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Invited Review Article

Importance of food safety management in meat value chain

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Abstract

Food is one of the basic human needs and access to safe food is vital for a healthy population. The incidence of foodborne disease outbreaks is raising global concern. Meat is a nutrient-dense food, provides all essential nutrients required for microbial growth. Post-slaughter processing activities can be a major source of contamination if proper precautions are not taken. Hence, implementing Good Agricultural Practices (GAP), Good Manufacturing Practices (GMP), Good Hygienic Practices (GHP), and Hazard Analysis and Critical Control Point (HACCP) during production and processing is the 'need of the hour' to minimize the risk of contamination. The food producers are ought to follow certain regulatory practices to ensure the safety of food produced. Moreover, the implementation of proper safety regulatory checks during food production ensures the confidence of consumers regarding the quality of the produce. Food safety demands continuous efforts and is essential from farm to fork. Ensuring food safety is a collective responsibility and hence requires the involvement of all personnel in the food value chain. In India, the Food Safety and Standards Authority of India (FSSAI) is shouldering the responsibility of the food sector. The strict implementation and compliance of FSSAI guidelines are bringing transformation in the Indian food sector. Honest food producers must be encouraged while offenders must be punished. The importance of a food safety management system in the meat value chain, and ways and means for the improvement of meat food safety have been discussed in the present article.

Key words: Food safety, Foodborne infections, HACCP, ISO, Muscle food

Highlights

- Food safety concern is growing worldwide.
- Food safety management system (FSMS) plays great role in prevention of foodborne illenesses.
- Adoption of Good Agricultural Practices (GAPs), Good Hygienic Practices (GHPs) and Good Manufacturing Practices (GMPs) facilitates safe food production.
- Globally recognized certification of food enterprises would build consumer confidence.
- Food safety is the collective responsibility and each player has vial role in food value chain from farm to fork.

Introduction

Globally, 600 million people are suffering from foodborne illness, and out of these 4.2 lakh people lose their lives due to the consumption of unsafe food annually (WHO, 2020). Meat is a great source of proteins, vitamins, minerals, fatty acids, and many more nutrients. This provides an ideal medium for the growth and multiplication of spoilage and pathogenic organisms. Food safety is a fundamental human right (Fung *et al.*, 2018) and it implies that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use (ISO, 2005). Meat and meat products may pose risk because of biological, chemical, and physical agents which find their way through numerous exposure points in the food chain and becomes the source of infection to consumers. Therefore, it is the

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need of the hour to produce safe food by the implementation of strict food safety guidelines from farm to fork. The most important meat-borne pathogens are *Escherichia coli* O157:H7, *Salmonella* spp., *Campylobacter* spp., *Yersinia entercolitica*, and *Listeria* spp. (Fig.1).

Continual efforts are required to improve the safety of meat and meat products. This could be accomplished by the use of cutting-edge processing technology, rapid sanitation, good manufacturing and hygiene procedures, and other preparatory programs. Standard operating processes (SOP) and efficient skilled labour are equally crucial. Creating consumer awareness on the proper handling of food according to the manufacturer's recommendations makes a substantial contribution to food safety (Sofos, 2014). Therefore, establishment of a robust and precise production system according to good practices can be useful in safeguarding the sustainable production of animals and the value of their products chain. Hygienic production and processing to ensure the safety and suitability of meat and meat products at all the steps during the food chain are necessary. Further, a risk assessment strategy may be useful in all the steps of meat production to prevent contamination and produce safe and wholesome meat and meat products. Similarly, management of identified risk (Table 1) and communication of risk among different stakeholders is necessary to minimize/prevent food risks.

Safefood production practices should also address socioeconomic, animal welfare, animal health, environmental, meat industry

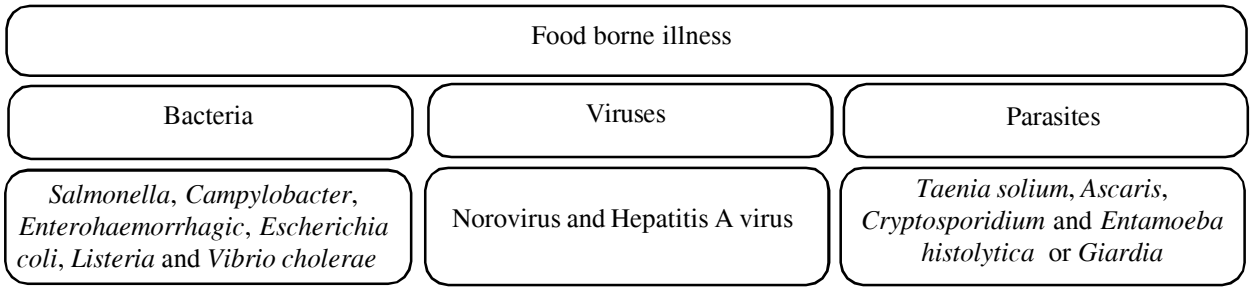

Fig. 1. Important meatborne illnesses

Table 1. Important meat-borne bacterial diseases

Sl No	Disease and incubation period	Causative agent	Symptoms in humans	Remark
1.	Anthrax 1-7days	*Bacillus anthracis*	The disease can be seen in three forms: cutaneous, respiratory, and gastrointestinal form. Malignant pustule, pneumonia, high temperature, headache, lack of appetite, and nausea.	Animal carcasses should be never cut opened to prevent the spread of the disease
2.	Brucellosis usually, 2-4 weeks but may be longer	*Brucella* spp.	Aches, chills, fever (undulating), sweating, fatigue, myalgia, arthritis, bronchopneumonia, epididymitis, orchitis, hepatic abscesses, and muscle weakness	-
3.	Listeriosis	*Listeria*	Septicemia, meningitis, convulsions, headache, fever, menin-	Listeria is an

Table 1., Cont. ...

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Sl No	Disease and incubation period	Causative agent	Symptoms in Humans	Remark
3-21 days		*monocytogenes*	goencephalitis, spontaneous abortion, stillbirth, or fetal infection, the higher case fatality rate	intracellular bacterium
4.	Campylobacteriosis 2-5days	*Campylobacter jejuni*	Diarrhea, fever, headache, meningitis, urinary tract infections, and short-term reactive arthritis. Guillain-Barre syndrome (GBS) is the post-infection complication	-
5.	Salmonellosis 6-72 hrs	*Salmonella* spp.	Headache, fatigue, fever, nausea, vomiting, abdominal cramps, and watery, greenish, and foul-smelling diarrhea or bloody diarrhea with mucous	*Salmonella typhi* causes typhoid in humans
6.	Haemolyticuraemic syndrome 3-8 days	*Escherichia coli*	Diarrhea (bloody), abdominal pain, vomiting, haemorrhagic colitis, haemolyticuraemic syndrome with acute kidney failure	*E. coli* O157:H7 cause food-borne infection
7.	Leptospirosis 5–14 days	Leptospira spp.	Haemolyticanaemia, jaundice, muscular pain, headache, conjunctivitis, vomiting, mental confusion, and sometimes meningitis	Known as Weil's disease in human
8.	Tuberculosis 14-84 days	*Mycobacterium tuberculosis*	Cough for more than three weeks, chest pain, bloody sputum, anorexia, chills, fever, sweating at night	-
9.	Shigellosis/bacillary dysentery 1-4 days	*Shigella dysenteriae*	Bloody or watery diarrhea, fever, abdominal pain	-
10.	Yersiniosis 4–6 days	*Yersinia enterocolitica*	Headache, fever, abdominal pain, diarrhea, and pharyngitis	Children are more prone
11.	Bacillus intoxication 8-16 hrs	*Bacillus cereus*	Abdominal cramps, watery stool (copious diarrhea), tenesmus, rarely vomiting	It is an acute intoxication
12.	Clostridial food poisoning 6-24 hrs	*Clostridium perfringens*	Abdominal cramps, nausea, and diarrhea	-
13.	Staphylococcal food poisoning 2–8 hrs	*Staphylococcus aureus*	Nausea and vomiting, mainly subnormal temperature, chills, headache, abdominal cramps with or without diarrhea	-

(Sources: Abebe *et al.*, 2020a; Almashhadany, 2021)

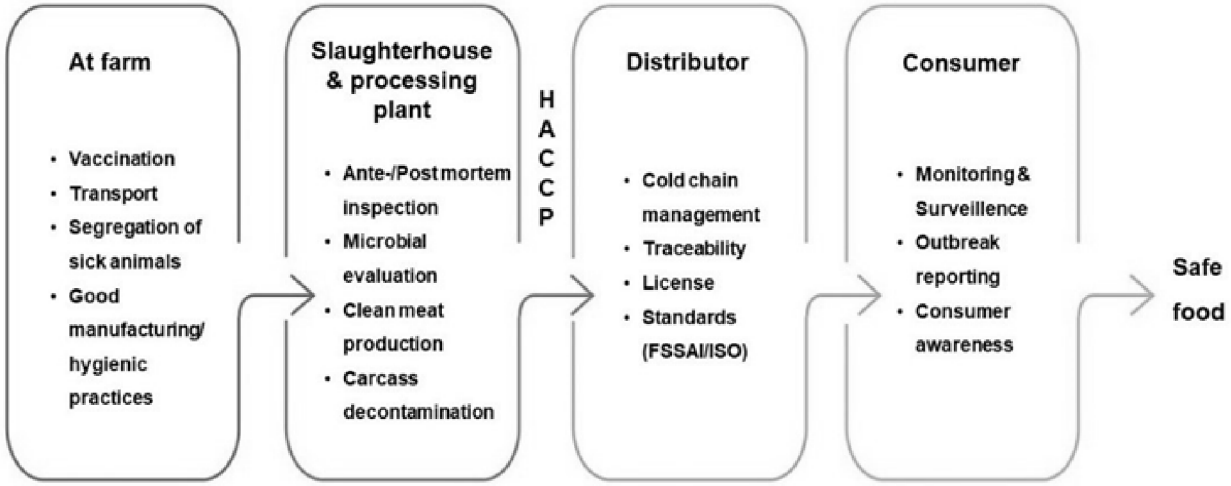

Fig. 2. Strategies for controlling microbial contamination from farm to fork

personnel, and consumer issues in a coherent manner. During meat production, at each level, due consideration is required for quality assurance (Fig. 2).

At farm: From farm to fork every stage can influence the quality of the final product. During livestock production at the farm, care should be taken to reduce the chances of introducing risks. All the animals should be properly labeled and documentation about health, vaccination, feeding, etc. should be maintained. Individual animal identification enables traceability so that source of meat can be traced back from the slaughterhouse to the farm location. Sick animals must be segregated from the rest of the flock to prevent the spread of disease. Further, the animals intended for slaughter needs to be monitored for proper withdrawal period post-treatment with antibiotics to prevent the spread of antibiotics in the food chain. The incidence of antimicrobial resistance has been rising and if the same situation continues future pandemic of antimicrobial resistance is inevitable. The importance of good agricultural/hygienic practices should be implemented strictly. During the transportation of animals from farm to slaughterhouse all precautions should be taken to avoid undue stress. Animal welfare should be given due consideration at the farm and during transportation to produce wholesome meat.

At slaughterhouse: Once animals arrive at the abattoir, animals should be given proper rest in the lairage so that stress caused during travel can be relieved. Animals are maintained in their respective groups and overcrowding and mixing of different species should be strictly avoided. The animals must be in a comfortable condition as any stress before slaughter would have an adverse effect on the meat quality. The ante-mortem inspection of animals should be carried out by a qualified veterinarian to diagnose any abnormal/diseased animal and the animals should be categorized based on their health state. If required, samples are collected from animals for diagnosis/confirmation of disease condition. During slaughter, all necessary precautions are taken to avoid contamination of meat. The critical control points must be identified, monitored, and controlled to achieve a quality product. The dressing should be carried out with utmost care to avoid puncture of the gastrointestinal tract and contact with hide/skin of animals to minimize contamination. Post-mortem inspection of carcasses and offals is equally important to produce safe and hygienic meat. After slaughter and dressing, the carcasses

should be decontaminated to reduce microbial load and improve the shelf-life of meat. The condemned carcasses and unsafe material should be handled properly to avoid cross-contamination. The equipment/knives used for slaughter should be regularly sterilized. Only potable water should be used for washing carcasses. The carcasses should be chilled as soon as possible to retard bacterial proliferation. The chilling room should be maintained clean. The carcasses should be kept on rails at a proper distance to avoid contamination. The deep muscles in the carcass should reach 6-7°C in 28-36, 24-30, and 12-16 h in beef, sheep, and pig carcasses, respectively (FAO, 2004).

Personal hygiene: Personal cleanliness is key to produce safe meat. The workers should wear protective clothing and sanitize hands regularly. Regular health checkups of employees should be carried out and awareness programs/trainings should be arranged frequently for employees to educate them regarding the role of personal hygiene in quality control. Smoking, eating, spitting, sneezing, and coughing should be strictly prohibited. Touching of eyes, ear, nose, and mouth during slaughter should also be discouraged. All required precautions should be taken to reduce the risk of contamination.

At distributor: Meat is a perishable commodity as it contains all the nutrients for microbial growth. Therefore, to restrict microbial growth and proliferation, a cold chain should be maintained till meat reaches to consumer. It is also necessary to have a traceability mechanism so that if any untoward incidences happen the product can be called back. Traceability has a major pivotal role in food safety and could be implemented by using different mechanisms like individual animal identification, product batch identification, etc. Radiofrequency identification (RFID) and barcoding techniques could also be used for traceability. Data recording and its management are important for an efficient traceability system. To maintain the quality of the product, different national and international standards are being implemented. In India, the Food Safety and Standards Authority of India (FSSAI) is playing a very important role in food safety management and provides licensing to the stakeholder depending upon the type of business. In India, it is mandatory to have FSSAI license for all the food business operators and food vendors.

At consumer level: Consumers can play a very significant role in the prevention of foodborne illness, provided they are aware and conscious about food quality. Strict monitoring and surveillance of food-borne illness outbreaks should be carried out to take precautionary measures and penalize the defaulter. There is a need for stringent action against such firms to have a robust system of food safety. Thus, consumer awareness could be increased using different mass media tools, training, education, etc. Several efforts are being taken nationally to educate consumers about food safety.

Food safety management system

A food safety management system (FSMS) is a company's programme plan for managing and executing a food safety programme to encompass and conform to internal and external standards, rules, and requirements. To ensure that food is fit for consumption, a food safety management system strives to carefully identify and eliminate physical, chemical, and microbiological contaminants throughout the production chain (ISO, 2005). The major focus of FSMS is to develop, document, implement, and maintain a functional FSMS. This encompasses the procedures and records needed to ensure the FSMS's effective development, implementation, and upgrading (Pillay and Muliyil, 2005). FSMS is a collection of interconnected components that work collectively to ensure that food does not pose a risk to human health. Programs, plans, policies, procedures, practices, processes, goals, objectives, techniques, controls, roles, responsibilities, relationships, papers, records, and resources are examples of these elements

(Davids, 2011). Further, FSMS is based on Good Hygienic Practices (GHP) and Hazard Analysis Critical Control Point (HACCP) principles, and is expected to cover both food safety control and assurance operations to ensure food safety (Jacxsens *et al.*, 2009).

The trust of customers/consumers is one of the most valuable assets of any food enterprise. Food safety is therefore one of the most fundamental components of any food operation, in addition to being a legal requirement. Consumer trust is built on this foundation. However, in today's world, guaranteeing food safety has become a difficult undertaking, as the food business is faced with a wide range of chemical, microbiological, and physical dangers that can contaminate food at any point along the food chain. Consumer protection measures, on the other hand, are frequently interwoven with other factors. A successful food business should fulfill a variety of other requirements in addition to food safety. These differ depending on a population's lifestyle, values, culture, degree of education, and perception (Motarjemi, 2016).

Global food safety initiative (GFSI)

Customers are increasingly demanding that their suppliers undergo an "Accredited Third-Party Audit" in recent years. Numerous high-profile international food safety issues happened during the 1990s, including Bovine spongiform encephalopathy (BSE), dioxin poisoning, and Listeria outbreaks. Brand owners and merchants understood that relying solely on food safety rules isn't enough to ensure food safety. In 2000, food industry executives founded the Global Food Safety Initiative (GFSI) to find collaborative solutions to global challenges, particularly to reduce food safety risks and strengthen consumer confidence. The GFSI is coordinated by the Consumer Goods Forum, with 400 members and >150 countries. The GFSI rapidly understood that establishing a single standard would increase competition among current food safety standards. As a result, GFSI chose the benchmarking method.

During the last couple of decades, diverse FSMSs have arisen that may be public or industry-based (Fig. 3).

FSMS	Public-based	International Organization for Standardization (ISO:9001)
		Hazard Analysis Critical Control Point (HACCP)
		ISO: 22000
	Industry-based	GlobalGAP
		British Retail Consortium (BRC)
		Safe Quality Food (SQF)
		International Food Standard (IFS)
		Food Safety System Certification (FSSC :22000)

Fig. 3. Food safety management systems (Adapted from Abebe *et al.*, 2020b)

International Organization for Standardization (ISO)

ISO is a separate, non-governmental, international association of 165 national standards bodies with a Central Secretariat in Geneva, Switzerland. ISO in collaboration with members brings all experts together to exchange knowledge and develop voluntary, consensus-based, market pertinent international standards, which support novelty and provides solutions to universal challenges (https://www.iso.org/about-us.html). ISO covers a wide range of standards which include: Quality management standards, Environmental management standards, Health and safety standards, Energy management standards, IT security standards, and Food safety standards. The Quality Management System (QMS): ISO: 9001 confirms that the firm has different forms of processes and procedures in the company to guarantee good performance. The ISO: 14001 deals with environmental safety and helps to reach out to the entire market that makes it a norm to follow environmental practices. It ensures better compliance ratings within the legal and customary requirements put forth by the Government. The food safety management: ISO 22000 certification ensures that all precautions and safety measures have been taken during the production and processing of food. It also contains elements of Good Manufacturing Practices (GMP) and Hazard Analysis Critical Control Points (HACCP). The ISO 22000:2005 sets the requirements for a food safety management system in which a food chain organization must demonstrate its competence to regulate food safety threats to assure food safety at the point of human consumption.

ISO 22000:2018 is globally recognized and exclusively deals with FSMS requirements of establishment, and requires that organization should prove its competency in controlling food safety hazards. It contains the ideas of the HACCP system as well as the application processes of the Codex Alimentarius Commission. It also integrates ISO 9001 standards and ensures safety. Furthermore, ISO 22000:2018 may be used regardless of existing standards. Using auditable necessities, it connects a processor's HACCP approach with Pre-requisite programs (PRPs). The standard requires the mitigation of all hazards associated with the process and facilities; it is only intended to address food safety issues, not necessarily quality issues. The ISO 22000:2018 employs a process approach that incorporates the Plan-Do-Check-Act (PDCA) which permits an organization to plan its processes and their interactions.

Codex Alimentarius Commission

The Codex Alimentarius Commission (CAC) is a worldwide food standards organization. The Food and Agriculture Organization and the World Health Organization jointly founded it in the year 1963. The basic goal was to protect consumer health and maintain fair trade practices. The Codex standards are based on risk assessment conducted by an impartial international organization. Codex standards, guidelines, and recommendations are recognized as reference standards for international commerce and trade dispute resolution by the World Trade Organization's Agreement on the application of sanitary and phytosanitary measures and technical barriers to trade. The CAC currently has 189 members, consisting of 188 member countries and one member organization. In 1964, India became a member of the Codex Alimentarius. The CAC is made up of a commission, an executive committee, and subsidiaries, as well as six regional coordinating committees and task forces (Asia, Africa, Europe, the Far East, South America, and North America). There are ten general subject committees and seven vertical committees in the Codex. The major food items (raw, semi-processed, and processed), processing machinery, residues, veterinary medications and pollutants, labeling, sampling and analysis, imports, and exports are all covered by the Codex (http://www.fao.org/fao-who-codexalimentarius/en/).

Food Safety and Standards Authority of India (FSSAI)

Prior to the FSSAI act, the implementation of separate laws for meat, milk, and other food commodities was a major hurdle for compliance in the country. This created lot of confusion and ambiguity among the stakeholders. Further, the need for single food law across the nation was felt and efforts in this direction have led to the emergence of a strong food regulatory body, FSSAI under the Ministry of Health and Family Welfare, Government of India. The prime objective of FSSAI is consumer protection through the provision of safe and wholesome food. This is an integrated food law that lays down standards and guidelines for consumer safety, protection of consumer health, and regulation of the food sector. This act is mandatory for all who are in the food business. Further, it seeks to harmonize Indian standards with international standards like CODEX and facilitates international trade in food articles. It also safeguards the interests of consumers by forbidding deceptive advertisement and penalizing adulteration. In other words, the Act aims to improve the quality of food-related information provided to consumers by establishing criteria that, if adequately enforced by state commissioners, would result in improved consumer welfare. The FSSAI also creates laboratory accreditation standards and provides food safety recommendations to federal and state governments. It also creates a Food Safety Appellate Tribunal to hear and decide cases concerning food safety infractions. The law is critical in ensuring that consumers are provided with high-quality food. Furthermore, it serves as a sole point of reference for all food-related issues. FSSAI registration/license rules are framed keeping the annual turnover, production, and qualifying conditions as a basis.

Hazard Analysis and Critical Control point (HACCP)

The Hazard Analysis and Critical Control Point (HACCP) is a reliable and effective tool endorsed by many regulatory bodies at the global level to address food safety from farm to fork. HACCP ensures food safety through analysis of physical, chemical, and biological hazards at all stages of production through the identification of critical control points. Although the HACCP system was intended to produce zero defect products, it is impossible to achieve 100% defect-free products. It aims at minimizing the risks during production to produce a safe product. HACCP should include the standards for Sanitation Standard Operating Procedures (SSOPs) and Good Manufacturing Practices (GMPs) as these are pillars of HACCP. To identify critical control points, it is necessary to develop a HACCP decision tree. Moreover, there are five initial phases and seven core HACCP principles (Fig. 4 and 5) that make up a HACCP strategy (FSSAI, 2018). The HACCP team conducts hazard analysis to identify the physical (Bone pieces, hairs, stones, plastic, glass, metal, etc.), chemical (chemical residues, pesticides, antibiotics, heavy metals and veterinary drug residues, food additives above specified limits, biological toxins, chemical contaminants) and biological (bacteria, viruses, fungi, parasites, etc.) hazards.

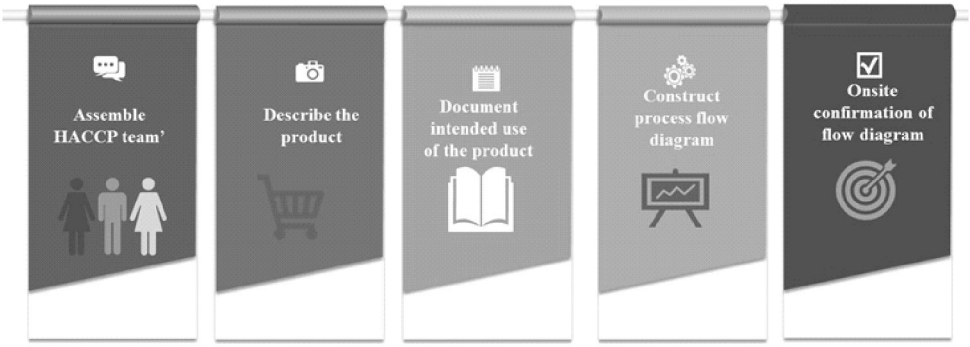

Fig. 4. Preliminary steps in HACCP plan

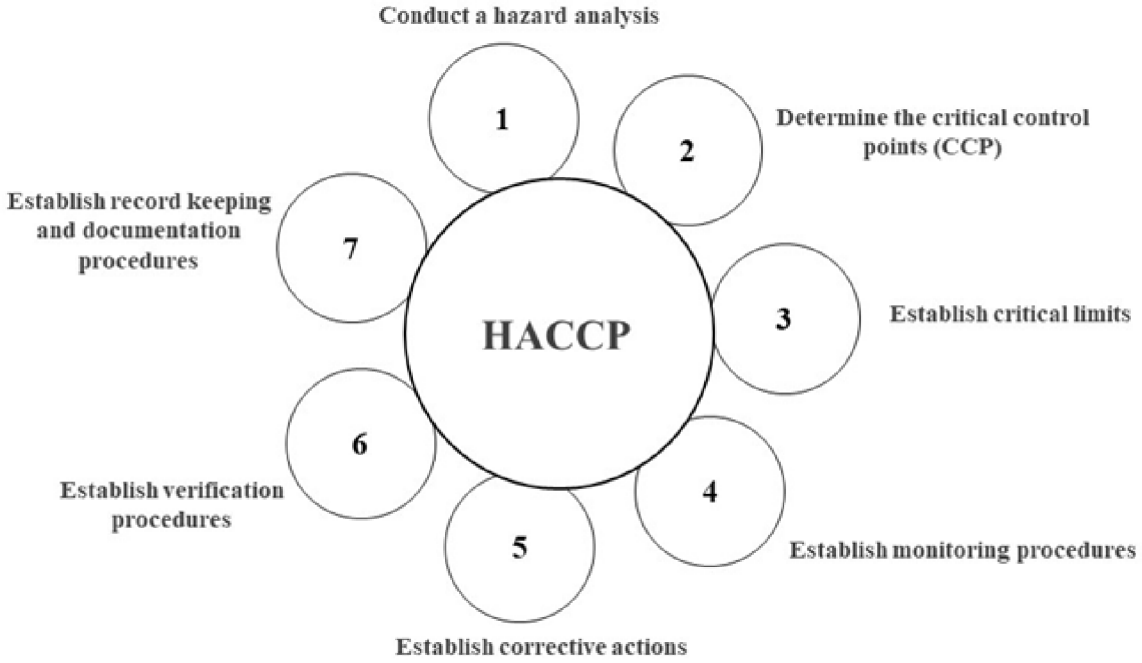

Fig. 5. Seven HACCP principles

The critical control points (CCPs) are steps wherein control can be applied to prevent, remove, or minimize food safety risks to acceptable levels (Rushing and Ward, 1999). The critical limit or extent of possible deviation can be set for each CCPs. Further, regular motoring of CCPs is done to identify any deviation. During monitoring, if a deviation occurs, needful corrective actions to be taken are established. The efficiency of the HACCP plan is verified through random sample collection, verification inspection schedules, etc. Finally, proper record keeping and documentation are very much essential to demonstrate that the food safety plan is working effectively. Recent developments in technology have enabled data management through the automated system using data acquisition and recording system software in the industry. This automated system monitors, records, and indicates any deviation in CCP, and also shows the trend over the period. This automated system and data repository could be helpful during audits and also ensure food safety.

Pre-requisite programs (PRPs) and Operational Pre-requisite Programs (OPRPs) play an important role in ensuring food safety. In PRPs, emphasis is on the hygienic status of the production environment (facility, programs, and people) while in OPRPs focus is on the prevention of hazard cross-contamination or proliferation risks during production (Mortimore and Wallace, 2013). The Pre-requisite programs (PRPs) are basic conditions and actions required within the organization and across the food chain to ensure food safety. The Operational Pre-requisite Programs (OPRPs) are one or more control measures applied to prevent or minimize a significant food safety hazard to an acceptable level, and where action criterion and measurement or observation enable effective control of the process and/or product (ISO, 2018). Akin to HACCP, Threat assessment and critical control point (TACCP) and Vulnerability assessment and critical control point (VACCP) are HACCP based program that deals with threats (food tampering, intentional adulteration of food, and food defense) and vulnerability (food fraud) respectively. TACCP is also known as food defense and it helps to protect food from behaviorally or ideologically motivated

deliberate contamination. In VACCP, food fraud is economically motivated.

FSMS implementation in the food industry is a must to ensure food safety. In developing countries, where small-scale food processing units face a major problem in implantation. The major challenges were unavailability of infrastructure, like the cold chain, water, uninterrupted electricity supply, reluctance of top management, financial involvement, in non-english speaking countries understanding of HACCP can be a hurdle, etc. For wide adoption, the contents should be translated in local languages. Human resource development is equally important for the successful implementation of FSMS (Hariyadi, 2009). In addition unorganized production in unauthorized, unregistered abattoirs/food processing units lack food safety system. For production of good quality meat, meat breeds are necessary. Preference for hot meat may hamper development of meat processing units. However, post-covid there has been increased awareness among the consumers and E-marketing is gaining momentum especially across the metro cities of the country. This is positive sign as acceptance of hygienically processed, well packaged meat and meat products by consumer will further strengthen the FSMS. More and more food business operators will opt for the globally recognized certification system.

Traceability and product recall system

Food safety has been of prime importance. During the food value chain, documentation of the source of food is equally important as it may help in tracing the origin of food throughout the value chain. This leads to the emergence of the concept of traceability. Traceability helps in providing transparency and security to the consumer and reducing food fraud. Traceability is the ability to identify at any specified stage of the food chain (from production to distribution) from where the food came (one step back) and to where the food went (one step forward) (Espiñeira, 2016). It documents and connects the production, processing, and distribution chains of food products and ingredients (FDA, 2020). Traceability has to play a vital role when defective food items have already been distributed to the consumers by the processor. Such problematic food can be called back/recalled using traceability. A recall plan is also a required element of a food safety plan when a hazard requiring preventive control is identified. The farm to fork approach supported by traceability can safeguard quality meat production and comply with global standards. Further, traceability-based quality assurance can help in the documentation of food safety hazards. The countries which have implemented traceability system expect that countries that export meat to these countries should also comply with the traceability system at par with domestic regulations. Therefore, meat that complies with traceability may find wider acceptance in the global market and facilitate export to earn premium prices. Labels on meat packages must be QR code/barcode-based with batch/animal number and abattoir registration number etc. Implementation of livestock identification and meat traceability is a joint effort and the sincere contribution of each player is important as any inadequacy at one level can jeopardize the entire system.

Building a sustainable production chain is essential in changing climate scenario. Industry-driven collaboration to advance food safety and traceability is essential to be at par with international standards. Judicious and responsible use of antibiotics to maintain health, hygiene, and welfare of animals, follow withdrawal period, etc. needs greater attention. The concept of one health with ensuring human/animal health, welfare, environmental protection and efficient usage of natural resources, and obtaining globally recognized certification for food value chain is need of the hour.

During meat production from farm to fork, critical control points need to be identified, monitored, and ensured that safe produce is generated. To achieve food safety, FSMS follows GMP, GHP, and HACCP. These

requirements particularly relate to quality assurance of the production processes and the production environment, as well as the analysis of possible risks to food safety. Further, a food safety management programme is mandatory to acquire FSSAI license. It is therefore imperative to have a strong quality management system for food safety. GMP and SOP are two tools that help for the production of high-quality and safe meat and meat products. The stakeholders including butchers, slaughter-house personnel, and consumers need to be educated about the importance of hygiene in safe meat production. Food safety is a collective responsibility and strict implementation of regulatory guidelines during all stages of food production will ensure safe meat and meat products to consumers.

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Author's contribution: All the authors conceptualized idea, collected literature, complied in the manuscript.

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