DEVELOPING AN INNOVATIVE TRACEABILITY SOLUTION TO TRACE BEEF ORIGIN THROUGH DIFFERENT PHASES OF BEEF VALUE CHAIN USING SMART TECHNOLOGIES

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ABSTRACT

Beef's rising popularity in Pakistan is evident as consumption pattern of people is progressively shifting towards it. Despite this, the beef trade remains constrained due to consumer distrust. A project, imbedded in eco-friendly principles and environmental biology, sought to boost transparency by capturing beef data throughout production, processing, and distribution stages, permitting consumers to trace its origin. A mobile based traceability app MeaTrax was developed and captured data for 311 beef animals, recording essential attributes; breed, color, age, weight and more. This app, with an eco-friendly focus, generated QR codes for consumer access. Results depicted 49.8% slaughter rate for crossbred animals, with Friesian and Sahiwal breeds exhibiting the highest carcass weight and dressing percentage. Conclusively, MeaTrax traceability app was found an innovative technique, using smart technologies to trace origin and other attributes of beef. This innovation was aimed to improve the beef value chain from farm to fork, contributing to enhance food safety.

Keywords: Beef, Tracability, MeaTrax app, Smart technologies,Food safety and Consumer trust.

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INTRODUCTION

Beef has become valuable food item in Pakistan and consumption pattern of people is shifting towards beef rather than any other meat. The rate of beef production is increased progressively than that of mutton production with effect from last 3 years and reached 2544 thousand tons annually (GOP, 2023). The halal meat industry, valued at around $600 billion, is a prominent part of the $ 3 trillion halal trade, attracting both Muslims and non-Muslims due to its safety, hygiene, nutritional value, and quality (Sohaib and Jamil 2017). Awareness is progressively made to eat red meat in current era of highest flow of information. In response to awareness about beef quality, beef trade is trigging in Pakistan through local consumption and export to gulf countries as well as neighboring country Afghanistan. That's why Pakistan's meat and edible meat offal exports have been reached US$339.93 million for year of 2021 as revealed by United Nations COMTRADE database on international trade (Trading Economics, 2023).

Beef meat has become a plentiful source of essential amino acids, vitamins, minerals, and bioactive components (Pereira and Vicente, 2013). Beef has different bioactive substances like creatine, taurine, Conjugated linoleic acid (CLA) and cholesterol. The creatine can be used as energy source for muscle growth & maintenance (Candow *et al*., 2014), whereas taurine serve antioxidant (Spriet and Whitfied, 2015) and CLA is a ruminant trans-fat with positive health benefits while consuming as part of a healthy diet (Koba and Yanagita, 2014). The dietary cholesterol has no effect on blood cholesterol and not injurious to health (Eckel *et al*., 2014).

Beef resources in Pakistan are mostly from beef and cattle calves, beef trade of these calves is at its largest at the occasion of Eid-Ul-Azha due to premium price. Despite the concerns expressed by public health experts regarding the overconsumption of beef and its association with increasing rates of obesity, heart disease, and type-2 diabetes (Garnett, 2014), boneless beef is becoming increasingly popular at wedding events, replacing chicken meat. However, beef trade is still limited in the year except Eid-Ul-Azha. Main reason is lacking consumer trust due to malafide practices of butcher, mixing of donkey meat, adding water into arterial system of carcass and selling beef from spent/disease 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. This is need of time to develop consumer trust on locally produced beef to ensure food safety. It is only possible if we implement concept of traceability in our production, processing and distribution

channels which helps consumers to trace farm to fork information.

Traceability tools hold paramount implication as they expedite the retrieval of historical data, usage details, and the spatial whereabouts of an object through recorded identifiers (Corina, 2013). These tools play a pivotal role in development of consumer trust within meat supply chains, ensuring transparency, and safeguarding consumer welfare (Kafetzopoulos *et al*., 2020). This strategic approach proves particularly invaluable in the trading of halal meat, ensuring particular compliance with halal standards. The surge in the global popularity of Halal food has resulted in adequate increase in Halal meat production (Mohammed *et al*., 2017). Mobile-based applications have appeared as established solution, endowing customers to directly access and verify information about halal products on their mobile phones (Kassim *et al*., 2012).

Keeping in view the importance of traceability solution, this project was designed with main target to develop methodology of traceable beef productions system with the help of private industry as public-private partnership. It was aimed to enhance consumer trust through trace back from farm to fork value chain. Specifically, objective were made to capture beef data through production, processing and distribution stages and enable end consumer to trace back the origin of beef from fork to farm through smart technology.

MATERIALS AND METHODS

Precinct of project study: This research project was conducted and controlled from the department of Livestock Production and Management, Faculty of Veterinary and Animal Sciences, Pir Mehr Ali Shah-Arid Agriculture University, Rawalpindi, Punjab, Pakistan. The google coordinates of PMAS Arid Agriculture University are 33°39'06.7"N 73°04'49.6"E. Data on beef, covering production, processing, and distribution phases, was collected from registered stakeholders in the districts of Lahore, Gujranwala, Faisalabad, Rawalpindi, Islamabad and Taxila within the Punjab Province.

Registration of Stake holders & their training: Multiple field visits were made to find and register stake holders for data collection and execution of project activities. The criteria for selecting stakeholders included only those traders engaged in the export or local supply of beef, encircling all three phases of the meat value chain—production, processing, and distribution. For the successful data entry and working, training sessions were held in different regions of Punjab, Pakistan. Additionally, a one-day workshop was also organized in Department of Livestock production and Management, Faculty of veterinary and Animal Science, PMAS Arid Agriculture University to educate stake holders on tasks such as data entry and retrieval through traceability software.

Selection of beef animals: A total of 300 beef animals were selected from the herds maintained by registered stake holders. The selection criteria were based on species, sex, age, and deformity status. Only animals of the cattle species, specifically male, aged 2 years or older for sacrificial purposes, and 1.5 years for beef supply, were chosen, ensuring they had no deformities. The selected animals were tagged for identification purposes and treated for external and internal parasites. Minerals supplementation and basic first aid were also provided to registered farmers for maintenance of better health conditions. Selected animals were also provided adequate feeding, management and comfortable housing conditions to ensure animal welfare.

Data collection from different phases in beef value chain and data analysis; Data were collected from following 3 phases of beef value chain; Production, Processing and distribution. Field visits were conducted to capture the data regarding individual animal through mobile based MeaTrax app using android mobile devices. Attributes of selected animals during production are given in Table 1, whereas data collected about processing and distribution phases are mentioned in Table 2. The collected data was

Table-1: Attributes captured during production phase under traceable beef production system.

Sr. No.	Main attributes	Available parameters in MeaTrax app
1	Breed	Bhagnari, Cholistani, Crossbred, Dajal, Dhanni, Dajal, Friesian, Kundi, Lohani, Nili Ravi, Non-descript buff, Non-descript cattle, Red Sindhi, Sahiwal.
2	Major body coat color	Black, Brown, Grey, other color, Red,White
3	Minor body coat color	Black spot, brown spot, No-spot, red spot, white spots
4	Horns type	Small, medium, large, polled
5	Horns position	Inward, outward, downward, half ring, full ring, dehorned. None.
6	Known age	Kheera/1.5 years or less, donda/2 year, choga/3year, chigga/4years, full mouth/5years, broken teeth/8 years or more/.

7	Housing roof type	Lenter, slabs, iron sheet, fiber sheet, other roof.
8	Housing floor type	Brick work, katcha, pakka, cubical, other floor
9	Stall type	Tie stall, free stall
10	Health status	Dull, alert
11	Disease condition history	Diarrhea, cough, fever, skin allergy, injury, indigestion, disease free
12	Drug withdrawal period	Completed, non-completed, no drug
13	Drinking water type	Ground water, supply water, canal water, pond water, unknown water sources
14	Select feeding dry roughage	Wheat straw, rice straw , hay, stovers, crop residues, no-straw, gram straw, multiple straw
15	Select feeding green roughage	Silage, maize, sorghum, sadabahr, bajra, oat, sarso, berseem, lucern, sugarcane, other forage, no-green forage, multiple forage
16	Select feeding concentrate	Grains, rotti, cotton seed cake, rape seed cake, wheat bran, TMR, wanda, gur, oil, molasses, no-concentrate, multiple concentrate
17	Grazing facility	yes or no
18	Hormonal therapy	yes or no
19	Ventilation facility	yes or no
20	Nutritional supplement	yes or no
21	Chilling facility	yes or no
22	Salt lick	yes or no
23	Deformity status	yes or no
24	Vet consultancy	yes or no
25	Vaccination status	yes or no
26	Deworming status	yes or no
27	Farmer Name	abc
28	Farmer address	xyz
29	Farmer phone No.	03xxxxxxxxx
30	origin	abc
31	Treatment history	history
32	Rearing relative humidity	%
33	Rearing climate	° C
34	Picture	-

Table-2: Attributes captured through MeaTrax app during processing and distribution phases under traceable beef production system.

Processing phase			**Distribution phase**	
S. #	**Main attributes**	**Available parameters**	**Main attributes**	**Available parameters**
1	Method of slaughter	Halal	Distributor type	Export or local
2	Date of slaughter	00-00-0000	Carcass Supply date	00-00-0000
3	Name of slaughter house	abc		
4	Name of Butcher	xyz		
5	Live weight	In kg		
6	caress weight	In kg		
7	Address	abc		
8	Beef cut packing	Yes or No		
9	Beef transport refrigeration	Yes or No		

Time duration for data collection: The project data was collected from one year time period w. e. f. 1st October, 2022 to 30th September, 2023 from selected animals from registered stake holders through frequent field visits.

Development of android mobile based traceability app and its features: MeaTrax is a mobile application designed and developed for meat traceability. It provided a centralized platform in beef value chain to store, manage, and access data related to animals used for slaughtering as shown in Figure 1. It had separate interfaces for users with administrative privileges and normal users. All the users had the right to add new

records and to view the newly and previously added records.Every time a record was added in this application, it generated a QR code suitable for pasting on the carcass or packed carcass cuts. Consumers could visualize the details of that particular animal by scanning the provided QR code.On the other hand, admin users had the right to update the previously added records of animals in case of any change in the previously set attributes. They also had the right to delete any existing record due to any reason. Both these functionalities were not available to the normal users to maintain the data consistency and accuracy and to avoid any misleading information provided by those normal users. In addition to this, only the admin users could manage user accounts and can change their passwords etc. Application was freely available on Google Play Store and could be downloaded from there. Any user who wanted to get information about any slaughtered animal did not need any login credentials and he/she could scan the QR code by just opening the QR scan code module. In return to this, all the details of that animal would be shown. For other tasks, the users would need login credentials and based on the credentials provided to them they would be granted access as admin or normal users.

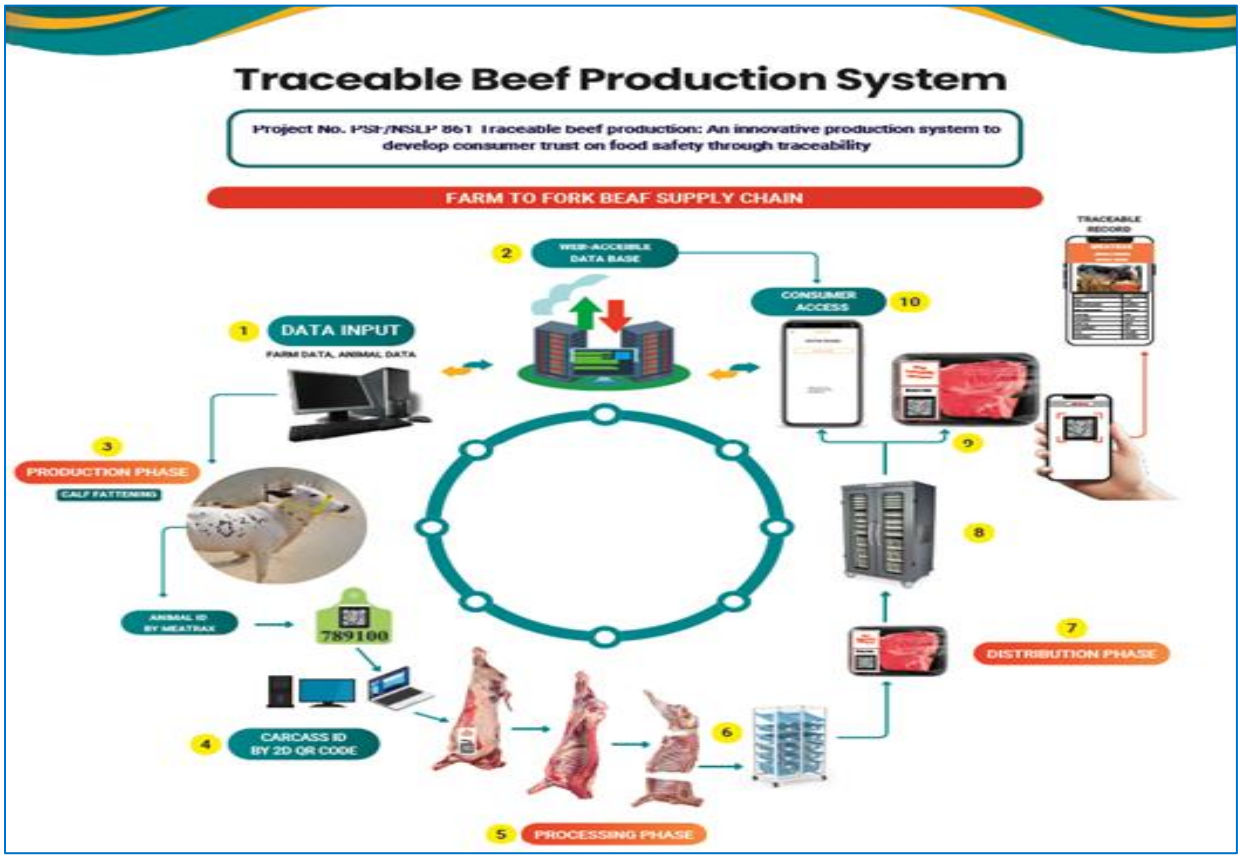
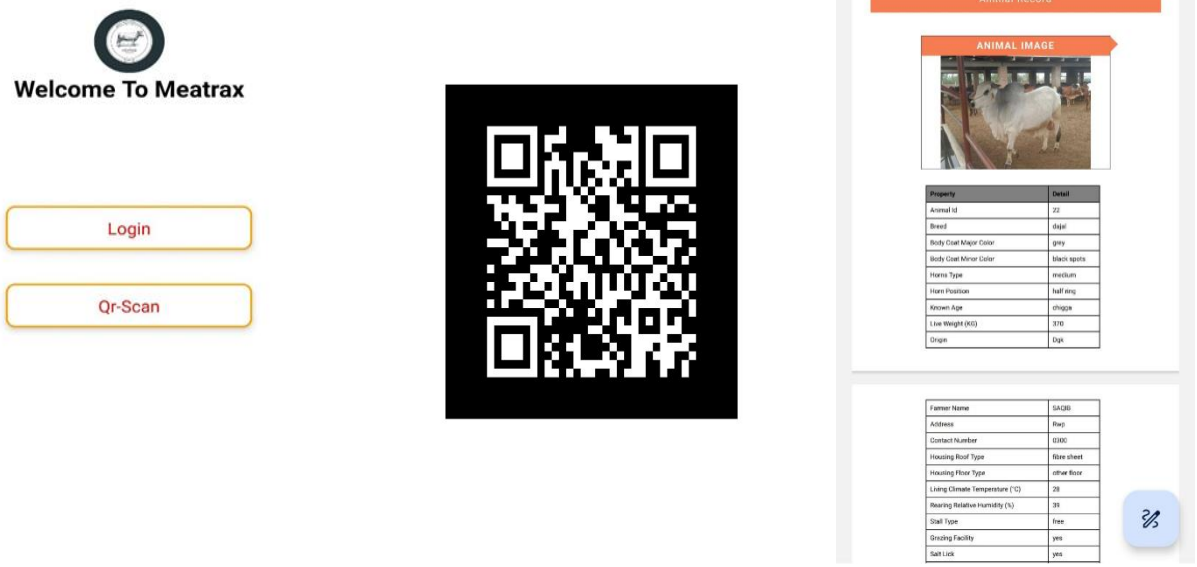


Figure 1: Beef value chain from production, processing and distribution phases under traceable beef production system.

RESULTS

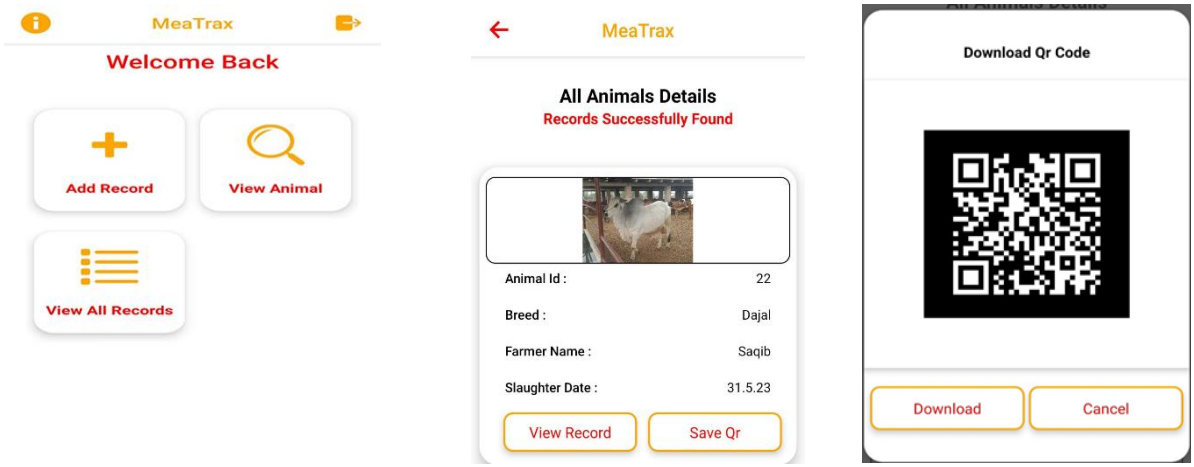
In response to methodological efforts, the subsequent findings were revealed, allowing for the capture of required input data across production, processing, and distribution stages. This empowered end consumers to trace back farm-to-fork details about beef animals.

MeaTrax app developed to capture input data: MeaTrax app was found available at google play store to download as shown in Figure 3. Two options were provided; login for capturing data and QR Scan for consumers. After successful login through giving particulars, 3 options were seen in app; add record, view animal and view all record. After clicking add record option, all attributes or data of production, processing and distribution stages could be entered easily. Consequently, a QR code was generated which could be pasted on meat cut for consumer's scanning.



Welcome to MeaTrax after download (Step-1) | **Scanning QR Code through android camera (Step-2)** | **Retrieval of entered data Pdf version (Step-3)**

Figure 2: Retrieval of captured data through MeaTrax app under traceable beef production system



Data Entry phase (Step-4) | **View added record (Step-5)** | **Generated QR code (Step-6)**

Figure 3: Capturing input data through MeaTrax app under traceable beef production system

Retrieval of entered data by user through MeaTrax app: The administrator of app could view entered data by scanning QR code or and login by viewing all records. However, consumers were also enabled to retrieve data only by scanning QR code given on meat pack through android mobile camera as elaborated in Figure 2. The consumer was also enabled to retrieve the entered data through pdf version.

Summary of captured and retrieved data through MeaTrax app: Data on beef animals (n = 311) were collected, comprising seven breeds: Friesian Sahiwal (FS) crossbred, Sahiwal, Cholistani, Friesian, Dhanni, Dajal, and Red Sindhi. The percentage of FS crossbred animals was found to be the highest among all other breeds of captured beef animals, as mentioned in Table 3. The highest percentage in crossbred cattle was followed by Sahiwal, Cholistani, Friesian, Dhanni, Dajal, and Red Sindhi. The average live weight at slaughter and carcass weight were higher in Friesian animals, followed by Dhanni and Dajal. However, the dressing percentage was highest in Sahiwal. The highest number of animals were slaughtered at the age of 2 years and above (Donda) as depicted in Figure 4. The majority of farmhouses had roof slab types and floor brickwork types, and the highest number of beef animals were fed maize fodder as green roughage and wheat straw as dry roughage. Bread pieces

were mainly provided as a concentrate diet in traceable production systems, as shown in Table 4. The average climate during rearing remained at 35.4°C ambient temperature and 54.7% relative humidity. The processed meat was mainly distributed at the local level, which was higher than for export.

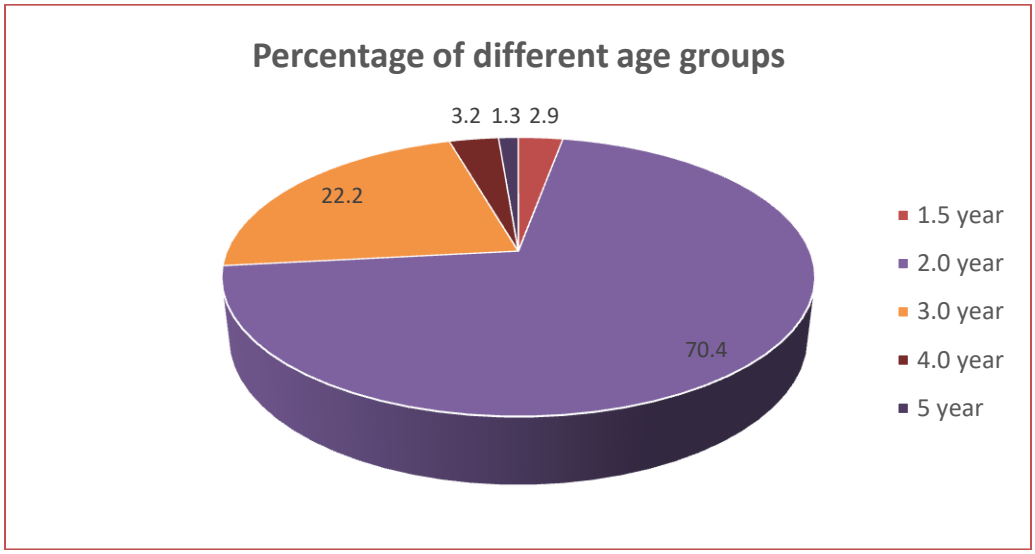


Figure 4: Percentage of different age groups of captured beef animals slaughtered under traceable beef production system

Table 3: Retrieved data of captured beef breeds and their carcass attributes under traceable beef production system through MeaTrax app.

S. No.	Breed of beef animal	No. captured	Breed %	Average live weight (kg)	Carcass weight (kg)	Average dressing (%)
1	Crossbred	155	49.8	234	113	48.3
2	Sahiwal	65	20.9	267	133	49.8
3	Cholistani	36	11.6	212	104	49.1
4	Friesian	29	9.3	465	194	41.7
5	Dhanni	18	5.8	365	171	46.8
6	Dajal	6	1.9	345	170	49.3
7	Red Sindhi	2	0.6	220	108	49.1
	Total	**311**	**100.0**			

Table 4: Retrieved data of Housing, feeding, climate and distribution attributes under traceable beef production system through MeaTrax app.

Housing Types		**Feeding regime**		**Climate**		**Distribution**	
Parameter	**(%)**	**Parameter**	**(%)**	**Parameter**	**Average**	**Types**	**%**
Roof type		**Green roughage**		Ambient		Local	85.5
Slabs	53.6	Maize fodder	70.4	Temperature	35.4° C	Export	14.5
Fiber work	16.7	Silage	03.0	Relative			
Iron work	2.3	Other forages	26.6	Humidity	54.7%		
Concrete	25.4	**Dry roughage**					
Others	02	Wheat straw	93.9				
Floor type		Rice straw	3.2				
Brick work	59.8	Hay & others	2.9				
Mud floor	30.5	**Concentrate**					
Concrete	8.0	Bread piece	34.1				
Others	1.7	Fattening ration	27.3				
		Grains & others	38.6				

DISCUSSION

Development of the Android-based MeaTrax software had made self-sufficient in capturing input data. This ability to capture beef data through different phases in the beef value chain was aligned with the findings of previously published studies. Traceability had been emerged as promising technique in meat industry with valuable control and enhancement possibilities in production processes (Kafetzopoulos *et al*., 2020). It could play a vital role in livestock management, encompassing the documentation and preservation of essential information regarding animal origin, upbringing, and slaughter (Girish and Barbuddhe, 2020). Traceability mechanism had become more valuable when incorporating consumer-oriented attributes like safety, farming practices, and animal welfare, as they add significant value (Dabbene *et al*., 2014). The breakthrough of the traceability application might be attributed to the use of smart technologies in the field of livestock management.

Retrieval of captured data through scanning QR codes was made possible using MeaTrax app as an innovative livestock management tool. The reason might be attributed to the awareness of stake holders about usage of android mobile, availability of internet and QR code technologies. The value of QR codes had been affirmed by several published reports, demonstrating their efficacy in providing comprehensive product information to consumers and ensuring food safety throughout the production to retail continuum (Narang *et al*., 2012; Ryu, 2013; Asareand Asare, 2015; Kshetri, 2017).

Consumer interest in QR codes had become fortified when provided with pertinent information about product (Ryu, 2013). Additionally, incorporation of QR codes in advertising enhanced consumer engagement (Hossain *et al*., 2018). However, it was mandatory to consider consumer perceptions when designing traceability solutions (Qian *et al*., 2020). The IoT-based traceability systems could help in elimination of low quality food products while decision making (Alfian *et al*., 2020). Innovative traceability solution had been also proposed in the formats of cloud-based solutions for beef and mobile based solutions for other meats (Chen, 2017). These traceability solutions could not only address concerns related to food waste and safety but also provided a reliable solution to inform customers about shelf life, consumption guidelines, and dynamic pricing (Lau *et al*., 2022).

The substantial percentage of FS crossbred animals slaughtered for beef in this study might be attributed to the abundant availability of crossbred animals in the Punjab province and their recognized potential for fattening, as previously endorsed by Jabbar *et al*. (2009), highlighted a 55.5% dressing percentage for crossbred calves. Most animals were slaughtered at 2 years and older, possibly due to the specific data collection timing during EidUlAzha (Muslim Sacrificial Annual Festival), where animals were raised for sacrificial purposes, and a 2-year-plus age was a mandatory eligibility criterion for sacrifice (Farhan *et al*., 2023). The higher dressing percentage in Sahiwal slaughtering animals couldn't been adequately established by previous literature and needed further observation for authenticity.

Conclusion: It was concluded that MeaTrax traceability app was found an innovative technique, using smart technologies to trace origin and other attributes of beef. This innovation was aimed to improve the beef value chain from farm to fork, contributing to enhance food safety.

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Ethical Approval: The current investigation did not require ethical approval, as it primarily involved the collection of beef animal data during 3 different phases; production, processing and distribution. Notably, the registered animals under scrutiny were not administered any pharmacological agents and not exposed to biological trials. However, selected animals were guaranteed the complete set of five freedoms, encompassing sufficient provision of food and water, freedom from stress and ailments, and the opportunity to manifest their innate behaviors in appropriate sheltered environments.

Authors Contributions: The successful execution of this research project was the result of a collaborative team effort. Dr. Muhammad Fiaz, as the 1st author, conceived the project idea, secured funding, and served as the principal investigator. Prof. Dr. Tanveer Ahmed, the 2nd author, functioned as the Co-Principal Investigator, providing invaluable assistance during various stages of the project. Dr. Zeeshan Muhammad Iqbal, the 3rd author, played a critical role in project

design and document composition. Mr. Muhammad Atif Raza, the 4th author and initial Research Associate, conducted frequent stakeholder visits for data collection. Mr. Muhammad Faizan, the 5th author, collected data from 300 animals, whereas 6th author uploaded data into the MeaTrax app and retrieved QR codes. Lastly, Miss Sahar Ghulam Mohyuddin contributed in data analysis and write up of the manuscript.

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