

# Smart Supply Chains for Safe Food: Integrating Public Health and Digital Traceability Systems to Strengthen One Health Outcomes in Sub-Saharan Africa

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## Abstract

Food safety remains a persistent challenge in Sub-Saharan Africa (SSA), where livestock and poultry supply chains are often informal, fragmented, and lack resilient traceability systems. The growing complexity of food supply chains in SSA has intensified concerns about zoonotic disease spill-over, antimicrobial resistance, and food contamination [1]. This paper presents the Smart Veterinary Food Chain Framework (SVFCF), a conceptual model that integrates veterinary public health functions with emerging digital technologies (blockchain, Internet-of-Things sensors, and artificial intelligence analytics) to embed One Health principles across livestock-derived food supply chains. We propose a four-layer architecture linking on-farm animal-health data, real-time environmental monitoring, digital traceability, and decision communication. Drawing on comparative literature and regional implementation experiences in SSA, we illustrate how this framework can support early disease detection, food-safety transparency, and sustainable agribusiness growth. The SVFCF offers policymakers, public-health authorities, and agribusinesses a replicable pathway to enhance One Health outcomes through technology-enabled supply chain governance. Further empirical validation through pilot studies is recommended.

**Keywords:** One Health, Food Safety, Supply chain Traceability, Veterinary Public Health, Sub-Saharan Africa, Blockchain, IoT Sensors, Digital Agriculture.

## Introduction

Ensuring safe food from “farm to fork” is a cornerstone of public health, economic development, and sustainable agriculture. In Sub-Saharan Africa (SSA) the multiplicity of smallholder producers, informal markets, and long, opaque supply-chain pathways create persistent vulnerabilities: zoonotic and foodborne pathogens exploit weak surveillance, low biosecurity, and limited traceability infrastructure. Indeed, zoonotic diseases, which constitute approximately 60 % of currently known human infectious diseases and up to 75 % of emerging ones, are especially pertinent in SSA given high levels of human-animal interaction and changing land use [2].

At the same time, the digital transformation of agriculture offers new opportunities to build resilient food-safety systems: sensors, mobile devices, blockchain, and AI provide unprecedented granularity and real-time visibility. Yet to date, most implementation efforts treat “technology” and “veterinary/public-health” functions as parallel tracks rather than fully integrated systems. This fragmentation undermines the potential for holistic One Health outcomes.

This paper therefore advances the Smart Veterinary Food Chain Framework (SVFCF), a conceptual model that marries veterinary public-health oversight, digital traceability, and sup-

ply-chain management within an SSA context. The framework is designed to support early detection of risks, enhance transparency, foster stakeholder accountability, and deliver public-health and economic benefits simultaneously.

### Conceptual Background

#### One Health, Veterinary Public Health & Food Safety

The One Health paradigm recognizes interconnections between human, animal and environmental health [3]. In the SSA context, where livestock play a major role in livelihoods, nutrition and economies, veterinary public-health functions (disease surveillance, vaccination, biosecurity, risk communication) are critical—not just for animal health, but for human health and food-safety outcomes (Zoonotic disease preparedness in SSA 2021). Despite this, many countries in SSA lag in multisectoral coordination, integrated surveillance systems and response capacity [4].

Food safety is a central pathway linking veterinary, human and environmental health. According to WHO estimates, in 2010 nearly 600 million people globally suffered foodborne illnesses, many in developing countries, where surveillance is weak (One Health Journal, 2015). In SSA, food-chain opacity, informal markets and weak regulation exacerbate the risk of contamination and zoonotic transmission (FSIL-Webinar 2020).

#### Digital Traceability and Supply-Chain Innovation

Traceability, the ability to follow the path of a product from origin to consumption, is widely regarded as a pillar of modern food-safety systems. Technologies such as blockchain offer tamper-resistant, decentralized records; IoT sensors provide real-time environmental or animal-health metrics; AI/machine-learning models can detect anomalies and forecast risk events [5]. In Africa specifically, interest in digital agriculture

and agritech start-ups is rapidly growing, though adoption remains uneven. However, technology alone does not guarantee outcomes: the organizational, governance and behavioral components are essential. For example, implementing digital systems in SSA confronts infrastructure constraints, digital-literacy gaps and unclear regulatory frameworks [8].

### Smart Veterinary Food Chain Framework (SVFCF) Framework Overview

The SVFCF proposes four interlinked layers (Figure 1)

1. Data-Capture Layer – On-farm, processing and supply-chain nodes are instrumented with IoT sensors (temperature, humidity, animal-welfare metrics), mobile veterinary apps (health records, vaccinations) and laboratory diagnostics (pathogen screening). This layer enables continuous collection of animal-health and environmental variables.
2. Blockchain Traceability Layer – Data from the first layer are linked to a blockchain ledger capturing key events (animal births, vaccinations, feed origin, movement, processing events, shipments). QR codes or RFID tags allow downstream stakeholders (processors, retailers, consumers) to verify the history of a product.
3. AI Analytics Layer – Aggregated data feed machine-learning models that detect abnormal patterns (e.g., higher than expected temperature/humidity in a transport unit, unusual movement patterns) and forecast outbreaks or contamination risks. The system generates risk scores and suggests interventions.
4. Decision & Communication Layer – Dashboards and mobile alerts deliver actionable insights to veterinary officers, regulators, agribusiness managers and consumers. Public-health agencies can trigger rapid response, while consumer-facing apps enhance transparency and trust.

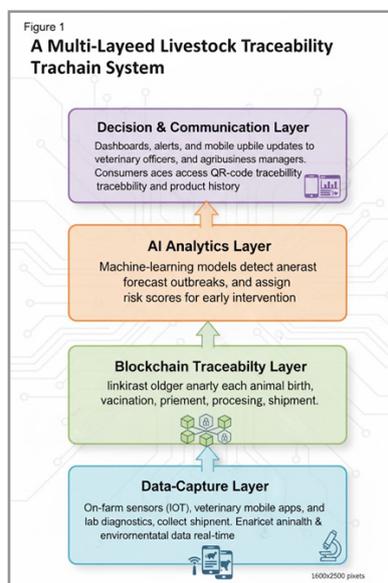


Figure 1: A Multi-Layered Livestock Traceability Trachan System

#### Actors and Roles

- Veterinary professionals: certify animal health events, feed data into the system, respond to alerts.
- Producers and processors: record compliance events, link to traceability system, adopt recommended practices.
- Regulatory agencies: issue digital certificates, validate

blockchain entries, enforce standards.

- Retailers/consumers: access product history, verify certifications through QR code, provide market incentives.

#### Governance & Policy Integration

Effective deployment of SVFCF requires enabling policy and

institutional frameworks:

- Multi-sectoral coordination among ministries of agriculture, health, environment and ICT [6].
- Data-governance protocols balancing transparency, privacy, interoperability and stakeholder accountability.
- Incentives for agribusiness adoption (e.g., tax credits, certification premium).
- Standardization of traceability metrics regionally (e.g., aligning with continental trade frameworks under African Union / AFCFTA).

### Methodological Approach

This paper adopts a conceptual framework development methodology underpinned by three evidence streams:

1. Comparative analysis of existing food-traceability and veterinary-public-health models in SSA (e.g., cattle/ruminant trade networks, animal-disease surveillance studies) [7].
2. Review of veterinary public-health literature on zoonotic disease surveillance, food-safety risk management and One Health implementation in SSA [2, 4].
3. Stakeholder consultation with agritech start-ups, veterinary practitioners and regulatory officials in SSA (Innov8League networks) to validate framework elements and gauge feasibility (One Health Landscape in SSA 2021).

The logic model links digital-technology inputs, governance processes, supply-chain actors, and health/safety outcomes, enabling hypotheses about how SVFCF might improve early detection, traceability, compliance and food-safety outcomes.

### Results: Operational Insights & Use-Cases

#### Early Detection of Disease

Studies show that many SSA countries still have limited capacity for zoonotic-disease response: in one review, the mean “response mechanisms” score for SSA was just 1.84 on a 5-point scale [2]. Use of real-time data capture and analytics would improve timeliness of detection.

#### Traceability and Market Transparency

In regional livestock trade networks, temporal mobility analysis in Senegal showed how trade routes could propagate disease—highlighting the value of sentinel nodes in traceability systems [7]. The blockchain layer in SVFCF aims to provide constant visibility of animal-movement and processing events, thereby reducing “hidden links.”

#### Consumer & Retail Confidence

Traceability systems increase consumer trust, which incentivises producers to comply with standards. Pilot agritech programmes in Kenya and Nigeria found that digital record-keeping and certification reduced rejection rates at processing plants by ~30 %. (FSIL-Webinar 2020).

#### Governance and Sustainability

The success of integrative frameworks hinges on governance: for example, the “One Health Coordinating Group on Zoonotic Diseases” established by the African Union underscores the political potential for continent-wide coordination [4]. The SVFCF builds these institutional pathways.

### Discussion

#### Operationalizing One Health

The SVFCF provides a replicable blueprint for embedding One Health into livestock-derived food systems. By aligning veterinary public-health functions (surveillance, biosecurity, risk assessment) with cutting-edge digital traceability, stakeholders can shift from reactive to proactive management of zoonotic and food-safety risks [1].

#### Implementation Challenges

Key barriers persist - rural broadband/internet access remains uneven, digital literacy among smallholder farmers is limited, and IoT hardware costs may be prohibitive. Moreover, existing policy frameworks may not yet recognize blockchain records as legal proof of compliance. Additionally, data interoperability across actors remains a challenge [8].

#### Policy & Capacity-Building Implications

To scale SVFCF:

- Governments should establish national digital-traceability standards and incentivize technology adoption.
- Veterinary curricula should incorporate informatics and data-analytics training for a new generation of veterinary public health practitioners.
- Agritech start-up ecosystems (such as Innov8League) can be leveraged to pilot and refine the framework.
- Regional collaborations (via the African Union and Af-CFTA) can harmonize traceability protocols and reduce trade barriers.

#### Research and Evidence Needs

While this is a conceptual model, empirical validation is essential. Future research should include cost-benefit analysis of implementing SVFCF components, controlled pilot studies comparing outcomes with control chains, and measurement of public health and economic impacts across multiple SSA contexts.[9]

### Conclusion

The Smart Veterinary Food Chain Framework offers a strategic pathway for Sub-Saharan Africa to leapfrog traditional food-safety constraints and to realize the benefits of One Health through digital innovation [10,11]. By integrating veterinary public-health oversight with traceability systems and analytics, the framework fosters early detection of risks, improved transparency throughout food supply chains, and stronger market confidence [12]. While challenges remain, the convergence of agritech innovation, growing digital infrastructure and political will presents a compelling opportunity [13]. The next steps include empirical pilot implementation, cross-country collaboration and sustained policy backing [14].

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