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Review Article

# Review on Enhancing Milk Safety and Quality in Ethiopia Through Farm Level HACCP Implementation

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## Abstract

Hazard Analysis and Critical Control Points (HACCP) is a preventive, science-based food safety system increasingly recognized as essential at the farm level, where most milk contamination originates. In Ethiopia, dairy production is largely dominated by smallholders who operate under diverse management conditions and often face persistent challenges including poor milking hygiene, limited access to clean water, lack of cooling facilities, misuse of veterinary drugs, and widespread aflatoxin contamination from improperly stored or contaminated feed. These factors create multiple biological, chemical, and physical hazards that compromise raw milk quality and pose significant public health risks. Applying HACCP at the farm stage is therefore crucial because it focuses on identifying hazards early and managing them at specific critical points such as milking, udder preparation, equipment sanitation, drug withdrawal compliance, and feed safety. Evidence from Ethiopian studies indicates that even simplified, smallholder-friendly HACCP models-such as cooperative-level plans or checklist-based approaches can substantially reduce microbial loads, minimize antibiotic residues, lower levels of aflatoxin M1, and decrease rejection rates at collection centers. Improvements in these areas directly contribute to better milk quality, reduced spoilage, higher acceptance by processors, and increased income for farmers through reduced losses and, where available, quality-based payment schemes. However, successful adoption of HACCP on Ethiopian dairy farms requires overcoming several structural and operational barriers. These include low awareness of food safety principles, limited training for farmers and extension workers, inadequate infrastructure for cooling and hygienic handling and weak enforcement of existing regulations. Moreover, many smallholders lack incentives to adopt improved practices in the absence of stable markets that reward quality. To achieve wider implementation, HACCP must be adapted to local production realities through low-cost interventions, practical training in hygiene and drug management, investment in shared or cooperative chilling and handling facilities, and the introduction of quality-based incentives from processors. Strengthening alignment with national standards and improving coordination among regulatory institutions will further support effective and sustainable adoption. Overall, HACCP offers a practical pathway to improving milk safety, protecting public health, and enhancing the competitiveness of Ethiopia's dairy value chain.

## Keywords

HACCP, Dairy Farms, Milk Safety, Smallholder Production, Contamination, Antibiotic Residues, Milking Hygiene, Critical Control Points

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# 1. Introduction

HACCP provides a systematic and science-based for identifying, assessing and controlling biological, chemical and physical hazards throughout milk production, ensuring safety before the product enters processing or reaches consumers [1]. The Codex Code of Hygienic Practice for Milk and Milk Products highlights the critical importance of farm level hygiene, animal health monitoring, and framework management as foundational components of safe milk production [6].

In Ethiopia, raw milk is frequently produced under suboptimal hygiene conditions. Common practices such as hand milking, use of plastic or poorly sanitized containers, inadequate access to clean water, and limited or intermittent cooling create environments conducive to microbial proliferation and chemical contamination [3]. These factors result in milk with elevated total bacterial counts, coliform levels and risks of zoonotic pathogens and residues, posing significant public health concerns. To mitigate these risks, Ethiopian food safety regulations including ES 929: 2021 explicitly promote the implementation of HACCP-based hygiene standards and good dairy farming practices at the farm level, encompassing milking procedures, equipment sanitation, animal health monitoring, and feed control [7].

By integrating HACCP principles into smallholder dairy operations, farms can systematically monitor critical control points, improve raw milk quality, reduce spoilage and chemical residues and contribute to safer dairy value chains that align with both national standards and international food safety expectations.

# 2. Key Hazards in Ethiopian Dairy Production

## 2.1. Biological Hazards

Raw milk frequently contains high Total Bacterial Counts (TBC), coliforms, E. coli, Salmonella and Staphylococcus aureus, as reported in multiple Ethiopian studies [2]. Mastitis is also common and significantly elevates microbial loads [14]. HACCP manages these hazards through clearly defined critical control points (CCPs) focused on improving milking hygiene, ensuring adequate udder preparation, maintaining equipment sanitation and achieving prompt cooling.

## 2.2. Chemical Hazards

Antibiotic residues are widespread due to poor adherence to withdrawal periods [8]. HACCP integrates veterinary drug management into the system by establishing critical control points (CCPs) for proper drug administration, strict monitoring of withdrawal periods and verification of compliance before milk is marketed. It also designates feed sourcing, storage and quality control particularly for aflatoxin prevention as essential CCPs to reduce chemical hazards entering the milk supply.

## 2.3. Physical Hazards

Physical contaminants including dust, hair and small foreign fragments are frequently introduced into milk when milking areas and equipment are inadequately maintained [2]. HACCP-based control practices such as routine hygiene measures and proper filtration are effective in preventing these hazards.

## 2.4. Zoonotic Hazards

Brucellosis, bovine tuberculosis, and mastitis associated pathogens constitute important zoonotic hazards. Effective control requires robust animal health management, regular disease screening and strict exclusion of milk from clinically or suspected sick animals [14].

# 3. Evidence of Benefits

Both Ethiopian and international studies consistently highlight the benefits of implementing HACCP and HACCP-aligned practices in dairy production. Improved hygiene practices have been shown to reduce total bacterial counts (TBC) by 1–2 log units and decrease rejection rates at milk collection centers [8]. In Borana, ILRI pilot interventions demonstrated that providing hygienic containers along with targeted hygiene training significantly improved microbial quality in raw milk [11]. Market-based incentives, particularly quality based payment schemes, have also been found to strongly encourage farmers to adopt safe milk handling practices [8]. On a broader scale, international evidence confirms that farm-level HACCP not only reduces processing losses but also extends shelf life and ensures compliance with global food safety standards [10].

# 4. Benefits for Farmers, Processors and Public Health

## 4.1. Public Health Benefits

Implementation of HACCP on dairy farms significantly reduces the risk of milk-borne infections, including diarrhea, typhoid, brucellosis and listeriosis [5]. It also minimizes veterinary drug residues and chronic exposure to aflatoxin M1, both of which are pressing public health concerns in the country [3]. By controlling hazards at the farm level, HACCP contributes to safer milk for consumers and enhances overall community health outcomes.

### 4.2. Farmer Benefits

Farmers experience tangible economic gains through HACCP adoption. Improved milking hygiene, equipment sanitation, and feed management reduce milk spoilage, lower rejection rates at collection centers, and increase acceptance rates [12]. Where quality-based payment schemes are in place, farmers can also earn price premiums for milk that meets defined safety and quality criteria, providing direct incentives to maintain high standards [8].

### 4.3. Processor Benefits

Dairy processors benefit from more consistent raw milk quality, reduced contamination hazards, and improved processing efficiency. Lower microbial loads and controlled chemical residues result in fewer rejected batches, longer shelf life, and more reliable production of pasteurized milk, yogurt, and cheese [13]. Collectively, these improvements strengthen Ethiopia's emerging formal dairy sector and enhance its competitiveness in both domestic and regional markets [15].

### 4.4. Regulatory and Market Alignment

HACCP aligns farm practices with international and national regulatory frameworks, including Codex standards and ES 929: 2021, as well as other relevant Ethiopian food safety regulations. This alignment not only enhances domestic food safety but also positions the country for potential export opportunities, supporting formalization of the dairy sector and integration into higher-value markets [7].

## 5. Barriers to Implementation

Key Challenges to HACCP Adoption in Ethiopia

The implementation of HACCP in Ethiopian dairy farms faces several structural and operational challenges:

Smallholder-dominated production and low economies of scale: Over 90% of milk originates from small farms with limited herd sizes, which constrains investments in hygiene, cooling, and record-keeping infrastructure [4].

Limited access to essential resources: Many smallholders lack reliable access to clean water, effective detergents, and milk cooling facilities, increasing the risk of microbial and chemical contamination [9].

Inadequate awareness and training: Low knowledge of hygienic milking practices, mastitis control, drug withdrawal and feed safety among farmers and extension workers undermines consistent hazard control [3].

Weak market incentives: The absence or limited use of quality-based payment systems reduces farmers' motivation to adopt HACCP-aligned practices, as they may not perceive immediate economic benefits [8].

These constraints highlight the need for simplified, low-cost and locally adapted HACCP models that are feasible within smallholder contexts. Approaches such as cooperative-level plans, checklist-based CCPs and stepwise interventions can facilitate adoption while maintaining the core principles of hazard analysis and preventive control. By addressing these challenges through context-specific strategies, HACCP can be effectively integrated into Ethiopia's smallholder-dominated dairy sector, improving milk safety, and quality and market competitiveness.

## 6. Discussion

In Ethiopia, milk production often occurs under challenging conditions. Hand milking, limited access to clean water, the use of sanitized containers, and irregular cooling create environments conducive to microbial growth and chemical contamination. Consequently, raw milk may contain high levels of bacteria, zoonotic pathogens, or drug residues, posing serious public health risks. HACCP addresses these hazards through clearly defined critical control points, including proper milking hygiene, udder preparation, equipment sanitation, feed management, monitoring of drug withdrawal periods, and regular health checks for animals.

Even simple, low-cost HACCP interventions have proven highly effective. Training farmers in hygiene practices, providing hygienic containers, and using practical on-farm demonstrations can significantly reduce microbial contamination and milk rejections. When combined with quality-based market incentives, farmers are motivated to maintain higher standards, leading to safer milk and improved economic returns. For processors, better milk quality ensures fewer rejections, more efficient production, and consistent dairy products, which strengthens the overall value chain and enhances market competitiveness.

Despite these benefits, widespread adoption of HACCP in Ethiopia faces challenges. Smallholders often lack resources for adequate cleaning, cooling and record-keeping. Knowledge gaps regarding proper hygiene, mastitis control, feed safety, and drug management further limit implementation. Fragmented market incentives and weak regulatory oversight also hinder consistent compliance. Overcoming these barriers requires context-specific solutions, including simplified HACCP models, cooperative-based interventions, practical farmer training, shared infrastructure such as community chilling centers, and stronger coordination among regulatory authorities. Overall, HACCP offers a practical pathway for transforming Ethiopia's dairy sector. By systematically managing hazards at the farm level, it enhances milk safety, protects public health, improves farmer livelihoods and strengthens the competitiveness and sustainability of the dairy industry.

## 7. Conclusion

HACCP is a practical, science-based and highly impactful

framework for enhancing milk safety and quality in Ethiopia, particularly when tailored to the realities of smallholder and resource limited production systems. Evidence from Ethiopian studies demonstrates that even low-cost, cooperative-based HACCP interventions such as checklist driven critical control points, shared chilling facilities and targeted hygiene training can significantly reduce microbial contamination, lower chemical hazards compliance with withdrawal periods and feed safety standards. These improvements not only enhance public but also increase farmer revenues by decreasing milk spoilage, lowering rejection rates at collection centers and enabling access to quality based payment schemes and formal markets. Moreover, consistent application of HACCP strengthens the overall dairy value chain by ensuring more reliable raw milk quality for processors, improving production efficiency and supporting regulatory compliance with national standards and Codex guidelines. Successfully scaling HACCP in Ethiopia requires coordinated investments across multiple dimensions; HACCP provides a robust platform for transforming Ethiopia's dairy sector into a safer, more competitive and sustainable industry that can meet both domestic and potential export market standards while supporting the livelihoods of millions of smallholder farmers.

## 8. Recommendations

1) Simplified, Low-Cost HACCP Models: Implement HACCP through practical, easy to use approaches such as checklist-based plans or cooperative-level critical control points (CCPs), supported by shared infrastructure investments to improve efficiency and feasibility for smallholder farmers.
2) Standards Alignment and Laboratory Support: Ensure integration with Ethiopian standards and Codex guidelines. Strengthen monitoring through enhanced laboratory testing for microbial loads and chemical residues.
3) Prioritization of High-Impact CCPs: Focus on key critical control points that have the greatest effect on milk safety, including milking hygiene, container sanitation, rapid cooling and feed quality.

## Abbreviations

| | |
|---|---|
| HACCP | Hazard Analysis and Critical Control Points |
| CCP | Critical Control Point |
| TBC | Total Bacterial Count |
| ES 929: 2021 | Ethiopian Standard 929: 2021 (Milk and Milk Products Hygiene Standard) |
| ILRI | International Livestock Research Institute |

## Author Contributions

**Tegegn Teshome:** Conceptualization, Writing – original draft, Investigation, Methodology, Formal Analysis, Writing – review & editing

**Seble Hailemariam:** Data curation, Validation, Visualization and Supervision

## Conflicts of Interest

The authors declare no conflicts of interest.

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