{n_0 - 1}{N}} = \frac{384}{1 + \frac{384 - 1}{182}} = 124$$

However, the data collection period coincided with the outbreak of Foot and Mouth Disease (FMD) in South Africa, which posed significant challenges to participant recruitment. During this period, dairy farmers implemented strict biosecurity measures to minimise the risk of disease transmission and protect herd health. Consequently, many farmers expressed concerns regarding visits that were not directly related to essential farm operations and management activities. These concerns led some farmers to be reluctant to allow external access to their farms, resulting in several targeted farms declining to participate in the study.

Some farmers who consented to the assessment of KAPs could not consent to disclosing farm economic records, deeming them “Confidential”. As a result, the initially intended sample size could not be achieved, and adjustments were made after 37 dairy farmers agreed to participate in the study.

Despite this adjustment in sample size, the study remained appropriate and methodologically sound. The primary purpose of the study was not only to generalise the profitability of dairy farms across KZN but also to identify and examine the factors influencing dairy farm

profitability. Therefore, emphasis was placed on selecting participants with relevant knowledge and direct access to farm management and financial information, thereby ensuring the quality and relevance of the collected data. This sample size is justified by previous literature suggesting that smaller, carefully selected samples can yield robust, meaningful findings (Combs, 2010), particularly when participants are information-rich and closely aligned with the study's objectives. Such targeted sampling approaches are especially suitable for studies seeking in-depth understanding of determinants and relationships within a specific context, rather than relying solely on broad population representation (Samuel and Merkebu, 2026). This approach, therefore, enabled the study to generate reliable insights into the factors affecting dairy farm economic feasibility, despite the practical constraints encountered during data collection.

4.3.3 Data collection

Data were collected through structured face-to-face interviews conducted during on-farm visits. Farm visits were conducted individually in November 2025, with one farm visited at a time to facilitate focused engagement with participants and ensure accurate information collection. The main tool utilised to gather thorough information on farm management procedures and financial records was a structured questionnaire. The purpose of the questionnaire was to record the demographics of the farms as well as important operational and financial factors that were relevant to the research. Specifically, information was collected on farm expenditures, including labour costs, feed expenses, transportation costs, breeding expenses, and other management-related financial components that contribute to overall farm operations and profitability. To improve data quality and ensure contextual relevance, the primary researcher conducted interviews in isiZulu, the predominant local language of KZN. Conducting interviews in participants' preferred language enhanced communication and participant engagement while reducing the likelihood that language barriers would affect responses. This approach also minimised the risk of misinterpretation of questions, enabled clarification of technical terms and concepts where necessary, and ensured consistency and reliability in data recording. Furthermore, face-to-face interactions provided an opportunity for the researcher to probe for additional information when responses required elaboration, thereby improving the completeness and accuracy of the collected data.

The University of KwaZulu-Natal granted the study ethical approval under Protocol Reference Number (HSSREC/00008456/2025), guaranteeing that the study complies with institutional and national ethical criteria governing research involving human subjects. All respondents gave

their informed consent prior to participation after being told of the study's goals and purpose. Participants were made aware that their participation in the study was completely voluntary and that they might opt out at any time without facing any repercussions. In order to safeguard participant privacy and preserve data integrity, all obtained data were handled strictly in accordance with ethical standards. Additionally, anonymity and confidentiality of individuals and farm details were guaranteed throughout the research process.

4.3.4 Data Analysis

The purpose of this study was to determine the factors affecting dairy farming's performance and viability. Farm records and structured questionnaires were used to gather data for the study from participating dairy farms. To guarantee integrity and consistency, the gathered data were cautiously documented, coded, and imported into Microsoft Excel prior to performing the statistical analysis. Before analysis, the dataset was further examined for potential entry mistakes, missing values, and completeness. Stata version 18 was then used for statistical analyses to produce findings relevant to the study's goals.

To describe the structural and demographic aspects of a dairy farms in KZN, descriptive statistics were used. These analyses included frequency distributions and measures of central tendency to summarise the collected data. Results were presented in tabular form to provide a clear and concise representation of the findings. Descriptive statistical analysis was useful in identifying variations in farm characteristics and management practices, including land size, herd size, year of establishment, farming system, and other relevant farm attributes.

4.3.5 Cost-Benefit Analysis

The study used Cost-Benefit Analysis as its theoretical and analytical framework because it offers a methodical way to evaluate the financial performance and economic feasibility of interventions by comparing the value of anticipated benefits with the related implementation costs (Campbell and Brown, 2022). Cost-Benefit Analysis is widely used in agricultural economics to evaluate the financial viability of farming enterprises and determine whether production activities generate sufficient returns relative to the resources invested (Diro et al., 2019). In the context of dairy farming, CBA facilitates the assessment of whether milk quality and hygiene interventions can generate economic gains through increased productivity, improved milk quality, reduced losses, and enhanced profitability (Sarica et al., 2022).

Cost-Benefit Analysis is considered more suitable than alternative approaches, particularly regression-based methods, because the primary aim of the study is not to establish statistical

relationships among variables but rather to determine the economic viability of interventions and their practical implications for farm decision-making. Regression techniques primarily estimate associations and predict the influence of independent variables on specific outcomes; however, they do not directly assess whether the monetary benefits of an intervention outweigh its costs (Lee, 2022; Kulaylat et al., 2023). In contrast, CBA produces direct and easily interpretable economic indicators that support policy development and farm-level investment decisions (Islam and Rehman, 2022). Therefore, the approach offers a practical and comprehensive framework for evaluating the economic sustainability and profitability of milk quality and hygiene interventions within dairy farming systems. The analysis considered both fixed and variable costs associated with dairy production (Sarica et al., 2022). Variable costs included feed expenses, labour costs, veterinary and medication costs, breeding expenses, transportation costs, electricity and water charges, and other operational expenditures directly related to production activities. Fixed costs included infrastructure, equipment depreciation, and other relatively constant expenses incurred during the production period.

Gross revenue was estimated from total income generated through milk sales and other dairy-related outputs. Economic performance and profitability were assessed using indicators such as total costs, total benefits, net benefits, gross margin, Benefit-Cost Ratio (BCR), and Return on Investment (ROI). Gross margin was used to determine the difference between farm revenue and total production costs and was estimated as:

$$\boldsymbol{GM = GR - TC}$$

The Benefit-Cost Ratio is given by comparing the value of gross returns to total costs, which helps determine the need for interventions (Sarica et al., 2022). A BCR value greater than 1 indicated that the dairy enterprise generated benefits greater than the costs incurred and was therefore considered profitable (Diro et al., 2020). A BCR equal to 1 indicated a break-even point, while a BCR value less than 1 indicated that production costs exceeded returns.

$$\boldsymbol{BCR = \frac{GR}{TC}}$$

Where:

GM = Gross Margin (R)

GR = Gross Revenue (R)

TC = Total Cost of production (R)

Return on Investment measures the economic returns generated with every investment made, which helps determine the production efficiency (Hounnou and Ouedraogo, 2025). In this study

ROI was used to determine the percentage return obtained from investments made in dairy farming activities and was calculated as:

$$\boldsymbol{ROI = \frac{GR-TC}{TC} \times 100}$$

A positive ROI indicates profitable investment performance, while a negative ROI indicated that production costs exceeded generated returns (Dadd and Hinton, 2023). Higher ROI values reflected greater efficiency in converting production costs into economic returns. These profitability indicators collectively provided a comprehensive assessment of the economic performance and financial sustainability of dairy farming enterprises in KZN.

4.3.6 Description of Variables

The factors utilised in the cost-benefit analysis and economic feasibility framework used in this study to evaluate the possible financial benefits of putting milk quality and hygiene improvement initiatives into practice among dairy farm workers in KZN are summarised in Table 4.1. The analysis integrates socio-demographic, institutional, production, cost, and revenue variables in order to capture both the drivers of production efficiency and the financial performance of dairy farming systems. These variables are essential for understanding how human capital characteristics, farm structure, and resource allocation influence costs, revenues, and overall profitability indicators such as net benefit, BCR, and ROI. The explanatory variables are therefore hypothesised to affect economic outcomes either positively or negatively depending on their role in enhancing productivity, reducing inefficiencies, and improving milk quality and hygiene compliance within dairy production systems.

Table 0.1 Variables for analysing dairy farmers economic feasibility for targeted interventions

Variable	Description and Measurement (Type)	Expected Outcome (+ / -)
Age group	Farm personnel age (1 = 18–30, 2 = 31–40, 3 = 41–50, 4 = 51+ years)	+
Gender	Farm personnel gender (1 = Male, 2 = Female)	+/-
Marital status	Marital status (1 = Single, 2 = Married)	+
Educational level	Highest education level (1 = Primary, 2 = Secondary, 3 = Tertiary, 4 = Degree)	+
Years of formal education	Total years of schooling completed	+
Dairy experience	Experience in dairy farming (1 = 0–5 yrs, 2 = 6–10 yrs, 3 = 11–15 yrs, 4 = 16+ yrs)	+

Employment status	Employment type (1 = Permanent, 2 = Contract, 3 = Casual)	+
Employment security level	Job security perception (1 = Low, 2 = Medium, 3 = High)	+
Monthly household income	Income category (1 ≤ R5,000; 2 = R5,000–10,000; 3 = R10,000–15,000; 4 = R15,000–20,000; 5 ≥ R20,000)	+
Access to extension services	Frequency of extension contact (1 = Weekly, 2 = Monthly, 3 = Quarterly, 4 = Annually, 5 = Never)	+
Organisational membership	Membership in farmer organisations (1 = Yes, 0 = No)	+
Diversified farming activities	Engaging in other farming enterprises (1 = Yes, 0 = No)	+/-
Hygiene training received	Formal training in milk hygiene (1 = Yes, 0 = No)	+
Awareness of hygiene benefits	Awareness level of hygiene importance (1 = Low, 2 = Moderate, 3 = High)	+
Herd size	Number of dairy cows per farm	+
Land size	Farm land area (hectares)	+
Milk yield per cow	Average milk output per cow (litres/day)	+
Feed cost	Monthly feed expenditure (R)	-
Labour cost	Monthly labour expenditure (R)	-
Veterinary and health cost	Animal health and treatment costs (R/month)	+/-
Transport cost	Milk and input transport costs (R/month)	-
Utilities cost	Electricity, water and operational utilities (R/month)	-
Equipment maintenance	Maintenance and repair costs (R/month)	-
Total cost	Aggregate monthly production cost (R)	-
Milk sales revenue	Income from raw milk sales (R/month)	+
Milk by-products revenue	Income from processed milk products (R/month)	+
Calf sales revenue	Income from livestock sales (R/month)	+
Incentives/subsidies	Government or cooperative support income (R/month)	+

Total benefits	Total revenue from all dairy outputs (R/month)	+
Net benefit	Total benefits – total costs (R)	+
Benefit-cost ratio (BCR)	Total benefits ÷ total costs	+
Return on investment (ROI)	(Benefits – Costs) ÷ Costs) × 100	+

4.4 Results and discussion

4.4.1 Socio-Demographic Characteristics of Dairy Farmers

The sociodemographic variables, dairy production systems, cost and revenue structures, and financial feasibility indicators of dairy farming enterprises in KZN are all thoroughly analysed in this chapter. The analysis is based on the study's primary goal, which is to evaluate the economic feasibility and possible advantages of implementing milk quality and hygiene improvement interventions into practice among dairy farmers. The results combine descriptive statistics and CBA, including key economic indicators such as net benefit, BCR, and ROI. Together, these results provide evidence on both the structural capacity of farmers to adopt hygiene interventions and the financial returns associated with improved milk quality management.

Table 0.2 Socio-demographic profile of respondents (n = 37)

Variable	Mean / %	Std. Dev.	Min	Max
Age (years)	44.25	6.89	28	58
Education (years of schooling)	13.83	2.75	8	18
Dairy experience (years)	7.35	5.82	1	25
Monthly income (R)	12,450	4,230	5,000	25,000
Male (%)	55.9	-	-	-
Female (%)	44.1	-	-	-
Single (%)	66.1	-	-	-
Permanent employment (%)	91.5	-	-	-
Diversified farming (%)	69.5	-	-	-

Hygiene training received (%)	12.0	-	-	-
Awareness of hygiene importance (%)	84.7	-	-	-

The socio-demographic profile of dairy farmers provides important insights into the human capital available for implementing milk hygiene and quality improvement interventions. Human capital characteristics such as age, education, experience, and income are critical determinants of technology adoption, compliance with hygiene standards, and responsiveness to training programmes (Pandey et al., 2025). The results show that the average age of farmers is 44.25 years (SD = 6.89), with ages ranging from 28 to 58 years. Similar to Homera et al. (2024), This indicates a relatively mature workforce that is economically active and likely to possess accumulated experiential knowledge in agricultural operations. According to Caffaro et al. (2022), from a behavioural economics perspective, this age structure may enhance risk awareness and compliance with hygiene protocols, as older workers tend to exhibit greater caution in production-related decision-making. Educational attainment is relatively high, with respondents having an average of 13.83 years of schooling (SD = 2.75). This level of education exceeds the national average for agricultural workers and suggests a strong cognitive foundation for understanding technical concepts such as milk contamination pathways, bacterial load control, and hygienic milking procedures. According to Sobhan et al. (2022), such a profile is particularly important for the successful adoption of structured hygiene interventions, which often require comprehension of standard operating procedures and quality control protocols.

However, despite relatively high general education levels, respondents report a modest average dairy-specific experience of 7.35 years (SD = 5.82). The wide standard deviation indicates significant variation in experience levels across farms. This suggests that while some personnel are highly experienced, others are relatively new entrants to dairy production (Weir, 2022). This imbalance may create inconsistencies in hygiene compliance practices across farms, as Moya et al. (2020) suggest that experience is strongly associated with routine adherence to milking standards and biosecurity measures. Monthly income levels average R12,450 (SD = R4,230), indicating moderate earnings with noticeable inequality across respondents. Similar findings by Khim et al. (2016) conclude that Income variability is important because it may influence worker motivation, retention, and willingness to engage in additional training. Furthermore, Bufe et al. (2022) state that workers with lower income levels may be more

vulnerable to external economic shocks, potentially affecting consistency in performance and adherence to hygiene protocols.

In terms of categorical characteristics, the workforce is predominantly male (55.9%), with females comprising 44.1%. The majority of respondents are single (66.1%), suggesting fewer household obligations that may otherwise affect labour availability and work intensity (Perry-Jenkins and Gerstel, 2020). A particularly important finding is that 91.5% of respondents are permanently employed, which is highly significant for institutional interventions. According to Osorio (2023), permanent employment enhances the feasibility of long-term training investments, as it reduces labour turnover and ensures continuity in skill development programmes. Similarly, 69.5% of respondents engage in diversified farming activities, which may improve income resilience but could also introduce biosecurity risks if cross-contamination between enterprises is not well managed (Mil-Homens et al., 2025). Most critically, only 12% of respondents reported having received formal hygiene training, while 84.7% indicated awareness of hygiene importance. Similar to Nyokabi et al. (2021), this reveals a clear disconnect between awareness and technical competence. While awareness reflects cognitive recognition of hygiene importance, it does not necessarily translate into correct practice execution. This gap strongly supports the need for structured, formalised, and practical hygiene training interventions. The literature confirms that awareness alone is insufficient to ensure behavioural compliance in agricultural hygiene systems (Lunner-Kolstrup and Ssali, 2016; Ahmed et al., 2020; Nyokabi et al., 2021).

4.4.2 Dairy Production System Characteristics

The production system characteristics reflect the structural and technological capacity of dairy farms in KZN. These variables are essential in understanding productivity differences and the potential impact of hygiene interventions on output and efficiency.

Table 0.3 Production system characteristics

Variable	Mean	Std. Dev.	Min	Max
Land size (ha)	45.6	18.3	10	95
Herd size (cows)	62	24	20	120
Milk yield per cow	18.4	5.2	10	32
Extension visits per year	3.45	2.91	0	12

The average landholding size is 45.6 hectares (SD = 18.3), according to Jayne et al. (2016), this indicates medium-scale commercial dairy operations. However, the relatively high variation suggests heterogeneity in farm size, which may translate into differences in production capacity and management intensity. The average herd size is 62 cows (SD = 24), further confirming that farms operate at a moderate commercial scale. This is consistent with findings by Dong et al. (2016), indicating that herd size variation is particularly important in dairy economics because larger herds often benefit from economies of scale, while smaller herds may face higher unit costs of production.

Milk productivity averages 18.4 litres per cow per day (SD = 5.2), which indicates moderate productivity levels. However, according to Craig et al. (2022), the substantial variation suggests inefficiencies in some farms, potentially linked to differences in feeding practices, herd health management, and hygiene compliance during milking. One of the most critical structural constraints identified is the low level of extension support, with farms receiving an average of only 3.45 extension visits per year (SD = 2.91). This is consistent with findings by Kassem et al. (2021); this is approximately one visit per quarter, which is insufficient for continuous technical support in areas such as milk hygiene, mastitis control, and quality assurance systems. The wide variation (0 to 12 visits per year) further highlights inequality in access to advisory services. Overall, Table 3 indicates that while farms operate at a viable commercial scale, the limited extension support and variability in productivity create conditions where hygiene interventions could significantly improve efficiency and output stability.

4.4.3 Cost Structure of Dairy Production

The cost structure of dairy production provides critical insight into how production resources are allocated and identifies areas where economic efficiency can be enhanced through improved management and hygiene practices (Fiorillo and Amico, 2024). From an agricultural economics perspective, understanding production costs is fundamental because profitability depends not only on increasing output but also on controlling the costs associated with generating that output. The findings indicate that feed costs represent the largest expenditure at R48,200 per month, confirming that feed remains the dominant variable input in dairy production systems. This result corresponds with earlier research showing that feed costs account for approximately 50–70% of total dairy production costs in intensive systems globally (Sarica et al., 2022; Ragkos et al., 2021). Feed efficiency is therefore an important determinant of farm profitability, as excessive feed wastage, poor ration formulation, and contamination-

related losses can substantially increase production costs while reducing output efficiency (Stathers and Mvumi, 2020). Investments in improved feeding strategies and hygienic feed storage practices may therefore reduce economic losses and improve resource utilisation.

Labour costs were identified as the second-largest expenditure at R32,500 per month, highlighting the significance of human capital within dairy enterprises. Although this differs from the findings of Sarica et al. (2022), the labour-intensive nature of milking operations and hygiene management may explain the relatively high labour requirement. Labour efficiency is a key economic indicator because workers directly influence productivity and product quality. Adequate worker training in milking procedures, sanitation practices, and milk handling protocols may reduce contamination, minimise milk rejection, and improve productivity, thereby lowering hidden costs associated with poor-quality milk.

Veterinary and health costs, averaging R9,800 per month, reflect expenditures associated with disease prevention and treatment. From an economic standpoint, these costs can be viewed as both production expenses and risk management investments. Poor hygiene practices increase the incidence of mastitis, which can lower the quantity and standard of milk while increasing treatment costs and economic losses (Jimenez et al., 2023). Additional operational costs, including transport, utilities, and equipment maintenance, also contribute to overall production efficiency and influence farm competitiveness. The average total monthly cost of R127,200 therefore establishes an important benchmark for profitability analysis and suggests that improving feed utilisation and labour efficiency through enhanced hygiene management could significantly improve the economic sustainability of dairy enterprises.

Table 0.4 Monthly cost structure (ZAR)

Cost Item	Mean (R)
Feed cost	48,200
Labour cost	32,500
Veterinary and health	9,800
Transport	6,700
Utilities	5,600
Equipment maintenance	4,900
Breeding costs	3,800
Consumables	4,200
Storage	3,100
Insurance	2,900
Other costs	5,400
Total Costs	**127,200**

4.4.4 Revenue and Benefit Structure

The revenue structure highlights the economic significance of milk quality and market performance in determining dairy farm profitability. Farm revenue composition provides an indication of the extent to which enterprises depend on specific income streams and reveals opportunities for improving financial sustainability (Alekperova, 2022). The findings show that milk sales contribute approximately 85% of total monthly revenue, amounting to R385,000, confirming that milk production remains the primary economic activity and income source for dairy enterprises. Moreover, Sarica et al. (2022) found that dairy farm profitability is greatly determined by milk volume, quality, and market acceptance. The high dependence on milk sales suggests that any factors affecting milk quantity or quality may have substantial implications for farm income and overall economic performance.

Additional revenue sources, including milk by-products (R28,500) and calf sales (R18,700), indicate a moderate level of enterprise diversification. According to Sun and Govind (2017), diversification reduces production and market risks by creating alternative income streams that can buffer farmers against fluctuations in milk prices or production challenges. Incentives and subsidies contributed R12,400, demonstrating the role of external support mechanisms in improving farm financial stability and encouraging investment in improved production

practices (Haskell, 2020). Total monthly benefits of R444,600 exceeded total production costs, suggesting positive economic returns. Consistent with Fiorillo and Amico (2024), the dominance of milk sales in the revenue structure implies that improvements in milk hygiene, including reduced bacterial contamination, fewer product rejections, and higher milk grading standards, could significantly increase revenue generation. Therefore, investment in hygiene interventions can be viewed not only as a production improvement strategy but also as an economically justified investment aimed at enhancing farm profitability and long-term sustainability.

Table 0.5 Monthly dairy revenue components (ZAR)

Benefit Source	Mean (R)
Milk sales	385,000
Milk by-products	28,500
Calf sales	18,700
Incentives/subsidies	12,400
Total Benefits	**444,600**

4.4.5 Cost-Benefit Analysis Results

The cost-benefit analysis provides a comprehensive economic assessment of the financial performance and sustainability of dairy farming systems under existing production conditions. From an agricultural economics perspective, indicators such as net benefit, BCR, and ROI are important measures used to evaluate farm-level efficiency and determine whether production systems generate sufficient returns relative to resources invested. The mean net benefit of R317,400 indicates that dairy farming enterprises generally operate at a profitable level, suggesting that the value of outputs exceeds production expenditures. However, the large standard deviation (R182,300) and the presence of negative values (-R20,320) reveal substantial variation in profitability among farms. This variability suggests that while some farms utilise resources efficiently and achieve favourable economic outcomes, others experience financial losses due to differences in managerial ability, resource use efficiency, and production practices. Similar findings by Hansen et al. (2019) indicated that larger farms often achieve higher economic returns due to economies of scale, advanced technologies, and improved operational efficiencies.

The average BCR of 3.92 demonstrates strong financial viability, indicating that for every R1 invested in production activities, farmers receive approximately R3.92 in returns. Such a ratio reflects a highly favourable allocation of production resources and suggests that dairy farming remains economically attractive under current conditions. Nevertheless, the high standard deviation (5.29) indicates considerable variability across farms, implying that economic efficiency is not uniformly distributed within the study population. Consistent with Sarica et al. (2022), larger-scale operations may achieve greater profitability because fixed production costs are distributed over larger production volumes, reducing average costs per unit of output.

Similarly, the ROI of 292.18% reflects high overall profitability and indicates substantial returns on capital invested in dairy production. However, the extremely large standard deviation (528.56) and broad range of values (-47.98% to 1794.56%) indicate considerable disparities in farm performance. These differences are likely associated with farm size, managerial competence, production efficiency, and adherence to quality management practices. Consistent with Mishra et al. (2009), variation in profitability may also be linked to differences in farmer experience and decision-making capacity, which influence resource allocation and production outcomes. The occurrence of negative ROI values further confirms the existence of inefficiencies within some farming systems. From an agricultural economics perspective, such inefficiencies represent avoidable losses resulting from suboptimal resource use and poor management practices. Reports by Habtamu et al. (2018) show that factors such as inadequate hygiene management, milk contamination, and milk rejection at collection points can contribute significantly to reduced profitability. Overall, these findings indicate that although dairy farming in KZN remains economically viable, substantial opportunities exist for improving efficiency and profitability through interventions aimed at enhancing milk quality, management practices, and hygiene standards.

Table 0.6 Economic feasibility indicators

Indicator	Mean	Std. Dev.	Min	Max
Net benefit (R)	317,400	182,300	-20,320	1,970,000
Benefit-Cost Ratio (BCR)	3.92	5.29	0.52	18.95
Return on Investment (ROI %)	292.18	528.56	-47.98	1794.56

Collectively considering the socio-demographic, production, and economic findings, an important agricultural economics perspective emerges; Dairy farming in KZN demonstrates considerable economic potential and profitability but remains constrained by structural

limitations that negatively affect production efficiency and long-term sustainability. Similar findings reported by Xulu and Naidoo (2023) prove that in agricultural production systems, profitability depends not only on the quantity of output produced but also on the efficient utilisation of resources such as labour, technical knowledge, technology adoption, and management capacity. The identified gaps in farmer training, extension support, and technical hygiene competence therefore represent important constraints to productivity and may contribute to both allocative and technical inefficiencies, ultimately reducing potential economic returns (Nyokabi et al., 2021). Similarly reported by Hogeveen et al. (2019), these inefficiencies can increase production costs through higher disease incidence, milk contamination, reduced milk quality, and product rejection, while simultaneously limiting output quality and market competitiveness.

The findings therefore provide support for the hypothesis that the implementation of milk quality and hygiene interventions is likely to be economically feasible and capable of improving farm profitability, productivity, and overall dairy farm sustainability. The observed production constraints, similar to Nyokabi et al. (2021), suggest that substantial opportunities exist for improving farm performance through targeted interventions aimed at strengthening milk quality management practices. Given the heavy dependence of dairy farms on milk sales as the dominant source of revenue, maintaining acceptable milk quality standards becomes not only a production requirement but also an economic necessity. Consistent with Murphy et al. (2016) and Fiorillo and Amico (2024), improvements in milk hygiene can generate direct and indirect economic benefits through reductions in production losses, improved milk grading, enhanced market acceptance, and increased revenue generation. From a cost-benefit perspective, investments in hygiene management, farmer training, and strengthened extension services should not be viewed solely as technical improvements but rather as economically justified interventions capable of increasing resource-use efficiency and enhancing returns on investment. Improved hygiene practices may reduce avoidable costs associated with poor milk quality while simultaneously increasing productivity and market value. Consequently, the implementation of such interventions has the potential to improve profitability and encourage dairy companies' long-term resilience and sustainability in KZN.

4.5 Conclusion and recommendations

The findings of this study demonstrate that dairy farming in KZN is economically viable, with positive net benefits, favourable BCR, and high returns on investment observed across the sampled farms. However, despite the overall profitability of the sector, considerable variation

exists among farms, indicating differences in production efficiency, resource utilisation, and management practices. Feed and labour constituted the largest production costs, while milk sales represented the dominant source of revenue, highlighting the critical relationship between production efficiency, milk quality, and financial performance. The results further suggest that inadequate training, limited extension support, and poor hygiene management contribute to inefficiencies that reduce profitability through increased disease incidence, milk contamination, and product rejection.

The economic findings should be interpreted within the context of the study sample. The analysis was based on 37 participating dairy farms, and participation was influenced by farm availability and willingness to provide economic information. Furthermore, the occurrence of FMD during the study period, differences in farm size and production systems, and constraints related to time and financial resources may have limited the representativeness of the sample. Consequently, the findings provide an indication of the economic performance of the participating farms but may not be directly generalisable to all dairy farms in KwaZulu-Natal.

Based on these findings, these are the targeted interventions recommended to improve both technical and economic performance within dairy enterprises:

- Capacity-building programmes should be strengthened to provide farmers and farm workers with practical training on milk hygiene, quality management, and efficient production practices.
- Extension services should be expanded to improve access to technical support and encourage the implementation of effective management procedures.
- Farmers should also invest in improved hygiene infrastructure and disease prevention measures to reduce avoidable losses.
- Policies that encourage financial support and incentives for quality improvement initiatives could enhance productivity, profitability, and dairy farming systems' long-term viability in KZN.

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CHAPTER 5:

Effect of parity and lactation phases on milk composition and yield in dairy cows in KwaZulu-Natal

5.1 Abstract

The sustainability of the dairy farming sector is significantly influenced by milk quality. However, because biological factors contribute the composition of milk, emerging dairy farms frequently fail to maintain milk quality. This study assessed how parity and lactation stages affected milk yield and composition of milk in dairy cows in the KZN. Dairy cows enrolled in the National Milk Recording and Improvement Scheme (NMRIS) provided production records via the Agricultural Research Council's (ARC) Integrated Registration and Genetic Information System (INTERGIS). Between May and June of 2025, milk samples and production records were gathered from specific dairy farms in KZN's southern districts. Major milk composition markers, such as milk fat, protein, lactose, and SCC, were examined together with milk yield. To assess their impact on production and compositional characteristics, cows were categorised based on parity and lactation phases. To assess the impact of parity and lactation phase on milk yield and composition, data were evaluated using the proper statistical techniques. The findings showed that lactation phase and parity had significant effects on milk output and composition characteristics ($p<0.05$). In most parity groups, milk yields peaked in the early to mid-lactation phase and decreased in the late lactation phase. Cows in their second and third parities produced higher milk yields compared with first-parity cows, reflecting greater physiological maturity and mammary gland development. Milk fat and protein percentages tended to increase during late lactation, whereas lactose content declined as lactation progressed. Somatic cell count increased during late lactation and in older cows, suggesting a greater susceptibility to udder health challenges. For milk yield, significant interactions between parity and lactation phases were found. According to the study's findings, milk yield and composition in KZN dairy cows are significantly influenced by both parity and lactation phase. To increase dairy productivity and profitability in the province, dairy producers and extension professionals can improve herd management techniques, nutritional planning, and milk quality control by having a better understanding of these relationships.

Keywords: Parity, Lactation phase, milk yield, milk composition, Somatic cell count

5.2 Introduction

Continued growth in populations, urbanisation, rising incomes, and shifting dietary habits have all contributed to a significant increase in consumer demand for dairy foods and milk in recent times (Bełdycka-Bórawska et al., 2021). worldwide milk output surpasses 950 million tonnes, according to the Food and Agriculture Organization (FAO, 2021), demonstrating the dairy industry's increasing significance in supplying food. The International Farm Comparison Network (IFCN, 2024) reports that global milk production is increasing at an annual rate of approximately 2.2%, closely matching the growth in demand, which is estimated at 2.4% per year. Dairy products and milk are consumed by almost 80% of people on the planet, underscoring the industry's vital role in human nutrition and global food security (FAO, 2019). Additionally, one major source of revenue is the dairy business, employing an estimated 240 million people directly or indirectly worldwide (FAO, 2021). Despite this high demand and pressure on production, dairy farming remains predominantly small-scale, with farms housing more than 100 cows accounting for less than 0.3% of all dairy farms worldwide. According to United States Department of Agriculture (USDA, 2025), the number of dairy farmers in South Africa has decreased by 60%.

The increasing demand for milk has placed considerable pressure on dairy production systems to enhance productivity while maintaining high-quality standards (Smith et al., 2022). Hence, the high pressure of production has raised concerns regarding milk safety and integrity. The 2008 Chinese milk crisis, whereby, to manipulate and raise the protein level in milk and baby formula, melamine was added to them., is a prominent example (Jia et al., 2012). This incident highlighted the critical importance of milk production and quality monitoring within dairy production. While there has been no clear definition of milk quality due to producer-consumer perspectives, milk quality has been defined by its composition, pathogenic and microbial safety (Fusco et al., 2020; Castellini et al., 2023).

Poor milk quality, often reflected through altered composition or elevated microbial contamination, can compromise consumer health and reduce the economic value of dairy products (Linehan et al., 2024). Research has shown that season, parity, and lactation phase all have an impact on milk production (Panchal et al., 2022; Chisowa, 2023). During lactation, milk yield and composition (fat, protein, lactose and somatic cell count) change over time. For this reason, the lactation period is divided into three phases (early, mid, and late), each with distinct influences on milk production (Yamazaki et al., 2009). Variations in parity, defined as the number of lactations a cow has undergone, also reflect physiological changes within the

cow that directly influence milk synthesis (Popescu and Angel, 2019). The dairy industry commonly uses SCC and lactose as indicators of and udder health. Elevated SCC levels, together with a decrease in lactose percentage, can serve as accurate indicators of mastitis (Antanaitis et al., 2021). In addition to impairing the nutritional value and processing quality of milk, mastitis causes financial damages because of lower yield, higher treatment expenses, and possible milk rejection (Olatoye et al., 2018; Kaskous, 2021).

Several studies have reported that biological factors can influence milk yield and its compositional characteristics (Gonçalves et al., 2018; Sabek et al., 2021). However, findings in the literature remain inconsistent. While some researches have shown no significant effect of parity and lactation phase and important milk components, others have reported significant impacts of such factors on milk composition (Bilal et al., 2014). These conflicting outcomes suggest that it is still unclear how parity and lactation stage affect milk synthesis. Furthermore, existing studies have been conducted in well-established commercial dairy systems, with limited attention given to smaller dairy farms (Fiorillo and Amico, 2024). In South Africa, emerging dairy farmers face a range of structural and management challenges that may influence production outcomes. Emerging farmers are smallholder farmers transitioning to the commercial sector (Khapayi and Celliers, 2016). A study by Molomo (2022) highlighted significant performance dynamics and yield limitations of South African emerging dairy farmers. Since dairy herds operate under distinct environmental and management conditions, this may lead to different patterns of milk production (Grobler et al., 2008). This suggests that there is limited context-specific knowledge on how parity and lactation phases influence milk yield and milk composition within emerging dairy systems, particularly in KZN.

A study by Marumo et al. (2022) emphasised the importance of understanding the relationships for improving herd management and milk quality in emerging dairy enterprises. Hence, generating empirical evidence on how parity and lactation phases influence milk production traits can help bridge the gap by adding to the literature and assisting farmers in improving farm productivity. This study aimed to determine the effect of parity and lactation phases on milk yield, fat, protein, lactose and SCC in emerging dairy herds in KZN.

The research objectives were carried out with the hypothesis that milk composition and yield vary across lactation phases and parity in dairy cows. Specifically, milk fat and protein contents are expected to increase as lactation progresses from early to late stages, whereas lactose content is anticipated to decrease, accompanied by an increase in SCC. It is anticipated that

milk yield will increase and peak in early phases of lactation, decline toward the middle, and reach its lowest point in the later phases. It is hypothesised that parity affects milk yields and composition. It is anticipated that the concentrations of milk fat and protein will peak during the first lactation, decline during the second and third lactations, then rise from the fifth to the tenth lactation. Lactose content and SCC are expected to be highest during the first lactation, decrease during the second and third lactations, with lactose continuing to decline while SCC increases from the fifth to the tenth lactation. Lastly, milk yield is hypothesised to peak during the first two lactations and progressively decline from the fifth to the tenth lactation.

5.3 Materials and Methods

5.3.1 Study site

The province of KwaZulu-Natal is situated on South Africa's eastern coast (Heye, 2022). The province covers approximately 94,361 km² and comprises ten district municipalities and the eThekwini Metropolitan Municipality. The province is characterised by a highly diverse and productive agricultural sector, supported by its varied climatic zones ranging from coastal subtropical regions to inland temperate areas (Ono-Raphel et al., 2025).

This diversity makes KZN a suitable study site for investigating the effect of parity and lactation phases on milk composition and yield in dairy cows. The province hosts a mix of commercial and emerging dairy farming systems, particularly concentrated in its southern and midland regions, where favourable rainfall, pasture availability, and moderate temperatures support year-round milk production (Xulu and Naidoo, 2023). These characteristics provide a representative and dynamic environment for examining variations in dairy cow productivity under different management and physiological conditions.

5.3.2 Sampling procedure

The Agricultural Research Council (ARC) provided production records through its Integrated Registration and Genetic Information System (INTERGIS) for a total of 321 individual dairy cows taking part in KZN's National Dairy Animal Recording and Improvement Scheme (NMRIS). Eleven dairy herds provided the records.

5.3.3 Data collection

The dataset comprised one production cycle, with milk sampling conducted over a defined period from 10 May 2025 to 17 June 2025, corresponding to a single seasonal window within the study year. During this period, milk samples were systematically collected from each

participating dairy farm. The production records included milk yield and key milk composition parameters, specifically milk fat, protein, lactose, and SCC. These variables are widely recognised indicators of milk production performance and udder health, making them essential for evaluating factors influencing dairy productivity and milk quality within the study population (Bochniarz et al., 2023). The compiled dataset therefore represents dairy production and milk quality over a single season in 2025, providing a consistent and well-defined basis for analysing variations in milk yield and composition among dairy cows in the participating herds.

5.3.4 Data editing

Prior to analysis, the dataset was screened and organised to ensure accuracy and completeness, with records checked for consistency across herds and cows. Cows were categorised into lactation groups according to parity to facilitate meaningful comparisons of milk composition, milk yield, and SCC across different stages of their productive life. Parity is a key biological factor influencing milk production and udder health because physiological maturity, metabolic efficiency, and mammary gland development change as cows progress through successive lactations (Marumo et al., 2022). In this study, five parity groups were established: First, second, third, and fourth lactation cows were classified as individual groups, while cows in their fifth to tenth lactations were combined into a single group.

This classification captures the progressive physiological development from early productive life to advanced lactations. Grouping parity in this way allows for the assessment of potential changes in milk yield, and milk composition associated with increasing age and lactation experience. In addition to parity classification, the lactation cycle was divided into three biologically distinct phases to account for temporal variation in milk production and quality. Based on the classification proposed by Gurmessa and Melaku (2012), early lactation was defined as days 1–150, mid-lactation as days 151–305, and late lactation as days 306 and beyond. These phases represent important physiological transitions within the lactation cycle. Early lactation is characterised by maximum production of milk and a negative energy balance (Angeles-Hernandez et al., 2021). Classifying cows by these lactation phases, therefore, provides a structured framework for evaluating how the physiological stage influences milk yield, milk components, and SCC within the dairy production system.

Following the approach recommended by Cozzi et al (2011), only observations that fell within biologically plausible ranges for key milk production and quality variables were retained.

Establishing these thresholds is essential when working with large secondary datasets, as recording errors, instrument malfunctions, or abnormal samples can introduce extreme values that distort statistical estimates and weaken the validity of subsequent inferences.

Specifically, acceptable ranges were defined as 2.5–7% for milk protein, 2.5–8% for milk fat, 3.5–6% for lactose, and 2–50 litres for daily milk yield. SCC values exceeding 1,500,000 cells/mL were excluded, as such extreme values are typically associated with severe intramammary infections or potential recording anomalies and may not accurately reflect general herd-level conditions. Applying these biologically informed thresholds ensured that implausible or erroneous observations were removed prior to analysis, thereby improving the robustness of the dataset (Cooper et al., 2015). This data validation step was particularly important given that the study aimed to evaluate the influence of parity and lactation stage on milk yield and milk composition.

5.3.5 Statistical Analysis

Prior to statistical analysis, all data were tested for normality using the *Shapiro–Wilk* and *Kolmogorov–Smirnov* tests. To test for homogeneity, *Levene's* test was used. Variables that did not satisfy normality assumptions were transformed using appropriate mathematical transformations. Milk yield was transformed using the square root transformation, fat percentage and SCC were transformed using $\log_{10}$, and protein percentage was transformed using the arctangent transformation. Lactose data were analysed using a Generalised Linear Model (GLM).

The Statistical Package for the Social Sciences (SPSS) was used for all statistical analyses. A two-way analysis of variance (ANOVA) was used to evaluate the primary effects of lactation phases and parity, as well as their interaction, on milk yield. One-way ANOVA models were used to evaluate milk composition data, fat, protein, lactose, and somatic cell count. Parity and lactation phases were tested independently. Tukey's honestly significant difference (HSD) test was used to perform mean differentiation in cases where significant effects were found. This test was selected because it allows pairwise comparisons among group means, while keeping the family-wise error rate (Nicholson et al., 2022). At $p < 0.05$, statistical significance was declared.

5.4 Results and Discussion

The results revealed no significant interaction between parity and lactation phases on milk composition parameters ($p > 0.05$); therefore, each factor was analysed independently to ensure accurate presentation of the individual effects of parity and lactation phase on milk parameters. Parity had a significant effect on milk fat ($p = 0.009$) and protein ($p = 0.015$) content, which increased from the first lactation (4,7±0,11 and 3,7±0,06, respectively) to the third lactation (4,80±0,07 and 3,81±0,05), declined during the fourth lactation (4,33±0,09 and 3,48±0,07), and subsequently increased again in the fifth lactation (4,61±0,09 and 3,68±0,05), as shown in Table 5.1. This pattern partially supports the hypothesis that parity influences milk production and milk composition, although the observed changes were not strictly linear as initially expected.

Table 0.1 Effect of parity on of milk fat, protein, lactose and SCC. Means in the same column with different superscripts indicate significant differences

Parity	Fat (%)	Protein (%)	Lactose (%)	SCC (× 10³ cells/mL)
1st	$4,70 \pm 0,11^{ab}$	$3,72 \pm 0,06^{b}$	$4,79 \pm 0,04^{b}$	$249,14 \pm 0,08^{a}$
2nd	$4,80 \pm 0,09^{b}$	$3,75 \pm 0,08^{ab}$	$4,66 \pm 0,04^{ab}$	$412,44 \pm 0,06^{ab}$
3rd	$4,80 \pm 0,07^{b}$	$3,81 \pm 0,05^{b}$	$4,70 \pm 0,04^{ab}$	$295,30 \pm 0,05^{ab}$
4th	$4,33 \pm 0,09^{a}$	$3,48 \pm 0,07^{a}$	$4,76 \pm 0,07^{b}$	$393,25 \pm 0,08^{ab}$
5th -10th	$4,61 \pm 0,09^{ab}$	$3,68 \pm 0,05^{ab}$	$4,55 \pm 0,05^{a}$	$446,92 \pm 0,05^{b}$

SCC: Somatic cell count; Mean ± standard error in the same column with different superscripts ($^{a/b}$) indicate significant differences at $P < 0.05$

The increase in milk fat and protein content from the first to the third lactation is biologically plausible and consistent with the findings of Sabek et al. (2021), who reported that younger cows continue to undergo physiological growth and development after their first calving. Similarly, Mekuriaw (2023) noted that first-lactation cows allocate nutrients toward both body growth and milk synthesis, which may limit their capacity for milk component production compared with more mature cows.

The decline observed during the fourth lactation, followed by a subsequent increase in the fifth lactation, suggests that the parity effect in the present study did not follow the classic smooth biological trend described by Feltes et al. (2016). Comparable fluctuations in milk fat percentage across parity groups were also reported by Sahu et al. (2018). Furthermore, Castro

et al. (2022) suggested that such irregular patterns may be associated with herd-level variability, smaller subgroup sizes within specific parity classes, differences in feeding management, or variations in cow health status among dairy herds. According to Sundrum (2020), milk production and composition are strongly influenced by non-genetic factors, including inconsistent nutrition, disease burden, environmental stress, and reproductive management practices. Therefore, while parity significantly influenced milk fat and protein content in the present study, the observed pattern likely reflects the combined effects of physiological maturity and farm management conditions within the local dairy production systems.

The results further revealed that parity had a significant effect on lactose content ($p = 0.005$). Lactose concentration decreased from the first lactation (4,79±0,04) to the second lactation (4,66±0,04), increased slightly up to the fourth lactation (4,76±0,07), and subsequently declined to its lowest level in cows within the fifth to tenth lactation group (4,55±0,05). This pattern differed from the initial hypothesis, as lactose concentration did not exhibit a consistent progressive decline with increasing parity. According to Mukherjee et al. (2021) lactose concentration is closely associated with the synthetic activity of the mammary gland. Similarly, Hervé et al. (2017) reported that under normal physiological conditions, lactose concentration generally remains relatively stable but may decline when mammary epithelial function is impaired.

The lower lactose concentration observed in cows within the fifth to tenth lactation group may therefore reflect reduced mammary gland efficiency and a greater susceptibility to udder health disorders in older cows. According to Colditz et al. (2021) advancing age in dairy cows is often associated with deterioration in mammary tissue integrity and an increased risk of recurrent intramammary infections. Such conditions may reduce the secretory capacity of the mammary gland and interfere with lactose synthesis. In contrast, the temporary increase in lactose concentration observed between the second and fourth lactations may indicate that cows within these parity groups were still at relatively productive and physiologically stable stages, thereby supporting more efficient milk synthesis and mammary gland function.

In contrast, parity had a significant effect on SCC ($p= 0.003$). The lowest SCC was observed during the first lactation (249.14± 0,08 cells/mL), after which SCC progressively increased, reaching its highest levels in the fourth (393.25±0,08 cells/mL) and fifth to tenth lactations (446.92± 0,05 cells/mL). These findings strongly support the hypothesis that parity influences

udder health-related indicators in dairy cows. The lower SCC recorded in first-lactation cows agrees with the findings of Gonçalves et al. (2021) who reported that younger cows are generally exposed to fewer mastitis-causing pathogens because of their shorter productive lifespan and limited exposure to milking and environmental stressors. As parity advances, cows undergo repeated lactation cycles and prolonged exposure to milking stress, environmental pathogens, and udder infections, all of which may contribute to the progressive increase in SCC.

The elevated SCC observed from the third to the fifth to tenth lactation is also consistent with findings reported by Sinha et al. (2021) who suggested that older cows are more susceptible to mastitis and declining milk quality. Increased SCC is widely recognised as an indicator of inflammatory responses within the mammary gland and has been attributed to variations in milk composition, reduced shelf life, impaired milk processing characteristics, and lower marketability (Dejyong et al., 2022; Danieli et al., 2023; Rowe et al., 2024). Furthermore, the concurrent occurrence of elevated SCC and reduced lactose content in later parities aligns with findings by Hamon et al. (2024) further suggesting a decline in mammary gland integrity and functionality with increasing cow age and lactation number.

This pattern indicates that cows in later parities may experience progressive deterioration in udder tissue integrity and immune resilience, thereby increasing their susceptibility to mastitis and elevated SCC while simultaneously reducing lactose synthesis. There is a well-established inverse association between SCC and lactose content, and it is associated with compromised mammary epithelial cell function, which negatively affects milk quality, processing efficiency, and the productive longevity of dairy cows (Costa et al., 2025).

The effect of lactation phase largely supported the study hypothesis and reflected the expected biological changes associated with the progression of lactation. Specifically, as seen in Table 5.2. Lactation phases had a significant effect on milk fat ($p < 0,001$) and protein ($p < 0,001$). Similar to Bondan et al. (2018), this study found fat and protein to be correlated. Fat and protein concentrations were lowest during early lactation, averaging 4.30±0,06 and 3.50±0,04, respectively, and increased progressively to peak values of 5.04±0,08 and 3.95± 0,07 in late lactation.

Table 0.2 Effect of lactation phases on milk fat, protein, lactose and SCC

Lactation Phases	Fat (%)	Protein (%)	Lactose (%)	SCC (× 10^3 cells/mL)
Days 1- 150	4,30 ± 0,06 [a]	3,50 ± 0,04[a]	4,79 ± 0,03[b]	310,40 ± 0,05[a]
Days 151- 305	4,82 ± 0,06[b]	3,77 ± 0,04[b]	4,64 ± 0,03[a]	373,87 ± 0,04[b]
Days 306 -	5,04 ± 0,08[b]	3,95 ± 0,07[b]	4,55 ± 0,04[a]	423,69 ± 0,05[b]

SCC: Somatic cell count; Mean ± standard error in the same column with different superscripts ($^{a/b}$) indicate significant differences at $P< 0.05$

The increase in fat and protein content from early to late lactation is consistent with the normal dilution-concentration effect observed by Morton et al. (2016), in which cows generally produce the greatest volume of milk, which often dilutes the concentration of milk solids, such as fat. However, a study by Garamu (2019) contradicts these findings as it states that milk fat and protein are highest during the first few lactating days, when the cow produces colostrum. However, the study further states that after production of colostrum, fat and protein levels drop and then increase as lactation nears the end. This indicates that as milk production decreases as lactation advances., the concentration of these components tends to increase (Kul et al., 2019). In addition, changes in energy partitioning, body reserve mobilisation, and mammary gland secretory activity across lactation may contribute to higher concentrations of milk fat and protein during late lactation (Andjelić et al., 2022). This finding supports the hypothesis that milk composition changes as lactation advances and is consistent with the physiological principle that late-lactation milk tends to be more concentrated.

Lactation phases had a significant effect on lactose ($p < 0,001$). Lactose concentration was highest during early lactation (4.79±0,03) and declined to its lowest level (4.55±0,04) in late lactation. This finding is biologically plausible. According to Hettinga (2019), Lactose plays a central role in regulating milk volume, and its concentration is often closely linked to the secretory activity of healthy mammary tissue. Findings by Andjelić et al. (2022) further emphasise these findings, stating that lactose is highest during early lactation may reflect active milk synthesis and relatively efficient osmotic regulation during peak milk production. As lactation progresses and milk secretion declines, lactose concentration may decrease, especially where mammary gland efficiency is reduced or where udder health becomes compromised. This decline may also be associated with the concurrent rise in SCC, as inflammatory changes in the udder can impair lactose synthesis (Džermeikaitė et al., 2025).

SCC followed the opposite trend (p = 0,001), increasing from its lowest mean value in early lactation (310.4 × 10^3±0,05 cells/mL) to the highest level in late lactation (423.69 × 10^3± 0,05 cells/mL). The increase in SCC from early to late lactation is consistent with well-established lactation dynamics and strongly supports the study hypothesis. Findings by Kul et al. (2019) support those of this study, stating that late lactation is often associated with increased SCC due to reduced milk volume and a higher probability of udder infections accumulating over time. The observed inverse relationship between lactose and SCC across lactation phases is particularly noteworthy. These findings are similar to those by Alessio et al. (2021), as they suggest that declining milk quality in late lactation may be linked to deteriorating udder health.

The findings presented an interaction that was significant between lactation phases and parity on milk yield (p = 0.008; Figure 5.1). Specifically, milk yield was highest during early to mid-lactation (days 1–150 and 151–305) across most parities and declined during late lactation (≥ 306 days). Cows in their second (13.7L) and third lactations (14,97L) generally produced higher milk yields compared with first-lactation cows (9.4L), particularly during the early lactation phase. Cows in the fifth lactation group exhibited lower milk yields compared with Second and third lactation groups of cows, particularly during the late lactation phase.

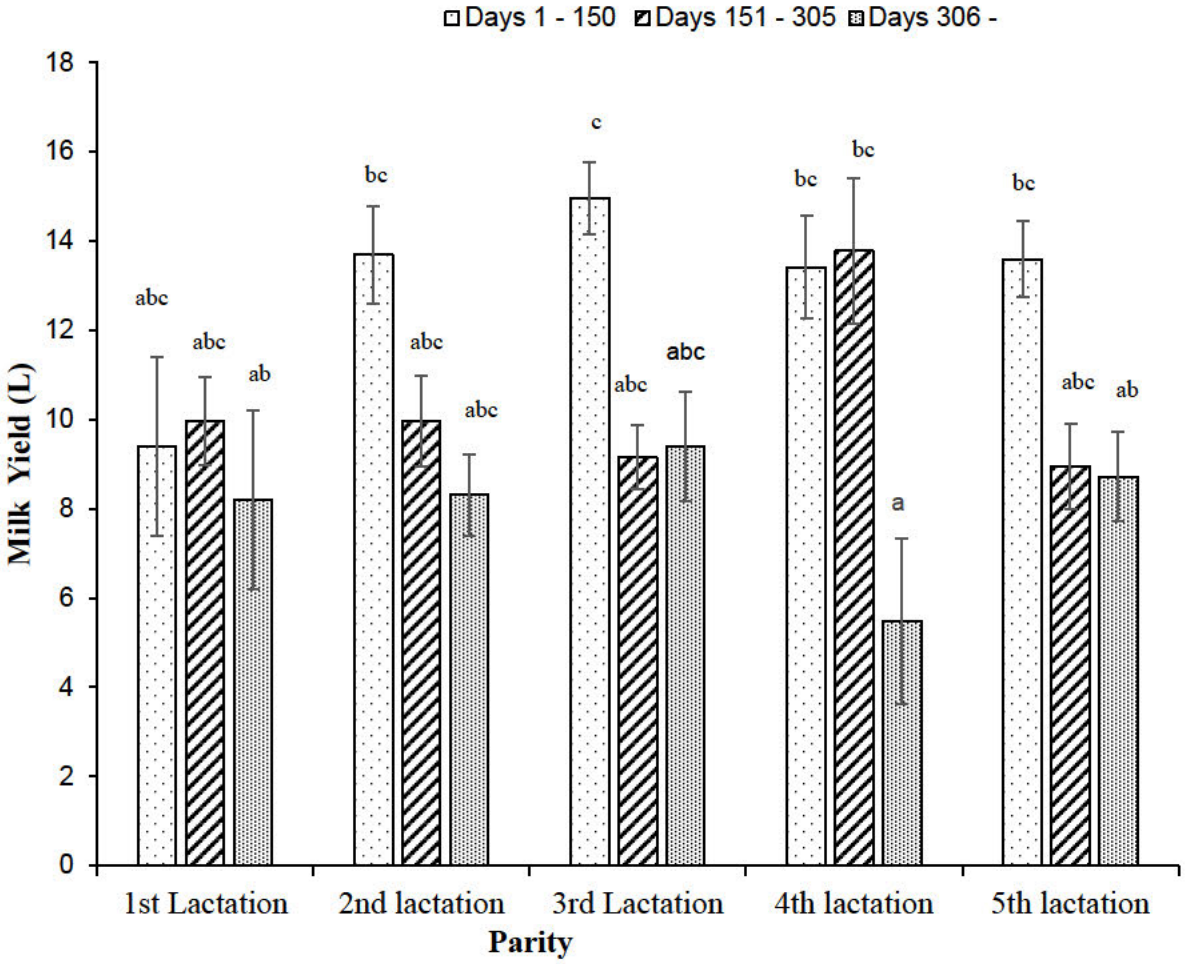

Figure 0.1 Effect of parity and lactation phases on milk yield. Different superscripts (a/b/c) indicate significant differences at P< 0.05. Error bars represent variability.

The significant interaction between parity and lactation phase on milk yield indicates that the effect of lactation stage on production differed according to the cow's number of lactations. The higher milk yields observed during early and mid-lactation across most parity groups are consistent with the normal lactation curve in dairy cows, where milk production typically rises after calving, reaches peak yield in early lactation, and is then maintained for a period before gradually declining as lactation progresses toward the late stage (Solodneva et al., 2022). This pattern reflects the physiological response of the mammary gland to the increased metabolic and hormonal demands associated with the onset and maintenance of lactation.

The comparatively higher milk yields recorded in second- and third-lactation cows, particularly during early and mid-lactation, may be attributed to their greater physiological maturity and improved mammary gland development relative to first-lactation cows. Primiparous cows are still undergoing body growth while simultaneously supporting milk synthesis, which may limit the proportion of nutrients available for milk production compared with multiparous cows

(Piantoni and VandeHaar, 2023). This suggests that cows in their second and third lactations have generally attained a more mature body size and possess more fully developed secretory tissue, enabling more efficient conversion of nutrients into milk. In addition, improved feed intake capacity and metabolic adaptation in these cows may further enhance their productive performance. These results align with those of Eşki and Kurt (2021), who found that milk yield tends to increase from the first to middle parities before declining in older cows.

In contrast, the lower milk yields observed in cows in the fifth lactation group, particularly during late lactation, may reflect age-related declines in productive efficiency and mammary function. Older cows are generally more susceptible to cumulative physiological stress, reduced metabolic efficiency, and a higher incidence of health and udder-related disorders, all of which may negatively affect milk production (Gussmann et al., 2019). The decline in yield during late lactation may therefore indicate reduced lactation persistency in older cows under the conditions of the present study. Although these findings contradict those by Vijayakumar et al. (2017), finding no significant interaction between parity and lactation phase on milk yield, such differences may result from variability in feed intake, herd management methods, breed composition, and environmental conditions between studies. Furthermore, while Weng et al. (2017) suggested that repeated lactation cycles do not necessarily cause wear on mammary tissue, the current findings indicate that, under emerging dairy production conditions, older cows may still experience a reduction in milk yield as lactation progresses.

Overall, the interaction between parity and lactation phase provides important insight into how milk production changes over time and across cow age groups, with practical implications for herd management, culling decisions, and productivity optimisation in emerging dairy systems.

5.5 Conclusion and recommendations

This research assessed how parity and lactation phases affected the yield and composition of milk produced by dairy cows in KZN. The results show that milk production and quality characteristics, including as fat, protein, lactose, and SCC, are highly influenced by both parity and lactation phase. When compared to primiparous cows, cows in their second and third lactations consistently produced more milk, especially in the early and mid-lactation phases. This trend can be explained by multiparous cow's increased metabolic capability, improved mammary gland development, and increased physiological maturity. Due to the partitioning of resources toward growth in addition to milk synthesis, first-lactation cows produced comparatively less.

The yield and composition of milk were also significantly influenced by the lactation phases. Early to mid-lactation was when milk yield peaked, while late lactation saw a decrease. Milk composition parameters showed variable trends, with fat and protein generally increasing as lactation progressed, while lactose tended to decline. Additionally, SCC levels were higher in later lactation stages and in older cows, suggesting increased susceptibility to udder health challenges such as mastitis.

The interaction between parity and lactation phase further highlighted that optimal milk production and quality are achieved when cows are managed according to both their physiological stage and age. These results highlight the significance of implementing focused management strategies that take these aspects into consideration in order to improve milk quality and efficiency in KwaZulu-Natal dairy systems. The following suggestions are put forth in light of the study's findings:

- Parity-Specific Management: Dairy farmers should implement parity-based management strategies. First-lactation cows should receive specialised nutritional and health support to compensate for their dual demands of growth and milk production.
- Lactation Stage-Based Feeding Programs: Feeding regimes should be adjusted according to lactation phases. High-energy feeds are necessary for early lactation cows to sustain peak production and avoid negative energy balance.
- Mastitis Control and Udder Health Monitoring: Given the observed increase in SCC in later lactation stages and higher parities, regular udder health monitoring and effective mastitis control programs should be strengthened.
- Record-Keeping and Data Utilisation: Farmers are encouraged to maintain accurate production and health records. Utilising systems such as milk recording schemes can help identify trends related to parity and lactation stage, enabling data-driven decision-making.
- Capacity Building and Farmer Training: Extension services and training programs should be enhanced to educate dairy farm personnel on the importance of parity and lactation stage in influencing milk production and quality.
- Genetic and Breeding Considerations: Breeding programs should aim to select cows with desirable traits for sustained productivity across multiple lactations, as well as improved resistance to mastitis and other production-related diseases.

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CHAPTER 6:

Conclusion and recommendations

6.1 Introduction

This chapter presents the summary and recommendations for future research from the study. This chapter summarises the key findings, conclusions and future recommendations of the study.

6.2 Summary

The overall study was detailed in Chapter 1 by outlining the worldwide and South African backgrounds of dairy production and highlighting the significance of milk quality and hygiene in guaranteeing food safety, consumer confidence, and the dairy industry's sustainability. The chapter acknowledged the mounting difficulties in preserving high-quality milk while stressing the dairy industry's importance to rural communities, agricultural development, and national food security. It was reported that inadequate farm management, biological variables influencing milk composition, poor milk hygiene standards, and a lack of understanding among dairy farm personnel continue to lower farm productivity and impair milk quality. This outlined the research problem and provided justification for the need to look into the KAPs of dairy farm personnel, evaluate the impact of parity and lactation stage on milk yield and composition, and determine whether implementing milk quality interventions is economically feasible.

The literature on the dairy sector, milk quality, and the variables affecting sustainable dairy production was reviewed in Chapter 2. The review found that economic conditions, biological factors including parity and lactation phase, and management methods all interact to impact milk quality. It also demonstrated that while financial, infrastructural, and resource limitations continue to restrict the adoption of suggested interventions, sufficient knowledge, positive attitudes, efficient training, and good hygienic practices among dairy farm personnel are crucial for enhancing milk quality and productivity. The literature showed a limited number of integrated studies looking at the combined impact of management, economic, and biological factors on milk quality within the KZN dairy sector. This gap made it clear that the province needs context-specific data to assist sustainable dairy farming. As a result, the current study adds to the body of knowledge by offering a thorough evaluation of these interconnected elements and producing data to guide management plans, the creation of policies, and interventions meant to enhance milk quality, dairy productivity, and the long-term viability of KwaZulu-Natal's dairy sector. All things considered, the literature evaluation provided the

study's theoretical and empirical foundations and supported the necessity of the conducted research.

Chapter 3 investigated the knowledge, attitudes, and practices of dairy farm personnel regarding milk hygiene in KwaZulu-Natal. The findings showed that dairy personnel generally possessed adequate knowledge of milk quality indicators and demonstrated positive attitudes towards milk hygiene and regulatory compliance. However, important deficiencies were identified in the implementation of recommended hygiene practices, particularly in formal training, record keeping, and herd management. Education, household income, access to extension services, age, farming experience, and membership of farmer organisations significantly influenced KAP levels. The chapter concluded that strengthening training programmes and extension support is essential to improve the adoption of good dairy management practices.

Chapter 4 evaluated the economic feasibility of implementing milk quality and hygiene interventions on dairy farms in KwaZulu-Natal using cost-benefit analysis. The findings demonstrated that dairy farming remains economically viable, with milk sales representing the primary source of farm income. Feed and labour constituted the largest production costs, while the calculated Benefit-Cost Ratio and Return on Investment indicated substantial profitability. Nevertheless, considerable differences in profitability among farms reflected variations in management efficiency and resource utilisation. The chapter concluded that investments in milk hygiene, farmer training, extension services, and quality management systems have the potential to improve both farm profitability and long-term sustainability.

Chapter 5 assessed the effects of parity and lactation stage on milk yield and milk composition in dairy cows in KwaZulu-Natal. The results demonstrated that both parity and lactation stage significantly influenced milk yield, milk fat, protein, lactose, and somatic cell count. Milk production was highest during early and mid-lactation, while milk fat and protein increased during late lactation. Somatic cell counts also increased in later lactation stages and older cows, indicating increased susceptibility to udder health problems. The chapter concluded that understanding these biological variations can help farmers improve nutritional management, herd health, milk quality monitoring, and production efficiency.

6.3 Conclusion

This study indicates that a comprehensive strategy that includes strong biological management, economic viability, and efficient farm management is necessary to improve milk quality and

guarantee the sustainability of dairy farming in KwaZulu-Natal. Although dairy farming is still a lucrative business, its long-term viability depends on the regular implementation of proper milk hygiene procedures, sufficient farmer education, increased extension assistance, and knowledgeable herd management that takes into account physiological factors affecting milk production and composition. The study shows that coordinated initiatives that jointly address management, economic, and biological obstacles are necessary to achieve permanent gains in milk quality. By presenting data on these interrelated elements, the study advances knowledge of the factors that influence milk quality and provides a basis for creating plans that improve KwaZulu-Natal's dairy industry's long-term viability, profitability, and productivity.

6.4 Recommendations

In order to promote the consistent adoption of advised milk hygiene and udder health measures by dairy farm personnel, the study recommends enhancing milk quality management through ongoing training, frequent monitoring, and more extension support. To reduce milk contamination and enhance quality, investments in critical farm infrastructure such as milking equipment, cooling facilities, clean water, and sanitation systems should be given top priority.

To maximise milk yield and composition, dairy farmers should include biological and economic considerations into herd management. They can accomplish this by applying management techniques that take parity and lactation phase into account, as well as by adopting cost-effective interventions for milk quality. To encourage better milk quality, higher farm profitability, and the long-term sustainability of KwaZulu-Natal's dairy industry, policymakers and industry stakeholders should support these initiatives through incentive programs, enhanced extension services, and ongoing research.

6.5 Limitations of the study

When evaluating the results, it is important to take into account the many limitations that the study encountered. First, the FMD outbreak, which led to stringent biosecurity protocols and limited access to several dairy farms, limited the sample size. As a result, not all of the targeted farms could have their data collected, which decreased the number of research participants. The sample size for the economic feasibility analysis was further decreased by some farmers' reluctance to divulge private financial information about farm revenue and expenses. The possibility to include a bigger and more varied sample of dairy farms throughout KwaZulu-Natal was limited by the available research funds, which also limited the number of farms that could be visited and the study's geographical coverage. Additionally, the research project's time

constraints restricted the amount of time available for data collection, making it impossible to conduct follow-up farm visits or longitudinal monitoring of management practices and milk quality indicators over several production seasons.

The results should be taken cautiously because they could not be entirely representative of all dairy farms in KwaZulu-Natal due to these constraints. However, the study offers insightful information about the biological factors affecting milk yield and composition, the economic feasibility of milk quality interventions, and the knowledge, attitudes, and practices of dairy farm workers. This information serves as a helpful basis for future studies with larger sample sizes and wider geographic coverage.

6.6 Future areas of research

Future research should aim to explore relationships of farm management on cow behaviour, milk production and udder health on a much larger sample size, which can allow generalisation of the KZN population. Studies should aim at assessing and comparing the management practices of different provinces in South Africa to determine the geographical aspect and identify differences in performance. Lastly, studies should investigate the effect of FMD on dairy farms in KZN, which could help provide recovery support for dairy farmers who faced the detrimental effects of the outbreak.

APPENDICES

Appendix A: Questionnaire



University of KwaZulu Natal

School of Agricultural Earth and Environmental Sciences

Discipline of Animal Sciences.

TITLE: The efficacy of knowledge, attitudes, and practices of dairy farm personnel in KwaZulu natal: A study on enhancing milk quality, hygiene and production.

INSTRUCTIONS: PLEASE ANSWER THE FOLLOWING QUESTIONS TO THE BEST OF YOUR KNOWLEDGE AND EXPERIENCE. YOUR INPUT IS IMPORTANT FOR IMPROVING MILK QUALITY AND HYGIENE PRACTICES ON DAIRY FARMS IN KWAZULU-NATAL.

SECTION 1: DEMOGRAPHIC INFORMATION

	1	**2**	**3**	**4**
Age	≤ 20	21-34	34-59	≥60
Gender	Male	Female		
Marital Status	Single	Married	Divorced	Widowed
Employment	Full-time	Part-time	Temporary	
Years of formal education				
Experience in dairy				
Employment security level				
Monthly household income				
Access to extension services				
Organisational membership				
Other farming activities				
Training status				
Awareness of hygiene benefits				

SECTION 2: KNOWLEDGE ASSESSMENT

Please indicate your level of knowledge on following statements (**Tick one**):

Statement	Yes (1)	No (2)	Maybe (3)
I am familiar with Total Bacterial Count and its role in milk safety.			
Somatic cell count is an indicator of udder health.			
I can identify signs of mastitis in dairy cows.			
Blood in milk is a sign of udder damage or infection.			
Poor milking hygiene can cause infections like mastitis.			
Bacterial contamination can be introduced during or after milking.			
I am aware of zoonotic diseases that can be transmitted through raw or dirty milk.			
I know the risks of using antibiotics without observing the withdrawal periods on milk-producing cows.			

SECTION 3: ATTITUDES TOWARDS MILK QUALITY AND HYGIENE

Please rate your agreement with the following statements (**Tick one**):

Statement	**Strongly Agree (1)**	**Agree (2)**	**Neutral (3)**	**Disagree (4)**	**Strongly Disagree (5)**
I feel responsible for the safety and cleanliness of the milk produced.					
It is important to adhere to milk regulations.					
It is important to have a quality-based payment system					
Wearing protective clothing during milking is necessary.					
Farmers cannot sell milk if it is not of good quality.					
Training on milk hygiene is not only for large-scale farms.					
I feel confident in my knowledge about dairy hygiene.					

SECTION 4: PRACTICES RELATED TO MILK QUALITY AND HYGIENE

Please indicate how often you perform the following practices (**Tick one**):

Statement	**Always (1)**	**Often (2)**	**Sometimes (3)**	**Rarely (4)**	**Never (5)**
Receive training on proper hygiene practices.					
Wash hands before and after milking.					
Use clean water and disinfectants when washing equipment.					
Use of udder disinfectant before and after milking.					
Report abnormal milk immediately.					
Discard milk from cows treated with antibiotics.					
Keep milk in a clean, closed container.					
Record cow health and milk production data regularly.					
Use stainless steel milk container.					

Wash milk container					
Communicate with supervisors or veterinarians about milking concerns.					
Follow a routine for drying off cows and introducing new cows to the milking herd.					

SECTION 5: ADDITIONAL COMMENTS (Optional)

Please use this space to provide any additional comments, suggestions, or concerns related to milk quality and hygiene practices on dairy farms……

……

……

……

……

……..

Thank you for participating in this survey. Your feedback is valuable in enhancing milk quality and hygiene standards in the dairy industry.

INSTRUCTIONS: PLEASE ANSWER THE FOLLOWING QUESTIONS TO THE BEST OF YOUR KNOWLEDGE AND EXPERIENCE. YOUR INPUT IS IMPORTANT FOR IMPROVING MILK QUALITY AND HYGIENE PRACTICES ON DAIRY FARMS IN KWAZULU-NATAL.

SECTION 1: DEMOGRAPHIC INFORMATION

	1	**2**	**3**	**4**
Dairy System	Smallholder	Semi-commercial	Commercial	
Herd Size	≤ 20	21-50	51-100	>100
Land Ownership	Land owned	Land rented	Other	
Land Size	≤ 20 ha	21- 50 ha	51- 100 ha	>100 ha
Feeding system	Pasture based	Total Mixed Rations	Other	
Year of Establishment	≤2000	2001-2010	2011-2020	2021-2030
Age				
Education (years of schooling)				
Dairy experience (years)				
Monthly income (R)				
Male				
Female				
Single				
Diversified farming				
Hygiene training received				
Awareness of hygiene importance				

SECTION 2: COSTS

Item			**Quantity**	**Unit Price**	**Annual Cost**
Feed		Monthly			
Pasture cultivation		Annual			
Labour wages		Monthly			
Leased Land		Annual			
Transport cost		Monthly			
Insurance (Property, Livestock)		Monthly			
Breeding	Artificial insemination	Annual			
	Bull services	Annual			
Equipment & Machinery	Milking parlour	Annual			
	Dipping system	Annual			
	Irrigation system	Annual			
	Feeding pens	Annual			
	Milking cluster	Annual			
Utilities	Electricity	Monthly			
	Water	Monthly			
Consumables	Gloves	Monthly			
	Overalls	Annual			
	Boots	Annual			
	Towels	Monthly			
	Sanitizer	Monthly			
	Teat dips	Monthly			
	disinfectant	Monthly			
Storage	Buckets	Monthly			
	Bulk tanks	Annual			
	Cooling system	Annual			
Veterinary & Health		Monthly			
Total Annual Costs					

1. What is your milk yield per cow?

2. What is the quantity of milk rejected?

3. What is the quantity of milk consumed in the farm?

SECTION 3: REVENUE

Source		**Unit**	**Quantity**	**Unit Price**	**Revenue**
Milk Sales	Monthly	Litres			
Milk by-products	Monthly	Litres			
Calf sales	Monthly	Calf			
Manure Sales	Monthly	Kg			
Incentives	Annual	R			
Total Revenue					

SECTION 6: ADDITIONAL COMMENTS (Optional)

Please use this space to provide any additional comments, suggestions, or concerns related to milk quality and hygiene practices on dairy farms……
……
……
……
……
……..

Thank you for participating in this survey. Your feedback is valuable in enhancing milk quality and hygiene standards in the dairy industry.

Appendix B: Ethical Clearance Certificate

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

01 July 2025

Mduduzi Base (224197320)
School of Agri Earth & Env Sc
Pietermaritzburg Campus

Dear M Base,

Protocol reference number: HSSREC/00008456/2025
Project title: The efficacy of the knowledge, attitudes and practices of dairy farm personnel in KwaZulu-Natal: A study on enhancing milk quality.
Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 28 March 2025 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

Incidents of adverse events and serious adverse events (AEs and SAEs) should be reported in writing to HSSREC, the study sponsors, and any regulatory authority (where appropriate), within 7 working days of the occurrence for local sites and 14 days for all other South African sites.

This approval is valid until 01 July 2026.
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

HSSREC is registered with the South African National Health Research Ethics Council (REC-040414-040).

Yours sincerely,

[redacted]

Doctor Shamila Naidoo (Interim Chair)

/nng

Appendix C: Gatekeeper's letter

KWAZULU-NATAL PROVINCE
AGRICULTURE AND RURAL DEVELOPMENT
REPUBLIC OF SOUTH AFRICA

DIRECTORATE

01 Cedara Road, Pietermaritzburg, 3200
KZN Department of Agriculture & Rural Development, Private Bag X9059, Pietermaritzburg, 3200
Tel: 033 355 9299
Office of the Chief Director: AS

University of KwaZulu-Natal
Pietermaritzburg Campus
Private Bag X01
Scottsville 3201

30 June 2025

ATTENTION : Mr Mduduzi Base

SUBJECT: Permission to Conduct Research

This letter serves to confirm that Mr Mduduzi Base, a registered MSc Animal science student at the University of KwaZulu-Natal (UKZN), has been granted permission to conduct research within the jurisdiction of the KwaZulu-Natal Department of Agriculture and Rural Development (KZN DARD) under the project topic: "**The efficacy of knowledge, Attitudes and practices of dairy farm personnel in KwaZulu Natal: A study on enhancing milk quality**".

Permission is granted on the understanding that participation of departmental officials is voluntary, and no disruption will occur to normal departmental operations. The department will not provide resources for your study, such as research assistance, transportation etc.

I take this opportunity to wish you well in your endeavour.

Kind regards,

[redacted]

MR LL JONGISA
CHIEF DIRECTOR: AGRICULTURAL SERVICES

Appendix D: Informed Consent letter



INDIVIDUAL INFORMATION SHEET AND INFORMED CONSENT FORM

Title of Study: **The Efficacy of Knowledge, Attitudes, and Practices on Dairy Farm Personnel in KwaZulu-Natal: A Study on Enhancing Milk Quality.**

My name is Mduduzi Base, a Masters student at the University of KwaZulu-Natal. I am researching "**The Efficacy of Knowledge, Attitudes, and Practices on Dairy Farm Personnel in KwaZulu-Natal: A Study on Enhancing Milk Quality.**". The region became of interest for research purposes because very few studies have been done to look at the contribution of dairy farm personnel on food security and livelihoods in the KwaZulu-Natal province. Therefore, you are pleasantly invited to participate in this study. Please be advised that your participation is voluntary, and you can also withdraw your participation in the study if you feel uncomfortable. The choice of whether to participate or not is yours. However, we would appreciate it if you do share your thoughts with us. Should you participate in the study, please be advised that the study procedure will follow three steps. Step 1 you will be expected to sign a consent form; in step 2, an enumerator will take you through all the questionnaire questions until everything is clear; step 3, the answering of questions can commence. The duration of your participation is expected to be at least 1 hour.

Any information shared will remain confidential, meaning that your name and address will remain anonymous. We study and report on the answers given by all the people we interview and not individually. The research data will be anonymous, with all personal respondent information removed, and will be archived at the University. The study has zero risks involved. The study will provide no immediate benefits, but we hope that this study's results will be of great help to all relevant stakeholders and deliver a foundation to start informed debates on the role that dairy farm personnel have in food security and profitability for dairy farms.

In the event of any problems or concerns/questions, you may contact the researcher at [redacted] or email: [redacted]m/ 224197320@stu.ukzn.ac.za & DR N.R MKHIZE, Tel: 033 260 5477, Email: mkhizen31@ukzn.ac.za or the UKZN Humanities & Social Sciences Research Ethics Committee, contact details as follows:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION

Research Office, Westville Campus

Govan Mbeki Building

Private Bag X 54001

Durban 4000

KwaZulu-Natal, South Africa

Tel: 27 31 2604557- Fax: 27 31 2604609

Email: HSSREC@ukzn.ac.za

INFORMED CONSENT FORM

I (participant #) ……. been informed about the study titled: **The Efficacy of Knowledge, Attitudes, and Practices of Dairy Farm Personnel in KwaZulu-Natal: A Study on Enhancing Milk Quality.**

I understand the purpose, procedures, and risk-benefit ratio of the study. I have been allowed to ask questions about the study and have had answers to my satisfaction. I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any procedurals that I would usually be entitled to.

I understand that if I have any further questions/concerns or queries related to the study, I may contact the researcher at [redacted] or email: [redacted]/ 224197320@stu.ukzn.ac.za & supervisor DR N.R MKHIZE, Tel: 033 260 5477, Email: mkhizen31@ukzn.ac.za

I understand that if I have any questions or complaints about my rights as a study participant, or if I may have concerns about any aspect of the study or the researcher's then I may contact:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION

Research Office, Westville Campus

Govan Mbeki Building

Private Bag X 54001

Durban 4000

KwaZulu-Natal, SOUTH AFRICA

Tel: 27 31 2604557 - Fax: 27 31 2604609

Email: HSSREC@ukzn.ac.za

…… …….

Signature of Participant **Date**

Additional Consent

Consenting for Audio Recording– when necessary

YES / NO

…… ……..

Signature of Participant **Date**

…… **…….**

Signature of Witness **Date**

……... **…….**

Signature of Translator **Date**

Appendix E: Turnitin Report

Final MSc Dissertation (Mduduzi Base) June 2026.docx

ORIGINALITY REPORT

12%	8%	8%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	researchspace.ukzn.ac.za	Internet Source
2	Submitted to University of KwaZulu-Natal	Student Paper
3	managementjournal.usamv.ro	Internet Source
4	"Management and Productivity of Dairy Animals under African Breeding Conditions", Springer Science and Business Media LLC, 2026	Publication
5	L.L. Sun, L. Liu, J.T. Brenna, Z.H. Wu, L. Ma, D.P. Bu. "Odd- and branched-chain fatty acic in milk fat from Holstein dairy cows are influenced by physiological factors", animal, 20	Publication
6	edepot.wur.nl	Internet Source
7	mro.massey.ac.nz	Internet Source
8	www.managementjournal.usamv.ro	Internet Source
9	www.preprints.org	Internet Source
10	repository.up.ac.za	Internet Source
11	Measuring Business Excellence, Volume 16, Issue 2 (2012-05-26)	Publication
12	www.animalsciencejournal.usamv.ro	Internet Source
13	worldwidescience.org	Internet Source
14	ulspace.ul.ac.za	Internet Source

turnitin

Digital Receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

The first page of your submissions is displayed below.

Submission author:	Mduduzi Base
Assignment title:	Paper
Submission title:	Final MSc Dissertation (Mduduzi Base) June 2026.docx
File name:	Final_MSc_Dissertation_Mduduzi_Base_June_2026.docx
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