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From Farm to Fork: Ensuring Safe Eggs and Quality Chicken

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Abstract

Poultry products, particularly eggs and chicken meat are important sources of high-quality protein and essential nutrients and contribute significantly to food and nutritional security. However, maintaining their safety and quality requires a coordinated farm-to-fork approach involving biosecurity, hygienic production, responsible antimicrobial use, effective processing, and appropriate storage practices. Poor farm hygiene and inadequate biosecurity can increase the risk of contamination by foodborne pathogens such as *Salmonella* and *Campylobacter*. In laying hens, *Salmonella* may persist within the flock and contaminate eggs through vertical or horizontal transmission, highlighting the importance of farm sanitation, vaccination, gut health management, and other preventive strategies. Responsible antibiotic use and adherence to withdrawal periods are also essential for minimizing drug residues and antimicrobial resistance risks. At the processing level, hygienic handling during catching, transportation, slaughter, processing, and packaging, together with effective chilling and maintenance of the cold chain, helps preserve poultry meat quality and reduce microbial growth. Quality assessment through visual and sensory examination, chemical analysis, and microbiological testing provides important information on freshness, safety, and acceptability. Furthermore, Hazard Analysis and Critical Control Point (HACCP) offer a preventive framework for identifying and managing biological, chemical, and physical hazards. Overall, an integrated farm-to-fork food safety approach involving farmers, processors, regulators, retailers, and consumers is essential for ensuring safe, wholesome and high-quality poultry products.

Key words: Chicken meat, Egg, Salmonella, HACCP, Safety

Introduction

With improvements in living standards and growing awareness of healthy eating, egg consumption has been steadily increasing around the world. Eggs are consumed globally by people of all ages and genders in both rural and urban communities throughout the year.

They are an integral part of cuisines across diverse cultures and are valued for their versatility in a wide range of food preparations. Owing to their exceptional nutritional composition, eggs are widely recognized as one of the most affordable and high-quality sources of protein, making them an essential component of a balanced and healthy diet (Pal and Molnár, 2021).

India is one of the world's leading producers of eggs and poultry meat, with the sector playing a pivotal role in improving food security, nutritional well-being, and rural livelihoods. Eggs are widely available and relatively affordable, making them an accessible source of nutrition for people across different sections of society. Often regarded as a highly nutritious food, eggs provide a well-balanced combination of essential nutrients that support normal growth, development, and overall well-being. Their versatility in cooking and impressive nutritional profile has made eggs a popular and valued component of diets around the world.

Poultry meat has become an important part of the human diet because of its rich, high-quality protein, essential amino acids, relatively low cholesterol content, appealing taste, and affordability. Its combination of nutritional value, palatability, and reasonable cost makes poultry meat a popular choice among consumers worldwide (Tahreem *et al*., 2024). Poultry meat is generally considered a form of white meat, in contrast to the red meat obtained from most other domesticated livestock. Among poultry products, chicken meat is particularly valued for its high-quality protein and rich supply of essential amino acids that support human health. Research from different regions of the world, encompassing diverse dietary patterns, cultural practices, and food preferences, has consistently highlighted the close connection between the foods people consume and their overall health and well-being (Ambaw, 2021). Several studies have highlighted the potential health benefits of chicken meat in a balanced diet, particularly in relation to cardiovascular health and the management of risk factors such as obesity and diabetes. These nutritional qualities make chicken a versatile and valuable food choice for people across different age groups as part of a healthy and balanced diet (Moftah and Blash, 2026).

Importance of Food Safety and Food System Integrity

In today’s global food system, people’s right to choose what food they eat and how it is produced is becoming increasingly important. This idea, known as food sovereignty, aims to ensure that people and local communities have a greater say in their food and farming systems. However, in recent years, food deception and adulteration have become growing concerns worldwide, raising greater awareness about the need for reliable

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food authentication and traceability systems. These measures are essential for verifying the identity and origin of food products and play an important role in maintaining food safety, quality and consumer confidence.

As the food industry becomes increasingly globalized, food products often pass through complex supply chains before reaching consumers. This has made ensuring the authenticity and integrity of food products more challenging than ever. Today, food authentication involves much more than detecting adulteration; it includes verifying product quality, checking the accuracy of labels, confirming traceability, and establishing the true identity and origin of food materials. In simple terms, food authenticity ensures that what is declared on the label accurately reflects the product's actual quality, composition, and source, thereby helping to protect consumers and build confidence in the food they purchase (Deng *et al*., 2024).

The "farm-to-fork" approach highlights the importance of creating value, maintaining traceability and ensuring transparency at every stage of the food supply chain. Within this system, slaughterhouses serve as an important link between livestock production at the farm level and the subsequent processing, distribution and marketing of meat. Their ability to maintain food safety, follow ethical production practices and meet certification standards can significantly influence consumer confidence and the reputation of food brands.

At the same time, modern food systems face several challenges related to unequal access to resources, concentration of economic power and agricultural policies that may not benefit all stakeholders equally. These concerns have become increasingly relevant in the context of global food insecurity, climate change, poverty, hunger and unequal access to nutritious food. In some cases, highly commercialized food systems tend to treat food primarily as a commodity rather than recognizing its fundamental importance to human well-being. Small-scale farmers, indigenous communities and rural workers can be particularly vulnerable to practices such as unfair subsidies, market instability, excessive control over natural resources, and the misuse of biological resources. Addressing these challenges requires food systems that are more transparent, equitable, sustainable and inclusive (Martínez, *et al*., 2024; Rowe *et al*., 2024)

Foodborne diseases continue to pose a major challenge worldwide, affecting public health and causing considerable economic losses. Poultry products, particularly chicken meat and eggs are frequently associated with foodborne illness when proper hygiene, handling, storage, and cooking practices are not followed. At the same time, these

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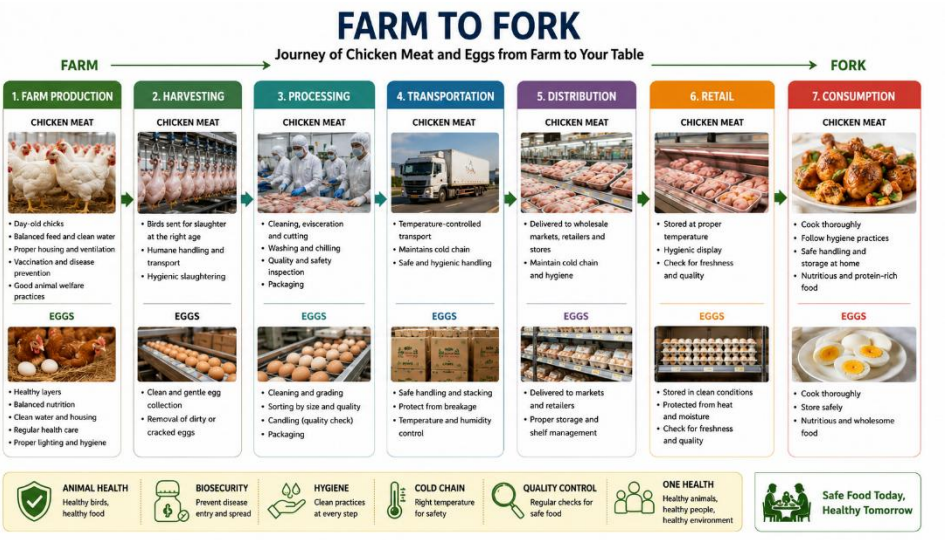
foods remain important sources of high-quality protein and essential nutrients for populations across the globe. Therefore, ensuring safe production, processing, storage and consumption of poultry products is essential for protecting public health while meeting the growing demand for nutritious food (Hessel *et al*., 2019). With the steady growth of the global population and changing dietary preferences, the demand for animal-derived foods is increasing. To meet this growing requirement, livestock production has become more intensive and increasingly focused on achieving higher productivity. However, intensive farming systems often involve large numbers of animals kept in relatively confined spaces, creating conditions that can favour the transmission and spread of infectious diseases, including those caused by bacterial pathogens. This highlights the importance of maintaining strong biosecurity, hygiene, and disease-prevention measures in modern livestock production systems (Trinchera *et al*., 2025).

In reality, the global food system continues to face significant inequalities, with vulnerable and marginalized communities often bearing the greatest burden of these challenges. Such disparities can limit their access to nutritious food, resources, livelihoods, and fair opportunities within the food supply chain (May *et al*., 2022; Zelber *et al*, 2024).



Biosecurity: The First Line of Defence

The Food and Agriculture Organization (FAO) classifies poultry production systems into four sectors according to their level of biosecurity. Maintaining good biosecurity practices is essential because poor farm hygiene can increase bacterial contamination, creating risks to public health and causing economic losses. A well-planned biosecurity programme should consider both conditions within the farm and factors outside it. Important aspects include the location of the farm, its distance from major roads, control of traffic and

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visitors, cleanliness of the surrounding area, condition of poultry houses, stocking density, quality of feed and drinking water, cleanliness of litter or bedding, and proper management of farm workers and visitors. Together, these practices help reduce the risk of disease introduction and spread and support safe and sustainable poultry production (Hafez *et al*., 2025).

Biosecurity is one of the most important ways to prevent the entry and spread of infectious diseases on poultry farms (Delpont *et al*., 2023; Saegerman *et al*., 2023).Good biosecurity not only protects the health and productivity of birds but also helps safeguard human health by reducing the risk of harmful foodborne pathogens such as *Salmonella* and *Campylobacter* entering poultry products (Horvat *et al*., 2022; Zaki *et al*., 2023).Proper biosecurity can also improve farm performance and reduce the unnecessary use of antibiotics which is important in controlling the growing problem of antimicrobial resistance. However, many poultry farms still face difficulties in following basic biosecurity practices such as controlling the entry of workers and visitors, maintaining hygiene barriers, and managing the movement of vehicles. Therefore, greater awareness, regular monitoring and proper implementation of biosecurity measures are essential for achieving safe, healthy and sustainable poultry production.

Responsible use of antibiotics

The presence of antibiotic residues in poultry products such as meat and eggs is an important concern for food safety, public health and the environment. Antibiotics are commonly used in poultry farming to treat infections and in some situations to prevent disease. However, improper or excessive use of these medicines can result in residues remaining in poultry meat and eggs. Consumption of products containing such residues may cause health problems, including allergic reactions, and may also contribute to the development and spread of antibiotic-resistant bacteria. Therefore, the responsible use of antibiotics and proper adherence to withdrawal periods are essential for producing safe and healthy poultry products (Abou-Jaoudeh *et al*., 2024; Hossein and Ripanda, 2025).

Preventing antibiotic residues in poultry products begins with responsible practices at the farm level. One of the most important measures is following the recommended withdrawal period, which is the required time between the last dose of an antibiotic and the slaughter of birds or collection of products such as eggs. Observing this period allows the medicine to leave the bird's system and helps ensure that poultry products reaching consumers are safe (Adegbeye *et al*., 2024). Failure to follow the recommended withdrawal period can leave excessive antibiotic residues in poultry meat and eggs, creating

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potential health risks for consumers. Educating farmers about the responsible use of antibiotics and the importance of seeking veterinary advice can help reduce unnecessary or improper medication. Regular record-keeping is also important, as it allows farmers to track the medicines used, monitor their application, and ensure that food safety requirements are followed. Together, farmer awareness, veterinary guidance and proper monitoring can support the production of safer poultry products and help reduce the misuse of antibiotics (Tcheou *et al*., 2025).

Maintaining egg quality

Layer hens can serve as an important reservoir of *Salmonella* which may spread through the oral–faecal route. Hens can acquire the bacterium by consuming contaminated feed or water or through contact with contaminated surfaces and materials within the poultry house. Infected birds may intermittently excrete *Salmonella* in their faeces, allowing the organism to persist and accumulate in the shed environment. Such environmental contamination can increase the chances of subsequent infection among the flock.

The presence of *Salmonella* in layer hens is also a major food-safety concern because it can result in contamination of eggs. Egg contamination may occur through either vertical or horizontal transmission. In horizontal contamination, bacteria from the surrounding environment can come into contact with the eggshell, particularly when eggs are laid in contaminated nesting areas or come into contact with contaminated litter, faeces, equipment or other surfaces. Maintaining good hygiene and effective environmental sanitation in layer houses is therefore essential for reducing the risk of *Salmonella* contamination and protecting egg safety (Li, *et al*., 2025).

Strategies for controlling *Salmonella* contamination

Controlling *Salmonella* in laying hens requires a combination of preventive measures because the occurrence and transmission of the pathogen are influenced by several factors throughout the production cycle. Important approaches include vaccination, selective breeding, genetic improvement, control of gastrointestinal colonization, and maintaining effective farm hygiene and biosecurity (Gast *et al*., 2024).

Vaccination

It is one of the widely used strategies for reducing *Salmonella* infection in poultry. Both live and inactivated vaccines are available and can help strengthen the birds' immune response. Although vaccination may not completely prevent infection, it can reduce the level of *Salmonella* colonization in the intestine and lower the severity and duration of infection.

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Breeding and genetic selection

It provides another promising long-term approach, as differences in resistance or susceptibility to *Salmonella* infection have been observed among different chicken lines. Selecting birds with greater natural resistance may therefore contribute to reducing the prevalence of the pathogen over successive generations.

Controlling gastrointestinal colonization

Maintaining a healthy and balanced gut microbial community can help prevent harmful bacteria such as *Salmonella* from becoming established in the intestinal tract. This can be achieved through competitive exclusion and the use of beneficial microorganisms, including selected probiotic bacteria such as *Bacillus*, *Lactobacillus*, *Bifidobacterium* and *Streptococcus*. Certain non-digestible carbohydrates, including inulin, fructo-oligosaccharides, galacto-oligosaccharides and resistant starch, can also support beneficial gut bacteria and contribute to intestinal health. Together, these approaches can help reduce *Salmonella* colonization and support healthier and safer poultry production.

HACCP Principles and Food Safety

Hazard Analysis and Critical Control Point (HACCP) is a preventive approach to food safety that focuses on identifying and controlling potential hazards before they affect the final food product. Unlike traditional quality-control practices that often emphasize detecting problems after they occur, HACCP is designed to prevent food safety hazards throughout the production and processing chain. Its development and widespread adoption have provided food businesses with a systematic framework for maintaining safe and hygienic food production.

HACCP-based systems help ensure that food reaching consumers meets essential safety requirements by identifying possible biological, chemical and physical hazards and establishing appropriate control measures. Food safety standards and guidelines are periodically reviewed to ensure that they remain scientifically relevant and practical for the food industry. ISO 22000 is an internationally recognized food safety management standard that incorporates HACCP principles into a broader management system framework. It provides organization involved in the food chain with a structured approach to identifying and controlling food safety hazards, including pathogenic microorganisms and other contaminants. Regulatory authorities and food safety agencies in many countries oversee the implementation of HACCP and related food safety systems to minimize the risk of contamination and prevent foodborne disease outbreaks (Awuchi, 2023).

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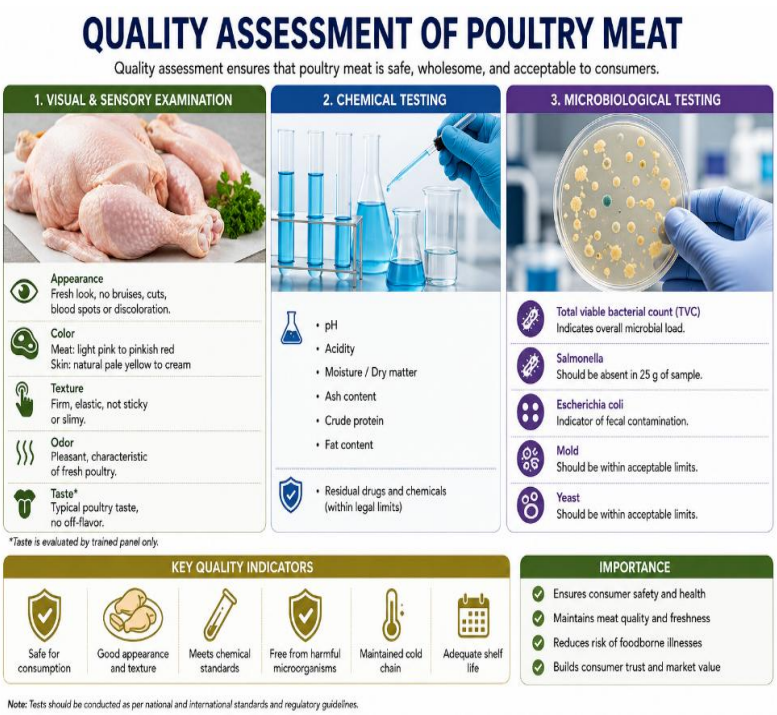
Regular monitoring of contamination throughout the food-processing sector is essential for evaluating the physical, chemical and microbiological safety of the food chain, from production to consumption. This is particularly important because microorganisms are constantly changing, with the emergence of antimicrobial-resistant and potentially more harmful strains creating serious challenges for food safety and global food security. Food contaminants, particularly foodborne pathogens, therefore pose a significant threat to both public health and food security. HACCP provides a systematic approach to addressing these risks by identifying Critical Control Points (CCPs) where specific preventive or corrective measures are required. These measures may include controlling conditions that prevent microbial growth or applying appropriate processes to reduce or eliminate harmful microorganisms while maintaining the quality and safety of food.

Producing safe and quality chicken



Producing quality chicken extends beyond raising healthy birds. Hygienic handling during catching, transportation, slaughter, processing, and packaging are equally important. Processing facilities should maintain strict sanitation standards to prevent contamination. Workers must follow good hygiene practices, use clean equipment, and maintain the cold chain throughout storage and transportation. Appropriate chilling after processing slows bacterial growth and preserves meat quality. Proper packaging protects chicken from physical damage and contamination while extending shelf life.

Quality assessment of poultry meat involves a combination of visual and sensory examination along with chemical and microbiological testing. These parameters help determine the freshness, safety, and overall acceptability of poultry products before they reach consumers.

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***Visual and sensory quality*:** Important sensory attributes include meat and skin colour, texture, odour, flavour, and overall appearance. Packaged poultry meat should be carefully inspected to ensure that it is free from visible blood accumulation and excessive frozen water within the package. Frozen products should remain properly frozen during storage and transportation. After thawing, the meat should retain a normal firmness and consistency and should not have a sticky or slimy surface. It should also be free from freezer burn, mould growth, and other visible signs of deterioration.

In fresh poultry meat, the amount of water released during storage, including water collected inside the package and absorbed by packaging materials, should remain within the permissible limit, generally not exceeding 6% of the packaged meat weight where applicable standards specify this value. Frozen poultry should not have unpleasant or abnormal odours, such as sour or rancid smells. The skin should have a natural and uniform colour and should be free from tears, bruises, swelling, discoloration, freezer damage, blood spots, and other physical defects. It should also be properly cleaned and free from feathers, dirt, foreign materials, and other forms of contamination.

***Chemical quality*:** Chemical evaluation provides additional information about the condition and safety of poultry meat. Commonly measured parameters include pH, acidity, moisture or dry matter, ash, crude protein, and residues of veterinary medicines or other chemical substances. The levels of drug and chemical residues should remain within the maximum limits established by the relevant food safety and regulatory authorities.

***Microbiological quality*:** Microbiological examination is essential for assessing the safety of poultry meat. Testing may include determination of the total viable microbial count and detection of important foodborne microorganisms such as *Salmonella* and *Escherichia coli*. The presence of spoilage organisms, including moulds and yeasts, may also be evaluated. Regular monitoring of these quality parameters helps ensure that poultry meat remains safe, hygienic, and suitable for human consumption (Uazhanovam *et al*., 2024).

Microbiological quality characteristics of fresh and frozen poultry meat

S.No.	Test	Minimum	Maximum
1	Total count of microorganisms(in grams)	104	106
2	Coagulase-positive staphylococci (in grams)	100	1000

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3	Coagulase-positive staphylococci (in grams)	0	0.1
4	E. coli (in grams)	45	450

Conclusion

Ensuring the safety and quality of poultry products requires attention at every stage, from farm production to final consumption. Healthy birds, effective biosecurity, proper farm hygiene, responsible use of antibiotics and appropriate control of *Salmonella* are important for reducing food safety risks in eggs and poultry meat. At the processing level, hygienic handling, clean equipment, effective chilling, uninterrupted cold-chain management and suitable packaging helps to maintain meat quality and reduce the possibility of contamination. Regular assessment of poultry meat through sensory, chemical and microbiological parameters further supports the identification of quality and safety concerns. HACCP provides practical frameworks for identifying hazards and establishing preventive controls throughout the food chain. Ultimately, producing safe poultry products is a shared responsibility involving farmers, veterinarians, processors, regulators, retailers, and consumers. By strengthening good practices and maintaining vigilance from farm to fork, the poultry sector can provide nutritious, safe, and high-quality eggs and chicken meat while protecting public health and building consumer confidence.

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