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Enabling Consumers to Trace Beef Origin across the Value Chain through an Android-Based Traceability App

Zainab Zulfiqar[1], Syeda Maryam Hussain[2], Muhammad Mushtaq[1], Kashif Ishaq[2], Muhammad Fiaz[2*], Hira Maryam[1], Muhammad Faizan[2], Muhammad Shoaib[3], Muhammad Shakeel[4]

[1]Department of Zoology, Wildlife and Fishries, PMAS-Arid Agriculture University Rawalpindi, Pakistan
[2]Department of Livestock Production & Management, PMAS-Arid Agriculture University Rawalpindi, Pakistan
[3]Department of Parasitology and Microbiology, PMAS-Arid Agriculture University Rawalpindi, Pakistan
[4]Department of Clinical Studies, PMAS-Arid Agriculture University Rawalpindi, Pakistan
Correspondence: dr.fiaz@uaar.edu.pk[2*]

ABSTRACT

Aim of the study: The study's main aim is to establish a traceable beef production approach that collects and integrates data from beef cattle throughout the production, processing, and distribution phases. It was also intended to empower end consumers by enabling farm-to-fork beef traceability using an Android mobile application and QR code technology.

Methodology: Data were collected from 60 beef animals during numerous field visits across the beef value chain: production, processing and distribution out of Attock and Rawalpindi districts of Punjab province, Pakistan. Important attributes such as breed, age, origin, health condition, feeding regimen, housing, climate, meat processing and distribution practices were accurately recorded and integrated into the MeaTrax application. The QR codes were generated in response to entered information, scanned through android cameras and retrieved data PDF using smart technologies like internet and QR code technology.

Findings: Statistical analysis showed that the majority of slaughtered animals were around two years old, primarily white colored, with an average 48 dressing percentage. This valuable information was made easily accessible to consumers through scanning QR codes and internet connectivity, ensuring farm-to-fork traceability throughout the beef value chain.

Conclusion: Based on the findings, it was concluded that end beef consumers were empowered to trace the origin of beef and access related information across the entire beef value chain using the Android-based traceability app. These results emphasized the potential of digital traceability solutions in enhancing transparency and served as a concrete step toward strengthening food safety.

Keywords: Beef Value Chain, Traceability, MeaTrax app, QR Code Technology and Farm to Fork Access.

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1. INTRODUCTION

Beef is the most preferred meat in Pakistan, influenced by cultural and religious factors**,** with increasing demand driven by affordability and availability, resulting in an annual production of 2630 thousand tons (GOP, 2023-24). The halal food sector's emphasis on quality and safety is in response to increasing consumer demand, which has significantly enhanced Pakistan's meat industry (Sohaib and Jamil., 2017). Beef meat has become an abundant source of various critical vitamins, essential amino acids, vitamins and minerals. Beef has different bioactive substances with positive health benefits such as weight management, anti-inflammatory effects, lower cholesterol and triglycerides. Dietary cholesterol doesn't directly affect the blood and overall well-being (Pereira and Vicente, 2013).

In Pakistan, cattle and calves are the primary source of beef, with the calf trade experiencing a significant surge in demand. The demand for these calves peaks during Eid-Ul-Azha, making it a major occasion for beef traders to capitalize on the premium price. Although public health experts have raised concerns about the excessive consumption of beef, citing links to rising rates of obesity, heart disease, and type-2 diabetes (Garnett et al., 2014), boneless beef is gaining popularity as a preferred choice at wedding celebrations, replacing chicken meat. However, beef trade remains largely restricted throughout the year, except for Eid-Ul-Azha, when demand peaks. The marketability and consumer satisfaction is mostly affected due to mixing donkey meat with beef, injecting water into carcasses, selling meat from sick and old animals. Consumers only get opportunity to consume high quality beef once a year on Eid-Ul-Azha and have no trust on beef for rest of year. These applications ensures the accountability and enhances the food safety measures by enabling the farmers, processors, distributors, and retailors to record and access information related to the origin, production, processing and distribution of meat products.

Traceability tools are defined as the capacity to track and identify the origin of beef (Shivanagowda et al., 2023). According to Kafetzopoulos et al. (2020), it has a very important role in assuring transparency towards consumers in the meat supply chain by verifying the origin, quality, and safety of meat products. Muslim consumer build trust because traceability ensures adherence to halal standards and guarantees the authenticity and integrity of halal products. On a world scale, with increasing demand for halal foods, halal meat production has grown tremendously (Mohammed et al., 2017). That's why it's the need of time to implement traceable beef production approach using smart technologies with internet connectivity and QR code technology. This study was designed with aim to enable the end consumer to trace back the beef origin and access related information throughout beef value chain.

2. MATERIALS AND METHODS

Study site: The study has been carried out in the Punjab province, with the Attock and Rawalpindi districts as the selected areas. These districts were included in Potohar region which is rich in natural vegetation provides grazing condition for animals. Beef farmers accessible from these sites were then identified and registered on-the-ground for systematic data collection. The selected districts constituted different environments which, thereby, made it possible to conduct an exhaustive analysis of beef farming in various climates.

Registration of stakeholders: Identification and registration of the stakeholder took place as a result of numerous field visits. The criteria used in selection were based on the participation of stakeholder in livestock business, especially one or more of the three important phases in the beef value chain as shown in Figure 2 which are production, processing, and distribution.

Selection of beef animals: Sixty beef calves have been registered according to age, sex, and deformity status. The cattle are provided with mineral supplementation and first aid basics to maintain good health on the farm. Economic management ensures enough feeding, proper management, and adequacy of housing for the welfare of the selected animals.

Traceable beef production model: For the purpose of data input and retrieval of the added information through Android devices, the pre-existing android-based application MeaTrax (Fiaz et al., 2024) was

utilized. The app was specifically designed in a way that it would trace the meat from the market, as demonstrated in Fig. 1 for this, many field visits were done to get relevant information about animals for the MeaTrax app.

1. **Data entry:** The MeaTrax application facilitates data entry during all three phases of the beef supply chain production, processing, and distribution. Information about the parameters related to each animal such as breed, age, health records, feeding practices, and vaccination history has got recorded during field visits as given in Table 1. Data were entered into MeaTrax app using android mobile having internet connectivity. The process involve capturing photos of the animals using android mobile camera, accessing to record climate conditions and then all the relevant data manually entered into the MeaTrax app.
2. **QR code generation:** After data collection and storage in the MeaTrax system, the app generated a unique QR code for each animal, which was printed on all products. By scanning the QR code, consumers could access detailed information about the meat's origin, processing, and distribution.
3. ***Data retrieval:*** In data retrieval all the gathered data (production, processing and distribution) for each animals was summarized into an extensive report. The report was saved as pdf file, making it easy to share with others and keep as record for future reference.

Table 1: *Attributes collected for traceability of beef origin through different phases of the beef value chain in Traceable beef Production System*

Sr. No.	**Production phase**	
1.	Breed	Dajal, Dhanni, Lohani, Cholistani, Nili Ravi
2.	Body Color	Black, Brown, Grey, Red, White (with/without spots)
3.	Age of Animal	1.5 years (Kheera), 2 years (Donda)
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
Sr. No.	**Processing phase**	
1.	Slaughter house	a, b, c
2.	Butcher detail	x, y, z
3.	Live weight	In kg
4.	Carcass weight	In kg
5.	Chilling & Packing	Yes/ No
6.	Date of carcass supply	00-00-0000
7.	Slaughter method	Halal
Sr. No.	**Distribution phase**	
1.	Distribution Type:	Local or Export
2.	Date of Carcass supply	00-00-000
3.	Contact Number	+9200000000

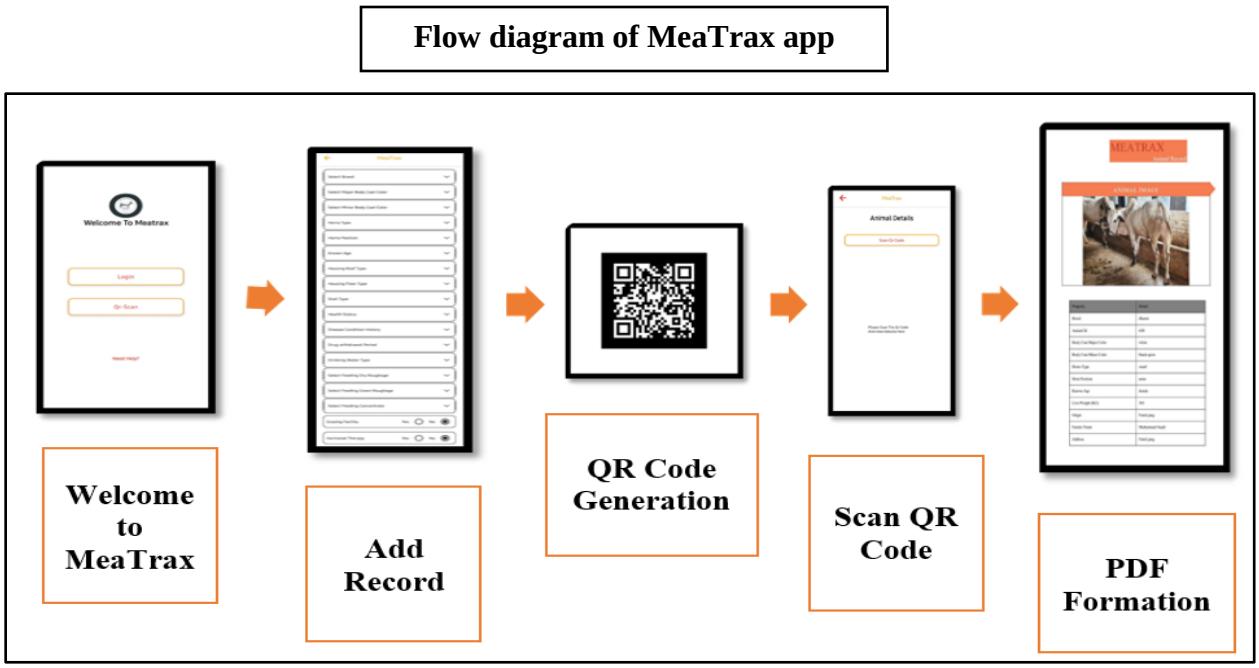


Figure 1: *Flow diagram illustrating the usage of the MeaTrax app for data entry and retrieval under the traceable beef production model.*

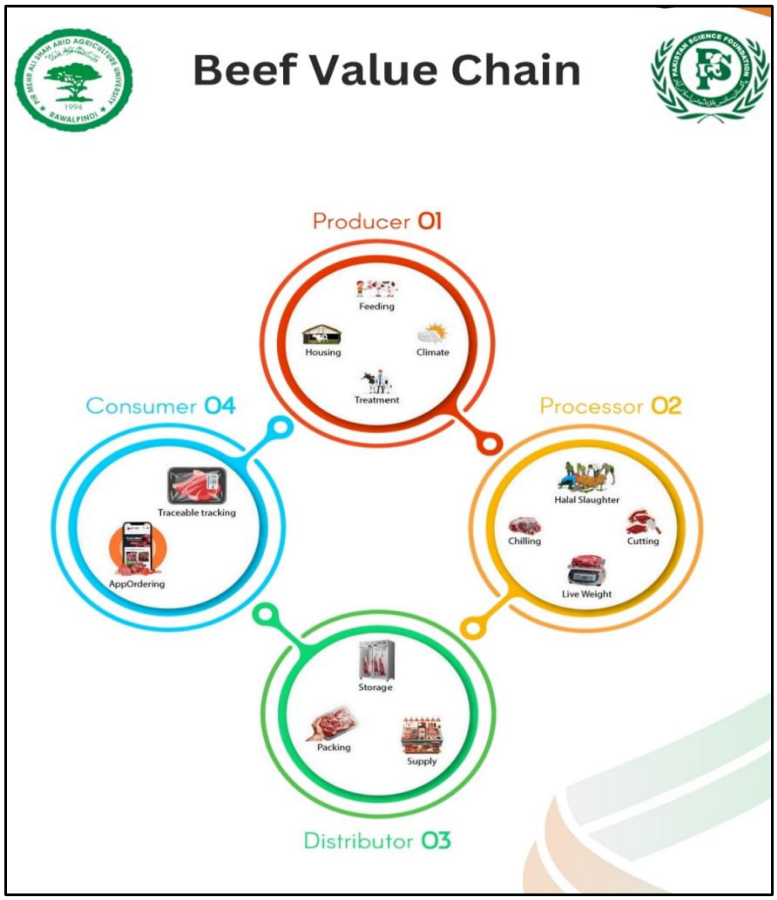


Figure 2: *Beef value chain from Farm to Fork*

3. RESULTS

Percentage distribution of different breeds: The F×S Crossbred had the highest representation, indicating its greater occurrence in the captured dataset. However, the Cholistani breed had the lowest percentage, indicating that it was present in the sample at a relatively low level as shown in Figure 3.

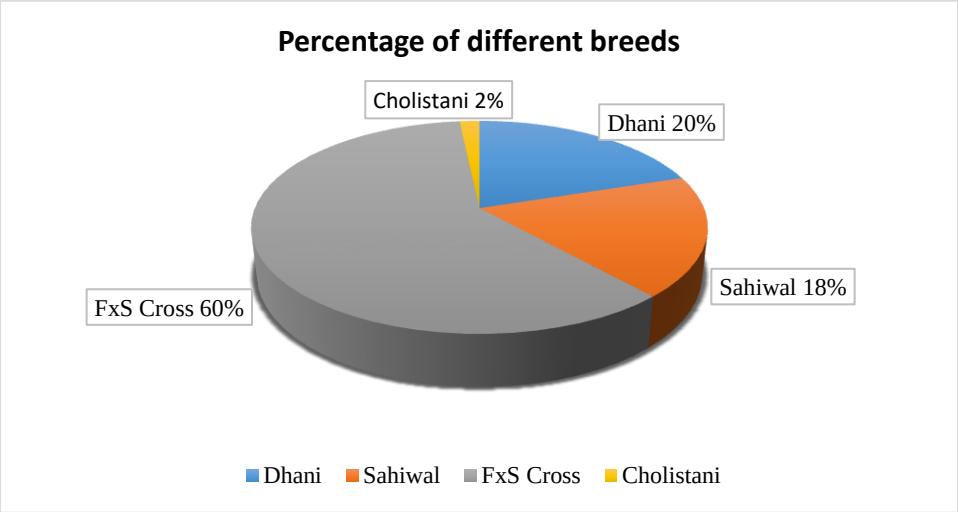


Figure 3: *Percent of cattle breeds in Beef Traceable Production System*

Age factor in beef value chain: The age distribution of the captured animals highlights a clear trend as illustrated in Figure 4. Animals aged 2 years were the most prevalent, accounting for 49 individuals, representing the majority of the population. This was followed by the 1.5-year age group, which comprised 10 animals. In contrast, the 3-year age group was the least represented, with only one animal recorded.

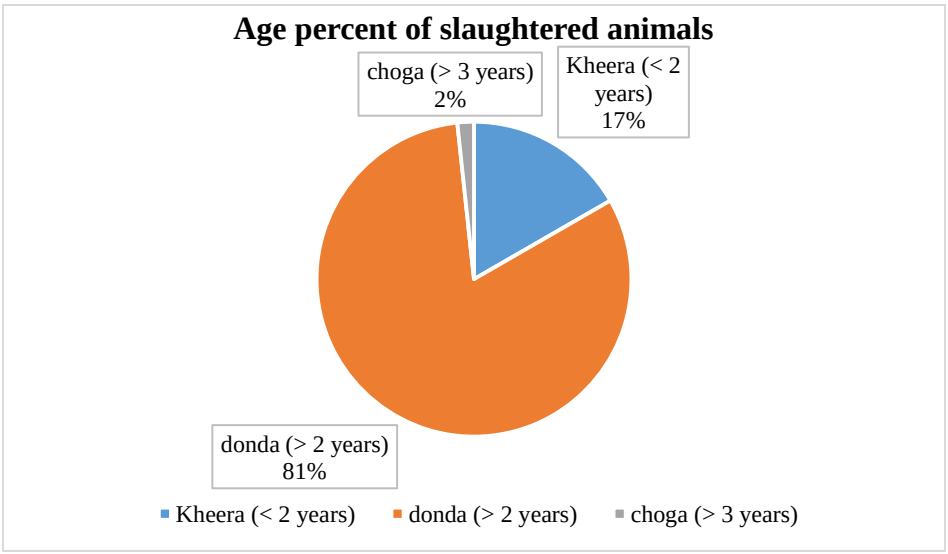
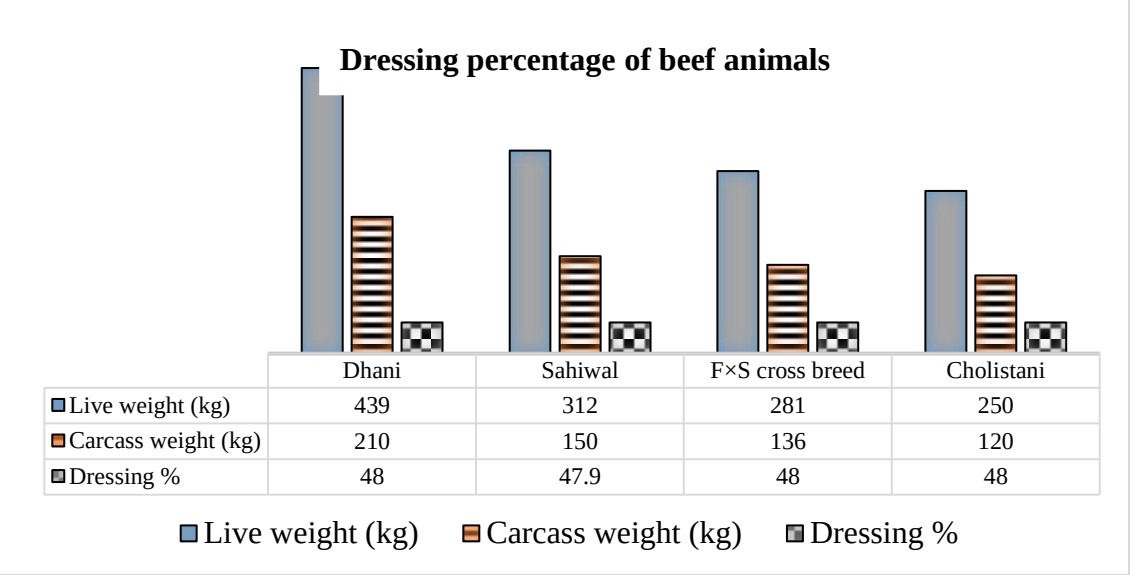


Figure 4: *Percent of different age groups of slaughtered beef animals under traceable beef production approach*

Live weight, carcass weight, and dressing percentage: The study revealed significant variations in live weight, carcass weight, and dressing percentage among the different cattle breeds, as demonstrated in Figure 5. The Dhanni breed, F×S crossbred and Cholistani breed exhibited the same value of 48%. In comparison, the Sahiwal breed recorded a dressing percentage of 47.91%.



	Dhani	Sahiwal	F×S cross breed	Cholistani
Live weight (kg)	439	312	281	250
Carcass weight (kg)	210	150	136	120
Dressing %	48	47.9	48	48

Figure 5: *Live weight, carcass weight and dressing% of different cattle breeds under Traceable Beef Production model.*

Percentage of body colour of captured beef animals: The captured animals exhibited a diverse range of body colors, including white, brown, black, and grey. White was found to be the most prevalent color dominating the population, while brown, black, and grey appeared in varying proportions as shown in the Figure 6.

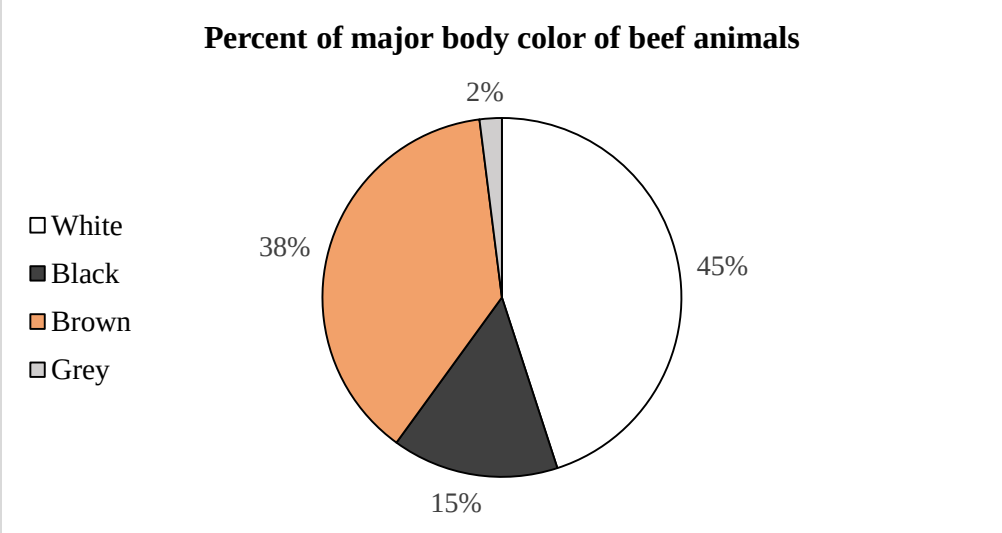


Figure 6: *Percent of major body colors of beef animals under Traceability*

4. DISCUSSION

A traceability system not only tracked the origin of animals but also provided beneficial data on breed-specific performance, which can enhanced product efficiency and consumer trust. Beef animals around the aged 2 years often preferred than younger animals (less than 1.5 years) due to its superior meat texture, flavor and composition. Animals gained more intramuscular fat as they become older, which enhances their juiciness and tenderness. Younger animals usually had less intramuscular fat which results in less tender meat as compared to older animals (Arshad et al., 2018). However, beyond a certain age, tenderness may decreased as the meat becomes tougher due to increased collagen cross-linking (Kopuzlu et al., 2018). Older animals had more developed muscle fibers, resulting in a more complex texture that some consumers found appealing. This muscle development was influenced by factors such as genetics, nutrition, and age (Sakowski et al., 2022). Older animals contained higher concentrations of long-chain fatty acids, which enhanced flavor characteristics (Arshad et al., 2018). Marbling, which referred to the intramuscular fat distribution, increased with age. Higher marbling scores were linked with superior taste and tenderness since fat served as a natural tenderizer and flavor enhancer (Kern et al., 2014). This implies that beef animals aged 2 years were preferred most probably due to superior texture, flavor enhancement, and chemical composition, all the case due to aging changes.

Among captured animals, coat color reflected genetic diversity, crossbreeding and environment adaptation. In cattle, coat color was influenced by genetic makeup such as base color genes and modifiers. Dominant genes for dilution or spotting can also lead to the appearance of white-haired cattle than ever darker base colors like black or brown (Kunene et al., 2022). Local breeds revealed an introduction of dilution genes through exotic breeds and often interestingly increased traits like white or lighter coat colors (Adinata et al., 2023). The climatic conditions affecting localization also include the influence of white coloration (e.g. Attock and Rawalpindi). Lighter colored coats ensure sunlight reflection, thus mitigating heat stress in cattle (El-Sherbiny et al., 2023). This may have also been the basis on past research which suggested that the heat-tolerant breed such as Dhanni was able to do well under arid and semi-arid conditions on account of such features as lighter coat pigmentation. It can be inferred that this diversity of coat colors among the captured animals is indicative of a genetic and environmental interplay process.

The Dhanni breed, with its live and carcass weights and dressing percentage, shows good adaptability to the existing local conditions and management practices. The dressing percentages of 48.6% and 48%, however, were slightly lower in comparison with the F×S crossbred and Cholistani breed. The lowest dressing percentage was in Sahiwal at 47.91%. The key factors contributing to these variations were more of body composition, and feed efficiencies of the breed types. Dressing percentage below 50% in all breeds might be attributed to the factor that farmers were unable to adequately finish beef animals before slaughter. The moderate dressing percentage of the F×S crossbred could be attributed to its intermediate characteristics as a crossbreed. The Cholistani breed, despite its hardy nature, showed poor muscle development with high body temperature, while the Sahiwal breed was developed mainly for milk production rather than muscle production (Suliman et al., 2021). Poor dressing percentage is attributable to an excess amount of non-carcass components like a large digestive tract and thin skin (Pacheco et al., 2023).

Traceability systems elevate consumer trust by giving detailed information regarding the origins, production, and distribution of meat products. Traceability labels and certifications tend to encourage the consumer to feel assured about the quality and safety of the products, thereby increasing their purchasing potential. Smart technologies such as Smart Ear Tags, the blockchain technology, and Android-based apps enabled the tracing of the beef value chain. The technologies were also backed up by earlier research (Fiaz et al., 2024; Erdos et al., 2024). The MeaTrax app was capable of tracking animals from processing to distribution through scanning QR codes. It was inferred that traceability built consumer trust through transparency and assurance regarding the quality and safety of the products.

On the other hand, online Qurbani played a very important role for building consumer trust and satisfaction. Online Qurbani was gaining much popularity, especially during the time of the COVID-19 pandemic, as it provided a comfortable and safe way to discharge one's religious obligations (Andik et al., 2022). Conversely, some of the reasons against this trend were logistics, qualities, and trust. The selling of donkey meat along with beef, injection of water in carcasses, selling of sick and old animals have so often hindered marketing and consumer satisfaction. To restore consumer trust in online Qurbani activities, service providers needed to guarantee that every part of the process, from animal selection to meat distribution, was carried out transparently and according to religious standards (Syatar et al., 2020). This was done based on a traceability system through an Android-based application. Traceability systems were inferred to be indispensable in creating consumer trust by ensuring transparency with regards to quality and safety.

5. CONCLUSION

Upon the findings, it was concluded that end users in the beef value chain could trace the origin of beef with the use of an Android-based traceability app to access information through the entire beef value chain. Furthermore, it was concluded that end consumers of beef could trace the origin of beef through all production, processing as well as distribution stages with the help of the Android-based MeaTrax traceability app. Most slaughtered animals were found to be two years old, predominantly white in color with 48% dressing rate.

6. IMPLICATION

These results emphasized the potential of digital traceability solutions in enhancing transparency and served as a concrete step toward strengthening food safety.

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ORCID's

Zainab Zulfiqar [1] https://orcid.org/0009-0009-3595-0421
Syeda Maryam Hussain [2] https://orcid.org/0000-0002-6009-2125
Muhammad Mushtaq [1] https://orcid.org/0000-0003-0574-8125
Kashif Ishaq [2] https://orcid.org/0000-0003-1040-305X
Muhammad Fiaz [2] https://orcid.org/0000-0002-3398-5243
Hira Maryam [1] https://orcid.org/0009-0000-1024-9852
Muhammad Faizan [2] https://orcid.org/0009-0008-9176-1361
Muhammad Shoaib [3] https://orcid.org/0000-0001-5431-7976
Muhammad Shakeel [4] https://orcid.org/0000-0001-8436-5741

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