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Enabling Consumers to Trace the Origin of Goat Meat from Farm to Fork through a Mobile-Based Traceability App

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ABSTRACT

Aim of the Study: The study was focused on creating a traceable mutton production system that would capture and integrate data from mutton-producing animals throughout the production, processing, and distribution phases. It also sought to bring out consumer transparency by allowing mutton tracing from farm to fork via an Android-based mobile application and QR code technology.

Methodology: The study was conducted in the Skardu District of the Gilgit-Baltistan region, where data was collected from sixty goats at different stages of the value chain.

Findings: The statistical analysis revealed that the goats mostly slaughtered were of age 2.25 years or older, with black as a predominant coat color. Age and weight distribution also showed variations due to market preference and production trends. The introduction of QR code technology made it possible for the consumers to fetch information about the attributes of the meat, such as the age of the animal, breed, and processing history, thereby earning more trust and confidence in the market. This digital traceability system improved awareness and transparency for consumers while ensuring accountability and quality control for the whole meat supply chain.

Conclusion: The investigation concluded that the end consumer's ability to trace the history and origin of goat meat along with the entire value chain via an android-based mobile application, "MeaTrax," has been tested and confirmed by the application of smart technologies, mainly QR codes, the internet, and smartphones. These findings indicate the potential of digital traceability solutions in promoting transparency, safety of food, and informed consumer choices in the livestock industry.

Keywords: Goat Meat, Traceability, MeaTrax App, QR Code Technology and Farm to Fork.

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1. INTRODUCTION

Domesticated goats (Capra hircus), or goats as they are popularly known, are one of the oldest livestock animals and have been supplying meat, milk, and fiber to people for thousands of years (Naderi et al. 2008). A Development Survey, Economic Survey on Pakistan 2023-24, mentions that goat population in the country is about 87 million, owing to the ever-increasing demand for mutton (GOP, 2023-24). This mutton industry makes vast contributions to the agricultural sector of the country with respect to local consumption and exports (GOP, 2023-24). For the diet of Pakistan, mutton has very much importance and cultural symbolism, especially at the time of religious festivities (Hussain et al., 2020). The mutton industry provides numerous livelihood opportunities to smallholder farmers, thereby taking its share towards contributing to the stability of the rural economy and food security (McGill et al., 2020). The industry has numerous challenges that have hampered its growth and sustainability.

Meat quality is highly variable due to the factors of breed and feeding practices, subjecting it to another major challenge (FAO, 2019). Another real challenge regarding this variability in meat quality is increased marketability and satisfaction of consumers due to inconsistent breeding programs and very poor animal husbandry practices (Pethick et al., 2005). Diseases like foot-and-mouth disease and parasitic infections are a real threat to sheep productivity, causing increased mortality rates (FAO, 2019). An equally significant problem is the inefficiency of the supply chain from production to market. Poor transport and lack of cold storage facilities may also cause high post-harvest losses and limit access to distant markets (McGill et al., 2020). Young farmers suffer in such a system as they often have to deal with exploitation by intermediaries who take away a huge share of profits leaving them very little returns (FAO, 2019).

In the meat industry, Traceability refers to being able to track the movement of meat products through the myriad of phases involved in production, processing and distribution (Golan et al., 2004). Effective traceability systems are necessary to ensure food safety, quality control and compliance with regulatory requirements (Regattieri et al., 2007). Such systems help to initiate a rapid response to food safety incidents by helping to identify and manage risks associated with the illness and contamination of meat (Kher et al., 2010).

In the development of technology, essentially in terms of mobile-based applications, the traceability systems have undergone a transformation to meet the demands of a real-time input of data and accessibility to all stakeholders along the supply chain (Li and Zhou, 2012). These applications provide traceability and enhance the food safety measures by allowing farmers, processors, distributors and retailers to record and access relevant information about the origin, processing and distribution of meat products (Karlsen et al., 2013).

Traceability app can improve efficiency by streamlining paperwork processes, reducing errors, and fast tracking the flow of information throughout the different phases of the supply chain (Thakur and Hurburgh, 2009). Besides, for the meat sector, this means economic advantages through decreased losses from food recalls, heightened operational efficacies, and improved market access for quality-enhanced products (Regattieri et al., 2007). For developing countries like Pakistan, traceability systems will also assist in complying with global food standards, thus giving rise to great export opportunities benefiting the economy (Thakur and Hurburgh, 2009).

2. MATERIALS AND METHODS

Location and Duration of Study: The study was conducted in the Skardu District of Gilgit-Baltistan, Pakistan. Skardu is located within the Himalayan range, providing a very crucial point for agricultural and pastoral activities. Over a period of four months, the research was conducted, specifically during the post-monsoon and pre-winter phases in Skardu that started from August till November 2024. This period is best known for farming of goat and the slaughtering activities, providing comprehensive data on the

mutton value chain. Additionally, this time period was also preferred to observe and study the seasonal variations in supply chain dynamics livestock health, and meat quality.

The climate of Skardu District of Gilgit-Baltistan has been categorized as cold desert because of the significant seasonal and diurnal variations in temperature. During the study period, from August to November, the average temperature ranged between 10 °C (50 °F) and 23 °C (73 °F) during the day, whereas the nights were cooler at times temperature would fall at 0 °C (32 °F) in late autumn. As compared to other regions of Pakistan, in Skardu, the range of rainfall was not that high, averaging around 50 - 75 mm annually, Specifically in August, there was a very light rain. Relative humidity during this period was around 45 - 60%, which created a relatively dry environment that could influence livestock health and meat quality, as mentioned in Table 1 (Weather Atlas, 2024).

Table-1: *Average climate of Skardu District during study period*.

	Year 2024			
Parameter	**August**	**September**	**October**	**November**
Average Temperature °C	21.5	16.5	10.0	3.5
Max Temperature °C	27.5	22.0	15.0	8.0
Mini Temperature °C	15.5	11	5.0	-1.0
Relative Humidity %	68.6	66.7	70.5	79.1
Rain fall mm	20.8	14.5	11.9	12.3

Field Surveys in Mutton Value Chain: Field surveys were conducted to engage various stakeholders involved in the mutton value chain. To completely understand the mutton value chain's dynamics, multiple farms, processing units and distribution centers were surveyed. At different phases of the mutton value chain, willing farmers, ranging from small-scale goat farmers to large-scale producers, were identified and contacted. Producers who managed breeding, feeding and rearing practices were made sure to include in order ensuring a diverse representation of farming methods, efforts. In an approach to understand the operational challenges and practices, processors, including those involved in slaughtering and initial meat processing, were also included. Similarly, in order to evaluate their role in traceability and maintaining meat quality, distributors and retailers were also contacted. These surveys, which included producers, processors, and distributors, allowed the collection of useful information, enabling collaboration among stakeholders and ensuring the app's design corresponded with their practical demands and operational workflows.

Selection of goat animals: For this study, a total of 60 goats were selected from the mutton value chain, ensuring diversity in age, color, origin and size. The criteria on the bases of which the selection of animals was made were the physical characteristics and of the animals from different areas within Skardu District. This ensured that the sample used to assess the traceability app was representative of the different mutton value chain phases.

2.1 Capturing and Entering Data

The data for the selected animals were captured using an Android device (Samsung Galaxy A30S) equipped with a high-resolution camera to ensure accurate and detailed imaging. Key parameters such as animal identification details, physical characteristics (age, size and color) and distinctive features were recorded visually. The captured data were then systematically entered into the traceable parameter system using the MeaTrax app, a mobile-based application designed to facilitate efficient data recording and management through all three phases: production, processing and distribution, as mentioned in Table 2.

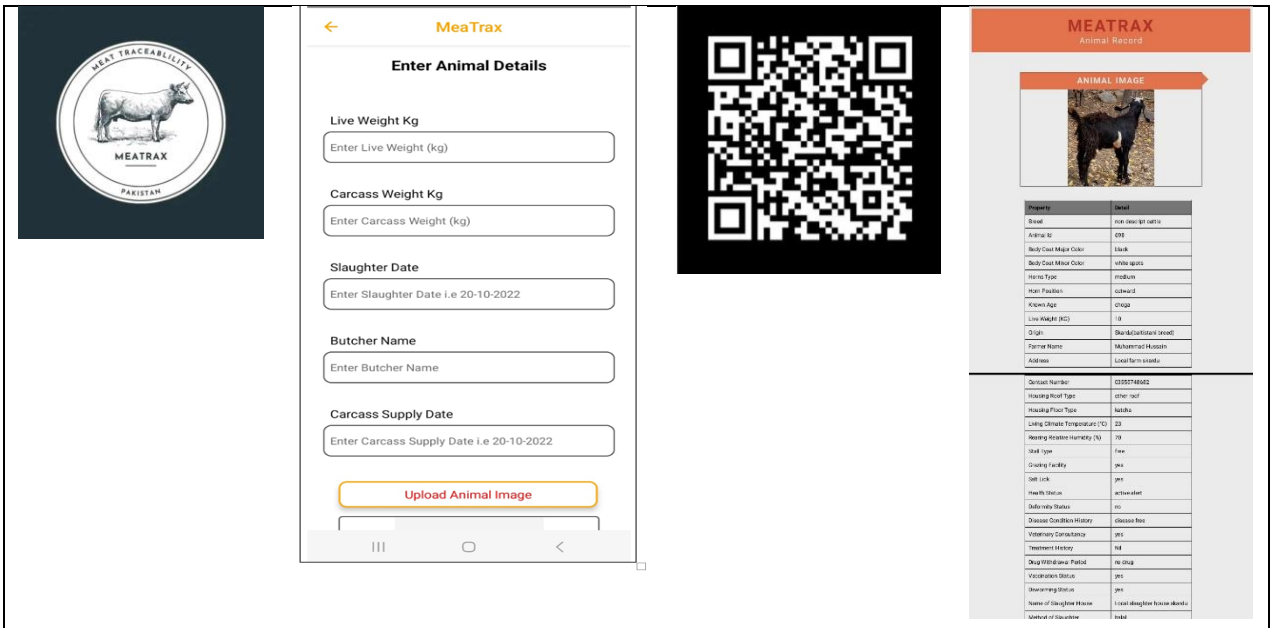
Table 2: *Attributes collected for traceability of goat meat origin through different phases of the mutton value chain in the Traceable Mutton Production System*

	Production phase	
1.	Breed	Nondescript, Baltistani
2.	Body Color	Black, brown, grey, white (with/without spots)
3.	Age of animal	< 1 year, 1 to 1.25 year, 1.75 to 2.25 year
4.	Housing floor design	Brick, mud, concrete, cubical
5.	Alert status	Dull/ Alert
6.	Ailment history	Diarrhea, cough, fever, disease-free
7.	Straw feed	Wheat straw, rice straw , hay etc.
8.	Fodder	Silage, maize, sorghum, bajra, oat etc.
9.	Farmer information	Name, address, phone number, animal origin
	Processing phase	
1.	Slaughter house	a,b,c
2.	Butcher detail	x,y,z
3.	Live weight	Kg
4.	Carcass weight	Kg
5.	Chilling & Packing	Yes/ No
6.	Date of carcass supply	00-00-0000
7.	Slaughter method	Halal
	Distribution phase	
1.	Distribution Type:	Local or Export
2.	Date of Carcass supply	00-00-000
3.	Contact Number	+9200000000

2.2 Generation of QR Codes for Traceability

The MeaTrax app was used to generate unique QR codes for each selected goat, enabling seamless traceability across the mutton value chain. Once the animal data was entered into the system, the app processed the information and encoded it into a distinct QR code. These QR codes contained all essential details about the animal, including its identification number, age, size, origin and processing and distribution information.

The generated QR codes were made accessible to consumers by embedding a link that could be scanned using a smartphone camera. Upon scanning, the QR code directed users to the stored data, which was retrieved in the form of a detailed PDF report. This final step provided consumers with comprehensive traceability information, including the animal's journey through the value chain, ensuring transparency and trust in the system, all these steps are mentioned in Figure 1.



Step 1: MeaTrax Android App | **Step 2: Capturing and entering data** | **Step 3: QR code Generation** | **Step 4: Retrieval of data in PDF report**

Figure 1: *Steps involved in capturing animal data through the MeaTrax app under the traceable mutton production system*

3. RESULTS

In response to the given access to consumers following are the findings. These results provide insights into the distribution of goat characteristics, including age, coat color and physical attributes along with the live weight and carcass weight. The findings highlight the system's role in ensuring transparency and reliability in the mutton value chain.

3.1 Percentage of Age group:

The age distribution revealed that the majority of goats (38) were 2.25 years or older (Chigga), followed by goats that were 1.75 years (Choga) (10), between 1 to1.25 year (Donda) (10) and younger goats less than 1 year (Kheera) (2), as depicted in Figure 2.

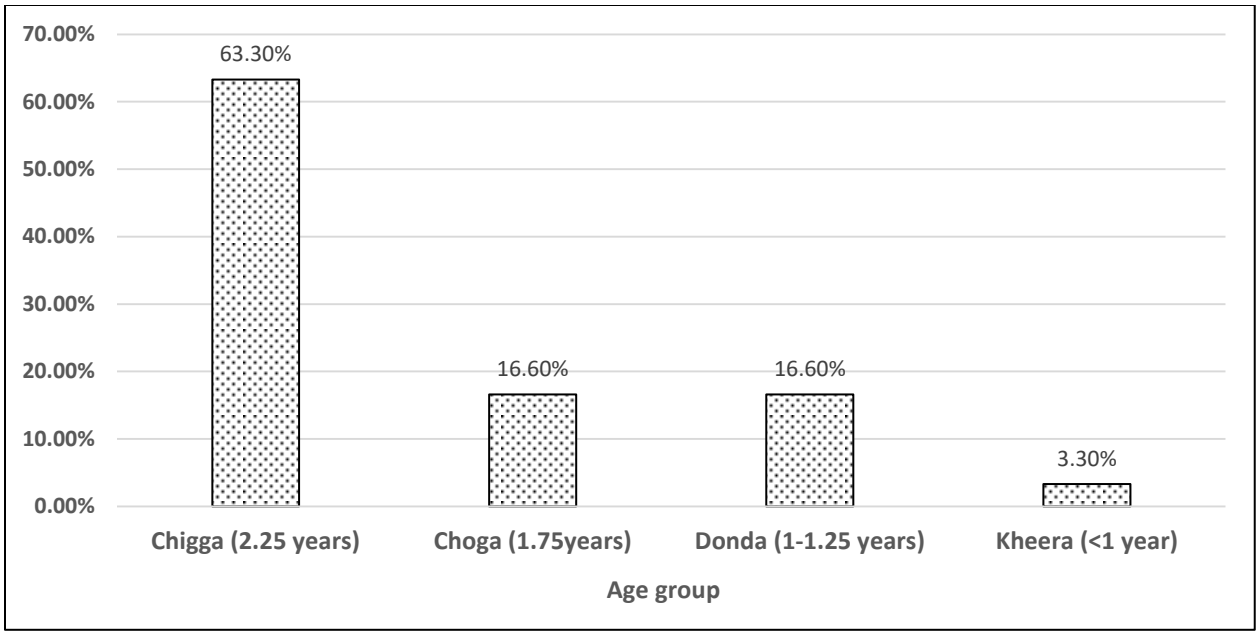


Figure 2: *Percentage of different age groups of goat animals in mutton value chain*

3.2 Percentage of Major body coat

The body coat analysis indicated that goats with Black coats constituted the highest percentage 41.6% (25), followed by goats with brown coats 28.3% (17), white coats 26.6% (16) and grey coats 3.3 % (2) as shown in Figure 2. The variation in coat colors highlights the genetic diversity in the studied population. The results are mentioned in Figure 3.

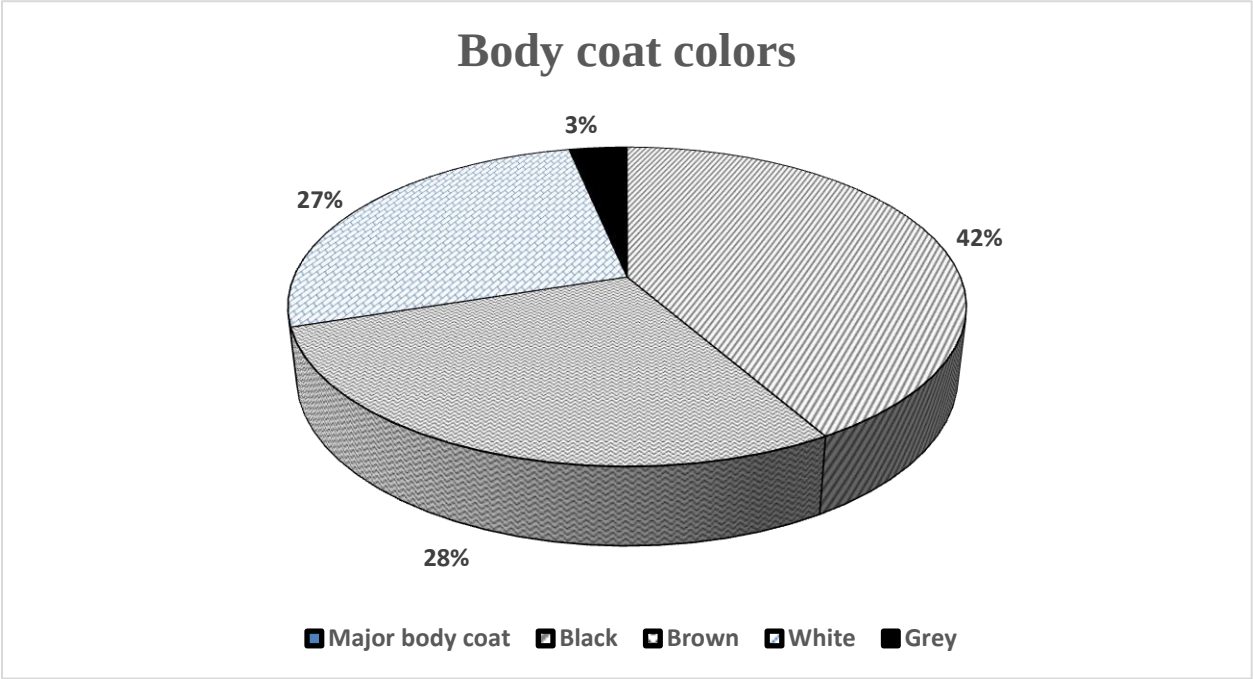


Figure 3: *Percentage of major coat color of goat animals in mutton value chain*

Enabling QR Code Traceability*:* The implementation of QR code scanning in the mutton value chain successfully enabled consumers to trace back the origin and various attributes of the meat they purchased. Scanned through a mobile application, the QR code provided a detailed account of its age, coat color, environmental conditions-including temperature and rainfall, feeding practices and housing conditions. This allowed digital traceability-the avenue through which the consumer verifies the meat's history, thus assuring confidence in its authenticity.

Enhancing Consumer Trust Through QR Code Usage: The use of QR code scanning and mobile applications significantly enhanced consumer trust in the mutton value chain. Consumers were able to retrieve verified data about the meat's source and production conditions, which reassured them about food safety and quality. The availability of transparent and real-time traceability information strengthened consumer confidence, making them more likely to trust and prefer meat products with digital tracking systems.

Percentage of Live & Carcass weight*:* The average live weight of the goats calculated to be 90.2 kg, with the highest live weight observed in goats aged 2.25 years and above. Similarly, the carcass weight averaged 45.19 kg, with the highest weights recorded for larger animals, as detailed in Table 3

Table-3: *Average live weight, carcass weight and dressing percent of goat animals in traceable goat meat system*

Age group	Average live weight	Average carcass weight	Average dressing percent
Kheera (<1 year)	16.5	7.98	48.36%
Donda (1-1.25 years)	18.9	8.90	47.12%
Choga (1.75 years)	27	12.69	47%
Chigga (2.25 years)	33.32	15.66	46.9%

4. DISCUSSION

In response to data analysis, it was found that male goats having age 2.25 years or older were more slaughtered as compared to the goats of smaller age groups. These findings are in line with those of Gawat et al. (2023), in which it was also reported that older goats are often preferred for slaughter due to their developed meat and distinctive flavor profile. As goats mature, their meat tends to have a stronger taste, which is desirable in various culinary traditions. Additionally, the meat from older goats is darker and less tender but juicier and more flavorful than that of younger goats (Gawat et al., 2023). There is the possibility that preference for mature goat meat plays a role in the higher slaughter percentages of older goats. From an economic standpoint, farmers are able to generate more profits for slaughtering their goats at a later age. In fact, older goats are heavier and higher yielding in terms of meat. This practice allows producers to maximize returns, as the sale of goat meat is positively associated with the profitability of the goat production enterprise (Gillespie et al., 2013). Therefore, retaining goats longer before slaughter can enhance economic benefits for producers.

The minimal slaughter rate (3.3%) of male goats under one year can be attributed to reproductive and herd management practices. Young male goats, especially those not intended for breeding, are often sold or slaughtered at a younger age to manage herd size and dynamics effectively. However, the low percentage observed suggests that many young males might be retained longer, possibly for breeding purposes or to reach a more desirable market weight before slaughter. This strategy aligns with findings that selling goats for meat, particularly slaughter goats, is positively associated with the profitability of goat production enterprises (Gillespie et al., 2013). Inferentially, male goats are more preferred for slaughter purpose at the age of 2 or more for its optimum taste and flavor.

In addition to variation in slaughter age, it was also found in the study that black colored male goats were numerically more slaughtered and were the predominant color as compared to the other coat colors. The

predominance of darker coat colors in the Baltistani goat breed may be an adaptive response to the cold, high-altitude environment of Skardu District of Gilgit-Baltistan. Darker skins absorb more sunlight, which helps to keep the body warm under cold conditions (Castro-Lima et al., 2015). There are studies concerning coat color and thermoregulation in goats that show black and brown goats are more adept at sustaining extreme temperature variations than the lighter animals (da Silva et al., 2013). This adaptation, therefore, probably accounts for their survival and reproductive success in the particular region, which possibly has elevated their numbers in the population.

Goat coat color is another trait that is socially influenced via selective breeding. In some pastoral and farming communities, darker-colored goats are often preferred because they are thought to be stronger, more resistant to diseases, and able to fetch better monetary returns (Tabbaa and Al-'Atiyat, 2009). Demand from the market could be a driving force behind the black-colored goat being bred in pastoral and other farming communities. Another reason for the maximum prevalence of black color in male goats could be demand factors and the site of the experiment, which is cold, Skardu District of Gilgit-Baltistan.

Mutton value chain backward tracing through smart technology by QR code scanning has enabled confidence in consumers. One of the key propellants of this trust-building endeavor has, therefore, been the role of smartphones and internet technologies on a mass scale in Pakistan. Availability of digital technologies has expedited the process of tracking and verification of food products by consumers (Fiaz et al., 2024). Charlebois et al. (2024) indicated the fact that QR code-based traceability systems set favorable impressions for consumers through easy access to the product history. Such research was supported by findings found by Kim et al. (2023) to indicate that consumers prefer traceable meat products to lessen worries about food fraud and mislabeling. The increasing trends of online Qurbani and digital meat purchasing platforms further enhance consumer confidence in QR-based traceability systems. It has been reported that details about animal origins, feeding practices, and environmental conditions serve as stimuli for the purchase-so-enhancing trust (Sarfraz, 2022; Wang et al., 2023; Conter, 2024). Regulatory bodies promoting food traceability in Pakistan and other developing nations have also aided the establishment of smart technologies in the meat industry (Zhu et al., 2022; Fiaz et al., 2024).

Supports the traceability using QR codes through related government regulations and industry initiatives to enhance food safety. For example, the Punjab Food Authority (PFA) has used QR codes to establish a track-and-trace system for food products to thwart counterfeit goods and ensure that edible commodities are safe for consumption. This regulatory impetus will compel food manufacturers to adopt digital traceability solutions and thus harmonize practice across the industry (Sarfraz, 2022). Other programs, such as the Pakistan Animal Identification & Traceability System (PAITS), have been started by government to regulate and monitor the livestock field. PAITS allows for digital tracking of animals from farm to market, thereby ensuring transparency and compliance with food safety standards. Integrated with a modern traceability system, it ensures adherence to Punjab Food Authority (PFA) regulations. In Pakistan, the QR code-scanning method in the mutton value chain is a progressive measure in improving food traceability through technological reach, consumer demand for transparency, and regulatory favor.

5. CONCLUSION

According to the findings of the study, older goats were preferred for slaughter, black was the dominant coat color in the Baltistani goats, and the end mutton consumers could trace back the history and origin of goat meat through different phases of meat value chain: production, processing, and distribution through an android mobile-based application using smart technologies like QR code, internet, and smartphones. Such findings underscore the contribution of digital traceability toward increasing consumer confidence.

6. IMPLICATIONS

The implementation of a mobile-based traceability app for goat meat could be a concrete step toward the improvement of food safety and build consumer trust by ensuring transparency in the supply chain. It can

help to detect fraud, reduce health risks, and make it easier to follow food safety rules. This system also benefits farmers and sellers by increasing market opportunities and improving supply chain efficiency.

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