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Review Paper

Farm-to-Fork Livestock Traceability for Quality Meat Production: An Overview

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ABSTRACT

Indian meat industry is emerging as one of the major players at the international meat market. According to the Agricultural and Processed Food Products Export Development Authority (APEDA) data for the year 2015-16, India's export of animal products was Rs. 30,137 Crores; of which Rs. 26,685 Crores was from the export of 1.31MMT buffalo meat alone. This fact must be construed as an achievement in the backdrop of the unorganized nature of the Indian meat animal production and processing practices. Although developing countries are the major importers, exploration of markets of the developed countries could significantly enhance the magnitude of the export. In order to achieve this goal, the Indian meat sector must strive hard to focus its attention towards the traceability backed quality control system across the meat supply chain. Globally, become a benchmark for the differentiation between the organized and unorganized systems of meat production. Integration of key players of the livestock value chain under the traceability umbrella enables forward and backward linking and it is foreseen to bring about a paradigm shift in the livestock production practices of India. This article provides an overview of the livestock traceability and details its components, requirements, global scenario and latest initiatives by the government so as to aid in the implementation of traceability system in India.

Keywords : *Meat quality, Traceability, Animal identification, RFID, Meat export*

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Livestock traceability is the ability to and the mechanism designed for tracing of an animal product along all steps in the production chain back to the holding of origin of the live animal from which the product was derived (FAO 2007). Traceability is a method that can guarantee the identification of animals or animal products within the food industry (Dalvit *et al.* 2007). Livestock traceability intends to establish a network of meat animal producers, processors and related stakeholders in the value chain (Smith *et al.* 2008). Traceability encompasses information flow and achieves livestock products tracking (Hagdrup *et al.* 2004). Majority of the developed countries (including European Union) have made the livestock traceability a mandatory obligation (Hobbs 2003; Smith *et al.* 2008). In the fast changing world, meat animal production at individual farms cannot be festooned in isolation. Country's animal production involves series of interconnected and networked activities. If these activities are managed by a centralized system; resultant networking would enable scientific production of livestock products (Clemens 2003). This review is aimed at providing brief information about the livestock and meat traceability, an account of recent developments enabling seamless environment for the implementation of livestock traceability system in India.

Components of livestock traceability system

For the effective conceptualization and implementation of the traceability system, understanding the components of the traceability system is a prerequisite (Manral 2009). Following heads highlight brief information about different components required for the establishment of a system.

Traceability implementation agency: Responsibility of establishing, running and monitoring of the livestock traceability system is customarily entrusted to a national level centralized agency (Maia de Souza *et al.* 2017). An empowered centralized agency tackles challenges and coordinates the system. The agency understands the value chain and ground reality, prepares a customized system in-line with the international requirements. The system encompasses setting of identification standards, issuing of identification codes, application on animals and maintenance of the centralized information database (Pelletier 2015). Such agency also works in close association with stakeholders for its effective functioning.

Livestock owner: Premise (holding) registration and animal identification are the basic pre-requisites of the traceability system (Becker 2007). Willingness and active involvement of

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livestock owner is extremely crucial. Owners must tag their animals and transmit data pertaining to the birth, death and the movement of animals to the concerned authorities. The system must be easily understandable, implementable and preferably in the vernacular language to accommodate education level and nature of the livestock holders. Adequate support system must be provided to enhance the confidence among the livestock owners so that they can understand system and aid in its implementation. Livestock owners must have easy access to ear tags and registration facility. Financial support for the purchase of consumables must be met by the government (at least in the initial stages). The system must be tuned for a range of services such as insurance, subsidies, loans, health management, etc. The livestock owners must be encouraged for their active role for the success of the system.

Meat processors: Abattoirs acts as a critical link in livestock traceability system. Abattoirs receive animals from various places for slaughter leading to meat production. If the slaughter animal is tagged (registered) then the meat processors must maintain its identity during slaughtering, dressing and packaging of the meat (Kondaiah *et al.* 2010). Traceability code needs to be placed over the label of meat package so as to enable tracing of the meat source (animal). System developed for ensuring traceability must take in to account the complexities associated with the slaughtering and dressing, personnel involved, education level of the personnel, processing time, speed, convenience and the cost. Adequate checks and balances must be placed to ensure appropriate labeling in order to ensure an error-free coding system. Recording of observations into the system made during the ante and post-mortem inspection and meat quality for each identification code serves as a valuable feedback for livestock owners for streamlining animal husbandry and health care practices at the farm (Girish *et al.* 2013).

Traders and transporters: Ideal traceability system requires record maintenance by the traders and transporters of the animals (animal received and sold by them). They need to provide animal transaction information and corresponding details at regular intervals to the concerned authorities. Transporters must provide information to the authorities regarding the animal transport. Even though they keep animals for a short period, their active contribution is essential for the effective functioning of livestock traceability system.

Consumers: Traceability involves cost and its implementation will be definitely an add-on to the product price. Enhancing awareness regarding the quality issues of meat/animal and benefits of the traceability among the consumers would ensure that they pay extra for the traceable livestock products in the interest of their health. If consumers are ready to pay extra price for the traceable meat, industry would try to meet its requirements and sustain the traceability initiatives in the long term. At present, awareness among consumers on the quality issues is minimal and it requires prompt addressing through intensive awareness programmes.

Legislation: Question of whether to make the traceability system mandatory or voluntary needs to be answered before initiating its implementation especially in the developing countries. Voluntary systems are driven by consumer interest or importing country's requirements, whereas, mandatory system requires legislative backing. The European Union (EU) adopted mandatory system consequent to incidences of bovine spongiform encephalopathy (BSE) that seriously affected profitability of the sector. Many countries are following voluntary system. It is suggestible to make it voluntary initially and once the burgeoning awareness is reached, the mandatory drive could be planned. To justify the cost of implementation of the traceability system, its comprehensive applications could be exploited.

Benefits of livestock traceability system

Ownership ascertainment: Once the animal is registered and ear tagged it will be easy for the livestock owners to prove their ownership. Apart from controlling theft, it will help in reducing inconvenience associated with acquiring transportation clearance of animals from the authorities.

Effective implementation of disease control programmes: If a disease (or disease causing agent) is detected during the meat inspection, the traceability system would enable tracking of its farm-of-origin (Johnston 2005). Once the source is identified, focused disease control activities could be implemented and adjoining farmers of the area could also be alerted about the health threats (disease outbreaks). Focused bio-security measures could help in the better control of diseases than the blanket approaches that often cover wide area.

Implementation of developmental schemes: First and foremost step in the implementation of any government developmental scheme is the identification of beneficiaries. Selecting correct beneficiaries determine the success of such schemes. Centralized database of the traceability system will hold information on farms, farmers, abattoirs, etc. Information of registered farms and abattoirs of selected area helps in taking informed decisions on selected beneficiaries. Apart from selection, continuous monitoring of the beneficiaries helps in

the impact analysis of such schemes through the traceability system. In India, government agencies have implemented several developmental schemes to promote animal husbandry and promote livelihood support of farmers. However, lack of information regarding livestock owners often leads to arbitrary selection of beneficiaries and crude estimates that affect effective implementation of schemes at grass root levels. Traceability system would support centralized availability of information about the farmers, farms (premises) along with contact details; such information would help in the effective formulation and efficient implementation of the government schemes.

***Food quality assurance*:** Quality and safe meat which is free from the physical, chemical and biological hazards (pathogens, chemical residues, etc) can be ensured only by the quality control and assurance protocols spanning through the abattoirs. Traceability based quality assurance programs help in the documentation of food safety hazards (Thakur and Hurburgh 2009). Information so collected also support stakeholders down the value-chain to implement required quality control/ assurance systems. In addition, it will also help in evaluating effectiveness of the animal health and disease control programmes of the livestock. Quality assurance system must be comprehensive for ensuring quality and safety throughout the value chain. Implementation of effective health management and quality assurance system from farm-to-abattoir and thereafter lead to better acceptability among the consumers at both domestic and international markets. Traceability system will help in the effective monitoring of the health programmes and targeted implementation of the quality control/assurance schemes.

Performance recording and increasing productivity: Selection of breeding stock must be based on performance of the breeder animal and its progeny. Traceability database provides software interface to collect and update the performance of animals. Long-term performance evaluation would support decisions pertaining to the breeding and feeding of animals (Herrero *et al.* 2013). Continued practice of stock selection for breeding purpose would improve the overall quality of the species or breed (germplasm).

Livestock census: India follows quinquennial livestock census across the country (Department of Animal Husbandry, Dairying and Fisheries, New Delhi). In the absence of registered farmer's census, it involves huge expenditures and manpower. Availability of the information at the centralized database would ease such efforts and increase accuracy of livestock census results.

Marketing of livestock products: Through the traceability system one can avail contact details of the farmers; person willing to sell animals and those willing to purchase (abattoir manager) would directly get benefitted by this database. Centralized availability of information also helps in avoidance of the unscrupulous middlemen thereby hastening the process of e-marketing practices in India in the livestock sector.

Increased market access and export opportunities: Developed countries especially the European Union, Japan, Uruguay, Australia, New Zealand and alike have established stringent livestock traceability systems supported by strong legislative framework. Countries that export meat to these countries must also comply with the traceability systems on par with the domestic regulations (Shackell *et al.* 2001). The trace-back capability of the system would augment consumer confidence in livestock products not only at domestic but even the international market. In the long run, it would help in tapping the export potential and increase the market access to the Indian meat sector and economically benefit the stakeholders.

Information technology (IT) based support system for animal production and processing: Traceability database can be used as a management information system; it can be used by farmers for the scientific management of farms. It enables real-time updating of the information pertaining to the essential farm activities (e.g. vaccination, insemination, deworming, etc) through registered accounts. Periodic reminders to farmers through text messaging (Short Message Service, SMS) about important farm activities would help the farmers updated to take-up needy operations in the farm.

Enhancing awareness and communicating essential information to stakeholders: Capacity building of farmers and providing of important information regarding healthcare and management messages (SMS) to the registered farmers will help in enhancing the knowhow of the farmers thereby promoting scientific animal production practices.

Methods for identification of animals

The core requirement of the traceability system is identification coding of an animal or a batch of animals using a suitable method and maintenance of animal data so as to trace it up to the animal's product. Retention of the code over the animal throughout its lifetime is one of the challenges of the traceability system; especially in India, where animals travel longer distances. The identification method must be resistant to varying environmental conditions, economical, easily applicable and tamper-proof (Frewer *et al.* 2005). Based on these requirements several animal identification methods have

been followed across the world *viz*., branding, tattooing, visual tags, bar code tags, radio frequency identification device (RFID) tags, implants etc (Musa *et al*. 2014). Characteristics of ideal animal identification method and brief details of different methods that are in vogue for the identification of animals are given below:

Characteristics of an ideal identification method: Animal identification method must be easily readable even when in contact with stain or moistures. Electronic identification enables number reading even though numbers are invisible to eye. However, if the identification tag is removed and re-applied it may lead to misrepresentations. The Radio Frequency Identification Device (RFID) ear tags are so developed that once applied, it can't be removed or tampered; hence, such tags can curtail malpractices. Identification method must not unnecessary induce pain in animals. Tags must be centrally produced and distributed to the farmers so as to maintain uniformity and also to inscribe numbering pattern in-line with the approved national policy or international guidelines such as International Committee for Animal Identification and recording, Rome (www.icar.org/ ICAR facts).

Different methods used for animal identification

Branding: Branding is a traditional method used for animal identification since centuries. It is a method of placing permanent identification mark on the animal's skin either by hot or cold processes. Hot branding is done using a hot iron tool; while, cold branding is done using an iron tool cooled using liquid nitrogen. Cold branding is less painful as compared to the hot branding. Branding is a cheaper method of animal identification still widely used by farmers. Major disadvantage of branding include devaluation of hide, difficulty in reading of long numbers, distortion of brands as animal grows, and animal welfare point of view the procedure is painful to animals.

Tattooing: It is a process marking animals with an indelible ink which is inserted into dermis of skin to change its pigment. For traceability, tattooing is done on the inner part of the ear. Tattooing usually applied for the confirmation of ownership. However, readability of tattoos is affected by the growth in animal, cleanliness and also changes of ownership leads to multiple tattooing.

***Visual tagging*:** Visual tags are the simplest of tagging methods where animal number is printed on the plastic tag and number is clearly visible. Usually no electronic device is attached to the tag. Good quality tag applied skillfully can last for animal's life. However, poor quality tag often fall or get bleached making the number unreadable. In the European Union animals are mostly identified using visible plastic ear tags having laser printed code; ear tags are provided in duplicates to farmers for placing on both ears so as to avoid possible confusion that could arise due to dropping of the tags. Different shape, size and thickness tags can be prepared depending on the type of animal tagged. However, major disadvantage of this method is due to possible human error expected while visually reading the tags. Therefore, visible tags have now been developed to contain electronic RFID encoding system at its base for reading the tag both visually and by electronic means.

Bar-coded tags: Bar-code is a machine readable optical label that contains information regarding the item to which it is attached. Code can be read using a bar-code scanner. However, if bar-code is combined with visible numbers, tag can be read visually also. Possibility of human error can be eliminated using scanners. Nevertheless, scanning becomes difficult when tags get dirty and this requires cleaning of the tag prior to the scan. Bar-code method also involves additional cost of a computer, software and scanner.

Radio Frequency Identification Devices (RFID): The RFID is a convenient non-contact electronic data reading automation technology (Costa *et al.* 2013). RFID is not affected by the dirt, has the advantage of long distance reading and high reading accuracy. For animal identification the RFID is one of the ideal options (Liang *et al.* 2015; Falco *et al.* 2017).

Quick Response (QR) code based tags: The QR code is a matrix bar-code system (Tarjan *et al.* 2014). It was first designed for automotive industry; however, now it is being used even for animal identification. The QR code makes use of four standardized encoding modes (numeric, alpha numeric, byte/ binary and kanji) to efficiently store the data. Reading of the QR code does not require sophisticated equipment; mobile software can also easily read such codes. It is convenient to use QR codes of the animal identification cards distributed to the farmers.

Scenario of livestock traceability

International scenario: Developed countries across the world have already implemented livestock traceability systems a decade ago (Greene 2010). In the European Union, a *"One Step Up, One Step Down"* traceability program is followed. The EU is a conglomeration of several member countries; all the countries operate and negotiate as a unit. After the BSE in cattle its probable link with the new variant Creutzfeldt Jakob Disease (CJD) there was a large scale crisis associated with the

cattle in the Europe (Sugiura and Onodera 2006).The British meat sector suffered the most from the crisis and by 2000 BSE was also discovered in other European countries like France and Germany. Consumption of beef (cattle meat) had dropped by 80% in Germany by February 2001. This prion crisis forced the EU to mandatorily legislate animal traceability system in order to protect the consumers and producers. The EU introduced Trade Control and Expert System (TRACES) in April 2004 with the aim to provide a central database to track animal movement within the EU and also other countries. The producer (Regulation EC 178/2002 Article 18) must have enough information (evidenced by sufficient records) about the *trace forward one step and trace back one step*. All food and feed imported into the EU market was made to comply with the EU standards (Regulation EC 178/2002 Article 11). This also necessitated traceability of the export items to the EU *i.e.* a product must be traceable in the same way like products are traceable in the EU. The Australia also has its own National Livestock Identification System to keep track of the livestock from birth to its destiny to the slaughterhouses (National Livestock Identification System, Meat & Livestock Australia (http://www.mla.com.au/Meat-safety-and-traceability/National-Livestock-Identification-System). Similarly, the Uruguay also has a designed system called *Traceability & Electronic Information System of the Beef Industry.*Global Food Traceability Centre, Institute of Food Technologists is also one such system in this line (http://www.ift.org/gftc.aspx).

Indian scenario: In India, Animal Husbandry Department, Maharashtra established Maharashtra Animal Identification and Recording Authority (MAIRA). The authority was established with the aim to record the production and reproduction performance of livestock and registration of the premises (http://mldb.in/mldb_maira.asp). All livestock owners and farms registered under MAIRA system are given priority benefit in the government schemes. However, main focus in the MAIRA is towards milk production and there are no specific provisions in the system for the meat traceability. ICAR - National Research Centre on Meat, Hyderabad has established livestock traceability database (www.livestocktraceindia.in); however, its main focus is buffalo meat industry (Girish and Kulkarni 2013). The National Dairy Development Board (NDDB) has established a traceability system for farmers of cooperative union in the Gujarat (Information Network for Animal Productivity & Health, National Dairy Development Board) (http://www.nddb.org/english/inaph/Pages/Inaph.aspx).

Molecular meat traceability

Molecular meat traceability is a system that enables traceability verification by comparing labeled meat sample with the reference sample preserved during the slaughter process (Negrini *et al.* 2008). Periodic testing of market sample with the preserved sample will ensure appropriateness of the traceability labeling. Pre-requisite for the molecular meat traceability is keeping of reference samples of each batch of the product until the period of its use. Molecular meat traceability is based on the variability within the DNA of individuals (Orru*et al.* 2006; 2009). Important features of DNA that makes it suitable for the purpose of meat traceability include DNA is unalterable, is stable even after processing of food and is present in every cell of the animal.

DNA based: The DNA is the molecule that contains information and determines development and functioning of the living beings. Nucleotide is composed of nitrogen containing nucleobases [guanine (G), adenine (A), thymine (T) or cytosine (C)], a monosaccharide sugar (deoxyribose) and a phosphate group. The pattern of arrangement of these four nucleotides is called a 'nucleotide sequence' and the complete sequence of nucleotides of an individual animal constitutes its genome. The DNA remains same in all the cells of an individual. However, the DNA sequence varies between different individuals (except in identical twins or clones). Also, the DNA provides an in-built proof of identity in the meat traceability system. A specific region within the genomic DNA is called as a locus. Sub-sets of sequences within the locus are called alleles. Each locus is perceived to have its own set of alleles. Alleles are inherited by the principles of the Mendelian genetics. At each locus one allele is inherited from each parent. An individual is said to be homozygous at that locus if the alleles are contributed by both parents are same; whereas, if each parent contributes a different allele then the individual is said as heterozygous. The genetic polymorphism is defined as the occurrence of two or more alleles at the same locus in the same population, each with appreciable frequency. Patterns of allele differences at a set of multiple loci can distinguish individuals. Frequency with which the components of such differences occur can distinguish species/breeds/individuals. These differences are referred to as DNA markers, and the variation between the markers acts as the basis of DNA-based traceability techniques.

DNA markers: Targeted segment or sequence on the chromosome of an individual which is used for studying polymorphism between different individuals or species is called genetic markers or DNA markers (Goffaux *et al.* 2005).

The Polymerase Chain Reaction (PCR) enables *invitro* amplification of the targeted nucleotide sequences and aid in the identification and analysis of genetic markers. Broadly, DNA markers are classified as unilocus and multilocus markers; unilocous makers are located at a single locus *e.g.* restriction fragment length polymorphism (RFLP) markers, microsatellite markers, single nucleotide polymorphism (SNP) markers, etc. Whereas, multilocus markers are distributed over multiple loci *e.g.* minisatellite or variable number tandem repeat (VNTR) markers, amplified fragment length polymorphism (AFLP) markers, randomly amplified polymorphic DNA (RAPD), etc. For the purpose of individual traceability of the livestock or its products, microsatellite and SNP markers are commonly employed (Oh *et al.* 2014).

Sample requirements for DNA based meat traceability: Molecular traceability is used as a tool for the verification of traceability. It verifies the label claim of meat package and authenticity of the traceability code. DNA traceability is not mere sample DNA analysis, rather it involves comparison of market sample with the live animal sample preserved (origin of meat). Hence, blood, tissue or hair follicle samples are collected from animal prior or during slaughter of animal and preserved. Analysis of the extracted DNA from the reference sample and corresponding meat sample using DNA markers authenticates and verify the traceability claims of meat sample.

Microsatellite markers: Individual traceability of meat can be achieved using microsatellite and SNP genotyping of meat (Seroussi *et al.* 2011; Fernandez *et al.* 2013). Microsatellite markers are short DNA fragments usually less than 100 bp; consist of motifs of 1-6 nucleotides, repeated several times and have a characteristic mutational behavior. They may be dinucleotide, trinucleotide or tetranucleotide, majority of the repeats are found in non-coding regions. These are also called as short tandem repeats (STR), single sequence repeats (SSR) or single sequence length polymorphism (SSLP). Origin of such polymorphism is most likely due to the slippage events occurring during the DNA replication. Microsatellites are classified according to the type of repeat sequence as perfect, imperfect, interrupted or composite. Microsatellites can be analyzed by PCR amplification of a single tandem repeat locus using primers that anneal at its flanking region (Shackell *et al.* 2005). The PCR amplified fragments expressing the size polymorphism are the alleles at the given microsatellite locus. They are phenotypically neutral, developmentally and environmentally stable. Qualities of microsatellites that make them preferred molecular markers include (a) displays high level of allelic variation that can be analyzed easily, (b) co-dominantly inherited and (c) possess versatility of application. Steps involved in the molecular meat traceability using microsatellite markers are as follows,

Selection of microsatellite markers: Markers are usually selected from the panel recommended by ISAG-FAO (International Society for Animal Genetics-Food and Agriculture Organization) advisory group (FAO 2011).

Extraction of DNA: The genomic DNA is extracted from both meat sample to be traced and the reference samples using standard protocols.

***Polymerase chain reaction*:** Using the extracted DNA polymerase chain reaction is performed for the amplification of selected microsatellite markers. If multiple markers are selected and the annealing temperature is in the close range a multiplex PCR can be set; otherwise, individual PCRs can be separately for each set of the microsatellite marker.

Analysis of PCR amplicons: The resultant PCR amplicons can be analyzed using suitable platforms. Poly-acrylamide gel electrophoresis (PAGE) determines the amplicon size and shows polymorphisms between the individuals. Ideally, capillary electrophoresis based methods are used for the analysis of amplicons.

Authentication: Once the size of the amplicon of each marker and individual is known, the result between the market meat and reference sample can be compared to verify the authenticity of origin labeling of meat samples.

SNP markers: Single Nucleotide Polymorphisms (SNP) are single base changes in DNA sequences (Kim *et al.* 2015). They are biallelic and have advantages over microsatellites. The SNPs are highly abundant in the genome (an average of one SNP at every 100–500 base pairs) and several technologies have now been established for SNP genotyping such as MALDI TOF assay, primer extension, TaqMan and several microchip techniques that allow high throughput automated analysis (Goffaux *et al.* 2005; Ramos *et al.* 2011; Dimauro *et al.* 2013; Heaton *et al.* 2014). Basic process involved in the identification and analysis of SNP markers is as follows:

Selection of SNP markers: Method of choice for the identification of SNP markers is nucleotide sequencing. Once the candidate gene is identified (targeted re-sequencing can be done for unrelated individuals) and aligned to screen for the presence of SNPs. Enormous data has been generated on SNPs of various livestock and mammalian species (Choi *et al.* 2016). Public database *'dbSNP'* is the most popular database

for the SNPs; it is hosted by the National Centre for Biotechnology (www.ncbi.nlm.nih.gov/snp/).

SNP genotyping methods: Various SNP genotyping methods are used for achieving molecular traceability; some of the methods are given below,

Direct sequencing: Candidate gene is amplified using PCR and its nucleotide sequence is identified for the precise SNP genotyping. However, cost involved in the sequencing deters its use especially when large number of samples and markers are analyzed.

***Restriction enzyme cutting*:** SNP–Restriction fragment polymorphism (RFLP) is used if the SNP under question has a restriction site. The target gene is amplified by PCR and digested using specific restriction enzyme; resultant restriction profile generated after agarose gel electrophoresis indicates the presence or absence of the SNP in the sample. The SNP-RFLP is more economical compared to the nucleotide sequencing.

Single strand conformation polymorphism (SSCP): This is one of the simplest, and most sensitive PCR based method used for the detection of polymorphisms. The SSCP involves electrophoretic separation of single stranded nucleic acids based on the subtle differences in their mobility through the gel. The mobility of double stranded DNA in gel electrophoresis is dependent on the strand size and length, but it is relatively independent of the nucleotide sequence. Mobility of single strands however is noticeably affected by minorsequence changes. Such sequence changes can be visualized using an autoradiogram, silver stained PAGE gels, complete sequencing or using snap shot automated DNA sequencing.

Tetra primer amplification refractory mutation system (Tetra-ARMS) PCR: In this method of SNP genotyping a mismatch is deliberately introduced at the 3 prime end of each of the two allele specific primers in order to increase the specificity of the reaction. Two outer primers can be designed to amplify a common fragment with the primers for two variant nucleotides at 3 prime end having opposite direction of amplification. Two allele specific products differing in sizes corresponding to each allele are then easily resolved on an agarose gel. This technique is simple and can be adopted by any laboratory having basic facilities of PCR and agarose gel electrophoresis.

SNP chip: The DNA chips can be used as variant detector arrays (VDAs) to look for the DNA sequences that differ by SNPs. In this, the DNA sequence of oligos differs only at the last position. To determine which alleles are present, genomic DNA from an individual is isolated, fragmented, tagged with a fluorescent dye, and applied to the chip. The genomic DNA fragments anneal only to those oligos to which they are perfectly complimentary. The computer reads the position of the two fluorescent tags and identifies the individual as a C/T heterozygote. Several commercial SNP chips are available for livestock for the purpose of genotyping and molecular traceability (Karniol *et al.* 2009).

Policy developments conducive for the implementation of livestock traceability in India: Following are the recent policy developments in India that have created conducive environment for the traceability system.

Indigenous cattle identification by ear tagging: The Department of Animal Husbandry, Dairying and Fisheries, Government of India is planning to launch a massive tagging programme to all the indigenous variety of cattle with the aim to improve progeny and milk production. It is proposed to issue Aadhaar like identification cards for the identified cattle. The ID card will have relevant information about the breed and the drive is intended to improve progeny and augment milk yields in these animals. Stated objective of the programme is to help small and poor farmers, at present these farmers own about 70% of the indigenous cow varieties. The objective of the initiative is to improve per animal milk yield of the indigenous cow varieties (from 2 litres to at least 5 litres a day) with the intension to improve annual income of small and poor farmers who own desi varieties. Tagged cows will also have health card known as 'Nakul Swasthya Patra' that contains information about the milk yield, disease and general health information. Veterinarians check animals for their health. Proposal aims to operationalize both the ID card and health card schemes with the help of state governments. If this scheme is completed in the targeted time-frame, it will trigger need for a similar system for other animal species also enabling horizontal expansion of the animal identification system across livestock species.

Meat.Net: It is an online system provided by the APEDA to offer services to its registered processing establishments (health certificate for export consignment of meat products). According to the current Export and Import Policy of the Government of India, each export consignment is subjected to compulsory microbiological and other tests by the Government laboratory and health certificate. The APEDA provides one time user name and password to the registered establishment while applying for the online Health Certificate

required for the export of the consignments of meat products (http://traceability.apeda.gov.in/meatnet). Registered processing establishment shall submit an application online (by using their User Name and Password), and later approach concerned State Animal Husbandry Office (to which their unit belongs), along with requisite fee, copies of the invoice, packing list, test reports, etc for collecting the health certificate. To process the Health Certificate application, State Veterinary officials of the State Animal Husbandry Office shall login with their respective User Name and Password allotted to them by the APEDA and issue the health certificate. This has enabled creation of a pool of identified, networked meat exporting establishments which is a perfect platform for the meat traceability. Linking this network with the livestock traceability system will eventually happen to complete the chain in due course of time.

Foot and mouth disease control programme (FMDCP): Government (DAHD&F) initiated Foot and Mouth Disease Control Programme (FMD CP) in the year 2004 in 54 districts of the country (governing 9 states and 1 union territory, A&N islands). In the XI plan, FMDCP was extended to 221 districts and later it is envisaged to cover all the remaining States in a phased manner (www.fao.org/docs/eims/upload/299829/an358e00.pdf). The FMDCP operates in a coordinated fashion across different states under the Animal Husbandry Departments. Veterinarians involved in the program are communicating to the upper echelons the need for animal identification for the effective implementation of the program.The FMDCP is also envisaging need for creating a livestock traceability system in India.

Renewed focus on disease free zones (DFZs): Livestock DFZ is the progressive process of establishing animal disease free regions in the country. Recognized disease free zone encourages seamless international trade in animals and animal products.With the view to promote export of livestock products, policies for disease free zones are being thought over by different agencies. Animal identification is the basis for implementing such DFZs. Renewed focus on DFZs by government is foreseen to create congenial environment for animal identification and traceability.

Aadhar Act, 2016: The Unique Identification Authority of India (UIDAI) is a central government agency of India. Its objective is to collect the biometric and demographic data of residents, store them in a centralized database and issue a 12-digit unique identity number called Aadhaar to each resident. On 26 March, 2016, The Aadhaar (Targeted Delivery of Financial & Other Subsidies, Benefits & Services) Act, 2016 was notified in the Gazette of India. This act provides legal backing to the Aadhaar unique identification number project. Several states have achieved 100 % Aadhar enrollment. Aadhar has now become the focal point for the disbursement of government benefits. Aadhar is creating a pool of identified and numbered farmers and stakeholders; it makes their enrollment possible even in the livestock traceability system. Linking Aadhar like systems with traceability would lead to better comprehensions and easier implementation.

Digital India programme: Digital India is a campaign launched by the Government of India to ensure that Government services are made available to citizens electronically by improving online infrastructure, increasing Internet connectivity and by making the country digitally empowered. It was launched on 2nd July 2015 by the GoI. This initiative includes plans to connect rural areas with high-speed internet networks. Digital India consists of three core components: creation of digital infrastructure, delivery of services digitally and enhancement of digital literacy. It is centered on three key areas – digital Infrastructure, Governance & Services on Demand and digital empowerment of citizens. Efforts are being made to connect 2,50,000 villages through GPON to ensure FTTH based broadband. This will provide the first basic setup to achieve towards Digital India. Digital Literacy mission will cover six crore rural households (http://www.digitalindia.gov.in). It is also planned to connect 550 farmer markets in the country. Internet connectivity is the prerequisite for implementing livestock traceability as the system requires updating of information on to centralized database regularly by the enrolled stakeholders. Digital India movement along with ever increasing mobile connectivity and decreasing data charges will interconnect stakeholders and it would create a network for the implementation of the livestock traceability system.

CONCLUSION

Livestock value chain is a complex network of farmers, traders, veterinary authorities, abattoir managers, retailers, consumers, etc. Integrating and networking of the players of this value chain is the basic requirement for the implementation of the livestock traceability system. Digital literacy of rural people in the country is on a constant raise. Penetration of internet and mobile connectivity to the every corner of the country has raised the hope of making livestock traceability possible in the near future. Different government initiatives like identification of indigenous cattle, online certificates by the APEDA, creation of disease free zones etc have created conducive environment for making livestock traceability a reality in India. However, consolidation of these discrete efforts

into a support systems leading to livestock traceability is the need of the hour at the national level.

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