

Farm to Fork Traceability in Beef Value Chain for Food Safety

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Summary: This chapter highlights the worth of beef as an important livestock product and depicts alarming issues of adulteration and unethical practices, creating concerns about beef quality in Pakistan. It highlights the need of traceability system to be implemented as an innovative livestock management tool which may enhance transparency, food safety and consumer trust. The use of smart technologies like the internet, Android mobiles, QR coding, bar coding and digital record keeping can be effectively implemented. The chapter also presents the MeaTrax App which is designed to capture data beef animals throughout the production, processing, and distribution stages of the value chain. Consumers can retrieve reliable data through simple scanning QR code and trace the origin of beef. Beef traceability may trigger beef business round the year both at local and export level.

Keywords: Beef traceability, Meat safety, Consumer trust, Digital records, QR Scanning

INTRODUCTION

Pakistan is blessed with a variety of cattle breeds that play a central role in the livestock sector and rural livelihoods. These animals provide milk, beef, draft power and a reliable source of income for farming families across the country. According to the Economic Survey of Pakistan, 2025, the national cattle population has reached 59.7 million heads, reflecting their growing importance in fulfilling the need of valuable food items like milk and meat. However, buffalo calves and old spent animals also contribute to the national beef supply but cattle remain the major source of beef production and specifically for beef export. Calves with two years of age are especially demanded widely during Eid-ul-Azha to fulfill the demand of Qurbani for sacrificial purposes.

Beef has become an important and nutritious meat item that provides not only high quality protein along with essential amino acids but also gives vital minerals. This is a rich source of iron, zinc, selenium and vitamin B₁₂ which are vital for blood formation, immunity, and energy metabolism. Beef is getting popular in society and is preferred over chicken meat at certain special occasions and gatherings due to recent dietary trends during the era of huge information flow. In spite of vigorous growing demand, this sector is facing real dilemma. Beef quality reaches its peak during Eid-ul-Adha but remains a major challenge for the rest of the year due to malafide practices in the market. Adulteration of meats included mixing beef with donkey meat, selling meat from diseased/dead animals and water injection in muscles create serious doubts among consumers. Consequently, consumer trust sharply declines. Small food entrepreneurs whose livelihoods depend on businesses face serious losses whenever news circulates in the media or on social platforms about donkey meat being mixed in the market.

In light of these facts, it is a dire need of time to implement the technology of traceability in our beef value chain from Farm to Fork to overcome the situation and enhance the end consumer trust over beef or beef value added products in the society. Traceability refers to the ability to track meat products through all the stages, production, processing and distribution phase. Smart technologies like Android-based applications, internet, QR coding, barcoding, and Radio-Frequency Identification (RFID) are increasingly used globally to ensure food safety and quality. These digital tools can be implemented in Pakistan to enhance the trust of consumers on beef quality and boost beef business round the year. Pilot projects by Pakistan Science Foundation and FAO have already demonstrated the potential of traceability in Pakistan to trigger the worth of traceability. Main objective of this chapter is to raise awareness among policymakers, producers, traders, industry stakeholders, and consumers, enabling them to adopt traceability practices as a concrete step toward food safety in Pakistan.

HISTORICAL PERSPECTIVE

Idea of meat traceability has changed dramatically over past few decades in response to shifting legal regulatory demands and advancement in technology. The current traceability concept has evolved into complex technologically advanced system. However, early traceability methods were traditional and mostly depends on human record keeping and simple animal identification for ownership. Digital developments like RFID, cloud-based database and block chain have been more popular than traditional systems enabling consumers for real time tracking of animal and meat products (Conter, 2024).

This development has been geared by variety of food crisis. Food safety incidents and disease outbreaks in livestock pointed out the weaknesses of earlier systems and catalyzed regulatory reforms. Bovine Spongiform Encephalopathy or Mad Cow Disease in cows motivated European nations to improve animal tracking and apply strict identification rules. Similarly, U.S. Food Safety Modernization Act 2011 had provided U.S. regulators more powers and focused the importance of traceability in food value chains, regulatory agreement and avoiding adulteration.

In the last decade, traceability systems have been progressive even more quickly as global supply chains became increasingly diversified. Advancements like block chain and its application to the meat sector and agriculture food sector are extensively studied and implemented (Ellahi et al., 2023). However, use of smart technologies in beef value chain is an innovative solution in ensuring food transparency (Zulfiqar et al., 2025). These innovations depicts technological advancement which may enable both policy makers and consumers to consider traceability as a modern tool for food safety, transparency and trust.

KEY COMPONENTS OF MEAT TRACEABILITY

Meat traceability production system comprises all three stages; production, processing and distribution out of beef value chain that ensure food safety and transparency from farm to consumer. Smart technologies may provide real time data and mechanism (Iftekhar & Cui, 2021). Technological advancements in identification of animals like RFID, QR code technology and DNA based traceability could help to corroborate species authenticity and avoid fraud. Android based Apps also aid to enter data and enable consumer for tracking livestock product origin. International certifications like ISO 22000 and ISO 22005 and advanced global traceability solutions trigger the adoption of digital technologies that ensure food safety, trade compliance and consumer trust.

IMPORTANCE OF TRACEABILITY

Protecting Consumer Health

Bacteria like *Salmonella*, *Escherichia coli*, connected with beef products are of great concerns in public health issues. These organisms can influence all stages in meat value chain which may gear up outbreaks and serious illness that affect people worldwide. Innovative farm to fork traceability systems are of great importance for monitoring and decreasing risk factors because these can empower authorities and concerned stakeholders to quickly identify infection hotspots and origin out of meat value chain. This innovation can save consumers to consume the product from contaminated cattle and ultimately help out to decrease foodborne outbreaks by efficient eradication of harmful products (Tesson et al., 2020).

Building Consumer Trust

Application of strong traceability solutions, sharp revealing technologies and open communication maneuvers are necessary to increase consumer trust in beef industry

affected by adulteration practices e.g. mixing donkey meat, putting water into carcasses and selling meat from sick animals. Progressive diagnostic methods e.g. immunological chromatographic technique with lateral flow and PCR based techniques facilitate for accurate finding of donkey meat in beef, ensuring its safety and validity (Atef et al., 2025; Zhu et al., 2020). Additionally, consumer friendly policies e.g. independent third-party certifications, quality assurance schemes and clear labeling increase consumer trust when properly delivered. By adopting smart technologies in tracing farm to fork traceability framework supports to restore consumer trust and also ensuring answerability throughout the beef value chain.

Regulatory and Trade Compliance

Beef exporting nations with no or little implementation of strong traceability systems commonly face major difficulties when trying to approach high value international markets. Because importing countries have high criteria to protect food quality, human health and consumer trust. For example, European Union requires all beef products be completely traceable from birth to retail with individual animal identification and comprehensive records on feed, health and processing history. In order to maintain their positions in the global beef trades, major beef exporting countries including Brazil, United States and Australia, have made investments in extensive national traceability systems. Using electronic ear tags and centralized databases, Australia Livestock identification System is regarded as one of the most advanced systems allowing for whole chain tracking of animal movements.

TECHNOLOGIES ENABLING BEEF TRACEABILITY

RFID and Barcoding

Innovative beef identification systems are increasingly implemented like Radio frequency identification tags (RFID) especially in nations with advanced beef traceability frameworks. RFID makes possible to automatically record attributes belong to production, processing and distribution phases. These electronic tags can fetch demonstrable data trail from farm to slaughterhouses, processors, distributors and ultimately to consumers when combined with 2D barcodes applied to carcass and retail packaging. Using smart technologies elevates supply chain transparency by decreasing human error and giving access to the data. Traceability supports food safety verification and give consumers reliable information about the origin and safety of beef, triggering trust in the supply chain (Mohammad et al., 2017).

Digital Applications and QR Codes

Enabling consumers through mobile based applications and QR code scanning is another innovative livestock management tool for increasing transparency. Beef origin can be traced back from Farm to fork throughout beef value chain by just scanning through a mobile camera. This tool can make a bridge between producers and customers. Detailed information about each animal such as its breed, feeding, age etc., through the MeaTrax program (Fiaz et al., 2024) can be

obtained. Mobile-based traceability system provides a workable way to restore credibility and enhance the value of beef products which will ultimately make them more appealing to smart consumer in competitive marketplaces where concerns about adulteration, mislabeling and foodborne hazards diminish trust (Zulfiqar et al., 2025). Mobile App traceability can be successfully implemented in online Qurbani system and connect producer with the consumer through access.

Whole Chain Data Integration

In beef traceability, connecting diverse data from different stakeholders is a major difficulty that leads to gaps, inconsistencies and limited visibilities. A solution is offered by the implementation of centralized data sharing platforms and Global Set of Standards which establish a common framework that guarantees stakeholders compatibility. It establishes a common framework to ensure compatibility among all stakeholders, enabling end-to-end traceability and efficient supply chain management. Moreover, enhanced efficiency and accountability warranties that can be quickly recovered and take measures against in the cases of food safety concerns, saving both customers and market reliability (Morreti et al., 2020).

Precision Livestock Farming and Blockchain Tech

Precision livestock farming and blockchain technology are of great concern of recent developments in beef traceability, which can ensure supply chain safety and transparency. Precision livestock farming triggers data driven management of animal welfare and production providing regular monitoring of animal health status and product quality, prompt eradication of illness before delivery to customers. These technologies can become of great importance when combined with blockchain can yield good quality of product and increase consumer trust, decrease fraud and quick accountability. Consequently, these technologies can satisfy consumer queries and regulatory needs (Nastasijevic et al., 2024).

CHALLENGES IN IMPLEMENTATION

Economic Barriers

Economics or funds required for traceability are one of the major difficulties, especially for small and medium-sized farms. Participation is frequently discouraged by the costly initial expenses of implementing technology like RFID tags, digital record-keeping systems and certification programs particularly in areas with narrow profit margins and restricted access to finance. It is found that where large scale producers can afford these expenditures to gain access to markets, smaller farmers view traceability as costly and unreliable (Shear & Pendell, 2020). This barrier makes it worse with the lack of significant market benefits such as premiums for certified beef (Tsakiridis & Wallace, 2020). Additionally, limited knowledge, infrastructure gaps and compliance expenses further hinder adoption, making traceability appear more as a regulatory burden than a value adding practice (Lestari et al., 2022; Mumba et al., 2024).

Stakeholder Reluctance and Lack of Awareness

Stakeholders such as farmers, processors, traders and distributors are usually reluctant to adopt traceability technologies, as they fear that it may impose new tax on their enterprise. A few of them do not intend to show their existing loopholes, weaknesses and unhygienic practices. Many perceive these systems as an additional burden that is why hesitant to use smart technologies. Some even hide the originality of their records, while others consider it a waste of time with no direct benefits. However, high qualified youth are usually more responsive and found cooperative for implantation of adequate traceability production system.

FUTURE RECOMMENDATIONS

To strengthen beef traceability and its implementation in Pakistan, policymakers and Government institutions should take active steps. Incentives can be provided to promote traceable beef production and sales. Whereas standards for traceability should be fixed to export the beef. Implementation of mobile based traceability app in online Qurbani systems, digital identification, and cost-effective electronic tags can aid record keeping and tracking. Implementing these measures will not only improve transparency and consumer trust but also help to trigger the beef business around the year globally. Furthermore, integrating traceability data with centralized digital platforms can enable real-time monitoring and rapid response to food safety issues. Collaboration between government, industry, and technology providers will be essential to ensure consistent implementation across the value chain. Such coordinated efforts can position Pakistan as a competitive player in the global beef market while safeguarding public health and consumer confidence.

CONCLUSION

Conclusively, it is stated that android based traceability solution is an innovative livestock management tool which can address the beef quality concern in Pakistan. It is a great initiative towards the journey of food safety. Consequently, it may help farmers to fetch premium price around the year. The consumer may be enabled through scanning QR code using android based mobile traceability Apps to track farm to fork information. Pakistan can implement step wise beef traceability system with the help of proper incentives over a period of the next 5 years to ensure transparency, food safety, and stronger domestic and export markets.

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