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# Safer Post-Harvest Processing, Proper Storage and Transport of Broiler Products to the Retail Markets

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## Abstract

The growing number of foodborne infections is rising competitively with consumer demands and growth of poultry products. The significant increase in the number of reported foodborne disease outbreaks specifically caused by *Salmonella* and *Campylobacter* is undermining the hard work of food safety stakeholders and regulators. It has become clear that current production and processing practices must be improved through both further research at the post-harvest level and further implementation of advanced legislation that adequately measures the reduction of the contamination levels in poultry products before displaying for customer choice. To achieve that goal, novel alternatives of monitoring and traceability of microbiological and chemical food hazards are required to develop and implement. It is essential that further advancement in controlling zoonotic pathogens in post-harvest processing levels should include alternatives for cleaning, sanitizing, and disinfecting the equipment and plants, proper storing, and safer transportation. Moreover, machine design must permit easy and thorough cleaning. From the farm-to-fork, poultry product safety vastly depends on post-processing, product handling, development, and implementation of acceptable zoonotic disease control methods, specifically GMP and HACCP that can limit end product contamination and increase proper preservation in the processing plants, storage facilities, and carriers.

## Introduction

Today, available forms and varieties of food products are quite different than those in the past few decades, specifically due to marketing policies, technological advancements and their application, grading, and leveling for consumer consciousness of animal products [1,2]. Now almost all countries, including both developed and developing countries, have a multitude of farm animal production and processing facilities that include commercial animal farms, feed producers and retailers, slaughter houses, processing and packaging plants, and chain retail markets or fast food restaurants [3]. In addition, cooking and consumption styles have also changed [1,4]. Ultimately, the whole food system is becoming more complex as our food becomes largely safer, more flavorful, more nutritious, more abundant, more diverse, more convenient, more accessible, and less costly than ever before.

Further progress of this complex food system is essential due to continuous technological advancements and global networks of news, media, and publications on the progress of the healthy food and their impact on health and diseases. Consumption of healthy foods such as fresh fruits and vegetables, white meat such as chicken and turkey, and pasture and chemical free foods has increased [5]. Further, now a single, tiny out-break can cost a recall of millions of pounds of food products and put companies out of business [6]. As the current favored protein sources of consumers are far different than those of the few decades before, the corresponding behavioral changes, epidemiological technical advancements, and diagnostics technical advancements have also changed the number and pattern of foodborne infection [7]. Most of the people in developed countries prefer to have chicken meat for their protein source, and that is why safety and quality of poultry and poultry products is of utmost importance. Growth of yearly poultry production is now more than 3% globally, and the products from same farm are now available in different parts of same continent and multiple continents [5]. Thus proper poultry farming, harvesting, slaughtering, processing and packaging, transportation and distribution, retailing, foodservice, and food preparation are extremely critical controls to keep foodborne infection in check. The impact of modern food manufacturing methods is evident in today's food supply. Quality of poultry products can be maintained or even improved, and food safety can be enhanced if farm level pre-harvest and post-harvest processing, packaging, and transportation can be performed properly following the integration of scientific information. In this review article, we aimed to summarize the recent research outcomes relevant to post-harvest processing of poultry products and recommendations for better practices.

## Possible Measurements to Prevent Microbial Contamination in Processing

To minimize the cross-contamination of chicken carcasses with microorganisms, specifically zoonotic pathogens, and to protect the safety of finished products, the basic principles behind Sanitation Standard Operating Procedures (SSOPs) and Good Manufacturing Practices (GMPs) in Hazard Analysis and Critical Control Points (HACCP) and its implications in education and training are very crucial. The major concerns of a chicken processing plant are briefly

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discussed in this section of the short review.

**External infection and pre-slaughter check**

Safe poultry production starts at broiler hatcheries. Evidence suggests that both *Campylobacter jejuni*/*coli* and *Salmonella* infections can be linked to horizontal contamination as well as vertical infection from hens to chicks [8,9]. Increased pre-slaughter mortality has been found on farms where farmers did not check the quality of arriving chicks [10]. To avoid the horizontal contamination, equipment that is in direct contact with eggs as well as the eggs themselves at hatcheries should be thoroughly sanitized. Chicks arriving from hatcheries should also be inspected before a new flock is received by the growers. Animal Health Consultant suggests hatcheries administer yeast-type preparation and a competitive exclusion product to prevent microorganisms from colonizing the guts of hatching chicks. Following the delivery of a new flock, hygienic housing is needed to maintain the health and safety of poultry. Proper housing practices are essential to reduce the spread of infection within commercial poultry populations. Mice, wild birds, and insects have been implicated in poultry infection transmission [8]. Therefore, it is important to inspect the cleanliness of the feed and implement hygienic storage of poultry feedstuffs. During warmer months, Ectoparasites, especially flies, Play roles in spreading *Campylobacter*, *Salmonella* and other pathogens on broiler farms. The use of fly screens has reduced the amount of flocks testing positive for *Campylobacter* [11].

The Food Safety Authority of Ireland suggested that pre-harvest random screening of zoonotic pathogen load in fecal samples should be implicated. The concentration of *Campylobacter* spp. should be less than $10^7$ CFU/g [11]. In addition, weekly post- harvest sampling is also recommended. Repeated violations of pre- or post-harvest microbial concentrations require review of sanitation practices within a facility.

**Antimicrobial effect of culling water, duration of treatment, and recycling of water**

Post-slaughter submersion in hot water is critical to remove the external poultry contamination present on skin and feathers and loosen skin to facilitate feather removal. Counter-flow scalding and tanks with multiple stages can reduce the number of bacteria remaining on poultry following scalding [11-13]. Counter-flow of scalding prevents microorganisms that were initially present from remaining on the carcasses and contaminate poultry at the end of the cycle. Sampling should be done to ensure that the water near the end of the cycle is less hazardous than the water at the beginning of the cycle. Adding fresh water to the end of the cycle might help meet the requirements for food safety [14]. Increasing the temperature of culling water from 56 ºC to 60 ºC reduces the amount of both Salmonella and Campylobacter [15]. In tanks with scalding temperatures below 57 ºC, carcasses should remain in the tanks for around three minutes or more, and at least a few minutes for carcasses in scalding water above this temperature [16]. In scalding tanks, water flow rates should be as high as possible and acidic disinfectant should be added to the water. Scalding water can also be heated to 75 ºC during breaks to reduce contamination between new batches of carcasses [17].

**Water speed and intensity of washing after de-feathering**

De-feathering practices have been identified as one of the important steps in favoring cross contamination sites during poultry processing. It has been reported that after de-feathering, there are increased hiding holes, such as follicles, that can harbor foodborne human pathogens, such as *Campylobacter,* Staphylococcus aureus and Salmonella. Nayak et al. reported that the scanning electron microscopy revealed bacteria lodged deeper in broiler skin that could not be recovered by rinsing or stomaching, but were recoverable by shredding. In addition, the picker fingers have also been identified as ideal vectors for contamination since they are located in warm, humid environments, and they are very difficult to clean and disinfect. To remove or inactivate unwanted bacteria, specifically zoonotic pathogens from skin and follicle holes, Water speed and intensity of washing after de-feathering play a crucial role in sanitizing efficiency. The presence of type and amount of organic matter on the skin in the de-feathering environment can determine the species of bacteria present and how readily cleaning and sanitizing agents can inactivate them. Thus, the evaluation of the type, proper estimation of the amount of organic matter and the type of contaminates should be considered to set the water speed and intensity with or without antimicrobial supplementation of wash water after de-feathering.

**Precaution and visual check of evisceration before put together for chilling**

Taking precautionary measures to prevent transmission of bacteria prior to evisceration of poultry carcasses can be extremely effective. *Salmonella* and C. *jejuni* cause the largest number of foodborne illnesses associated with poultry as a food product [12]. Evisceration is one of the most critical points of poultry processing where cross-contamination occurs [8]. It is possible to reduce the chances of contamination by these bacteria with simple preventative steps. The maintenance of slaughtering equipment is imperative for good sanitation. Improper alignment of the equipment can cause evisceration failures, which can lead to contamination [11]. Appropriate adjustment to the bird's size prior to evisceration is essential. When evisceration failures are monitored, they can indicate improper sizing or dysfunctional equipment, which may need to be replaced [11].

Prior to packaging, certified inspectors who are qualified to identify any abnormalities perform a visual check of each individual carcass on site pre and post chilling [18].

The personnel inspect the inside and outside of each carcass looking for feathers/hairs, damaged internal organs, skin discolorations, exposed flesh, conformation, disjointed/broken bones, missing parts, and pathological lesions/tumors in accordance with the USDA quality criterion [18]. Damaged internal organs can be a large problem because fecal matter can contaminate the carcass and render it condemnable. Once the qualified personnel have examined each carcass they declare the inspection "passed", "trimmed/ salvaged/washed passed", "retained for disposition by a veterinarian" or "condemned" [18]. If the carcass is deemed condemnable it may be reprocessed, but if it is diseased it must be disposed of [18].

**Viability of bacterial cells in chilling environment**

Colonization of the chicken gut by *Salmonella* and *C. jejuni* provides the opportunity for cross contamination during poultry processing. Within the chicken's intestinal tract there can be a

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bacterial load of up to $10^8$-$10^9$ CFU/ml [18]. Luckily, most carcasses leave processing plants with less than 1 log CFU/ml of *Campylobacter* after chilling [19]. This is less than the infectious dose of 500 bacterial cells [18]. However, if the viscera are not removed intact or the skin is not cleaned properly, it is possible to have fecal contamination of the carcasses providing the pathogens with the opportunity to colonize [12]. The infectious dose of *Salmonella* is higher than *Campylobacter* with $10^6$ CFU needed [18]. *Salmonella* is a heat-sensitive bacterium that is not damaged by chilling, but ceases to multiply at chilling temperatures. This places importance on thoroughly cooking the poultry to an internal temperature of at least 70 °C before consumption to actively kill the bacteria [18]. Prior to 2014, it was required of all processing plants to chill the carcasses to 4.4 °C within 4-8 hours of processing depending on their weight [20]. *Campylobacter* ceases to multiply when temperatures drop below 30 °C [18]. As of August 2014, there have been modernized guidelines for the inspection and chilling of poultry post-slaughter published by the USDA Food Safety and Inspection Service [20]. The FSIS developed the requirements to ensure poultry processing plants could incorporate a chilling method into their individual HACCP plans [20]. Under the new regulations each plant must ensure that immediately after slaughter the carcasses are chilled to a temperature that prevents pathogen proliferation [20]. Although they are no longer in effect, it is highly recommended by the FSIS to incorporate the former regulations.

**Alternatives of monitoring and traceability of biohazards**

Currently, many hospitals and health care systems have started to incorporate the new methods such as Radio-Frequency Identification (RFID) for tracking and identifying items/products to control the contamination levels of equipment that moves in and out of the organization. This technology is being successfully tested in agriculture for environmental monitoring, irrigation, specialty crops and farm machinery [21]. This digital system reduce the costs, improve safety, and manage to deliver the right location effectiveness as well as monitoring theft prevention, distribution management, and recipients. Similar digital and advance technologies are essential to evaluate and recording the hazard levels on the product before shipping to the storage and/or retailers. Implementing such technology may improve the distribution and management of the products and reduce the recall and/or help to collect the recalled packages efficiently.

**Recommendation for safer storage**

Controlling environmental conditions of broiler products during storage will assist in the prevention of bacterial growth and pest control. Cases of improper storage quickly result in microbial proliferation, leading to food spoilage and/or poultry-associated foodborne illness. Temperature is the first of several environmental conditions that must be strictly regulated. Broiler products are safest stored by either chilling or freezing. Chilled poultry requires that meat be reduced to 4 °C within 4 hours of slaughter [22], giving products a shelf life of 2 to 3 weeks [23]. In addition, most insect activity is inhibited below 4 °C, although some can survive long exposure to these temperatures [24]. Chilling is used for fresh poultry products that must not be held at freezing temperatures to ensure their label claim. This method slows, but does not prevent, the growth of bacterial pathogens. Freezing is a method that allows products to be stored for months to a year in temperatures between -28.9 and -40 °C. The maximum storage temperature for frozen poultry is -23.3 °C [18]. Freezing methods have shown excellent vitamin retention in temperatures below -20 °C. In some cases, nutrient levels have been proved better in frozen products than fresh products, depending upon the age of fresh product [23]. Temperatures between 4.4 and 60 °C are referred to as the "Danger Zone," and result in rapid bacterial growth and spoilage. Broiler products kept above 4.4 °C for longer than 2 hours should be disposed of [18].

Water activity, or humidity, is another important aspect of the environment of stored food items. Water activity is measured at the point when the relative humidity of the air is in equilibrium with the humidity of the food product. Moist products, such as fresh cuts of poultry, should have a water activity of 0.85 or above. Frozen poultry requires even higher water activity levels. While high moisture is necessary to maintain high quality poultry, it also increases chance of bacterial growth. *Campylobacter, Salmonella,* and *Staphylococcus* aureus require a minimum water activity levels of 0.98, 94 and 86, respectively. Since the minimum humidity for growth of some pathogenic bacteria can overlap with the optimum humidity for poultry storage, chilling or another barrier is necessary to control microorganisms [22].

Methods and materials of packaging for poultry products are other important ways of controlling the environment. Packaging serves to protect products from contamination, delay spoilage, and regulate gaseous conditions during storage. Modified atmospheric packaging is the process of controlling the mixture of atmospheric gases within the packaging to minimize microbial growth [18]. High levels of $CO_2$ are effective in reducing the level of bacterial growth on poultry products [24]. Consequently, it is important that the packaging has a good $O_2/CO_2$ barrier to prevent any gas from migrating [18]. Overall, leak-proof packaging has been proved significantly more effective at minimizing contamination than conventional packaging [11], specifically plastics. Plastics are a commonly accepted packaging material due to environmental durability, barrier permeability, and resistance to breakage but those not environment friendly. Therefore, biodegradable packaging materials are needed to develop. To further increase safety of storage, packaging materials can be sterilized prior to use (i.e. hydrogen peroxide) or pretreated with active ingredients (i.e. antioxidants, oxygen scavengers) to protect them throughout storage [18].

**Proper transport for shipping to the retail stores**

Transportation of processed food including poultry products is an essential step in modern food production and marketing. Now raw materials and food ingredients are all transported on a local and global level by land, sea, and air, and in many cases, products are in the carrier for a few hours or even a few weeks [5]. In the modern world, consumers all over of the world vastly depend on imported foods, particularly frozen meat and other proteins sources, and retailers are likely to display their products year-round. As such, non-local poultry products are often integrated with local products and transported in the same carriers. Thus long-distance transport of many foods has become commonplace [24]. Transportation of food is also considered short- term storage. Therefore, control of temperature and humidity of the carrier, cleaning and cross- contamination of

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the product during transportation, and training of the drivers or handlers are important controls in food safety. In addition, improper transport causes physical and mechanical stresses and possibly rapid changes in temperature and humidity, which impose a high risk of compromising the products during transport, loading and unloading. Products delivered on unscheduled delays especially need to be checked thoroughly.

## Conclusion

The safety of poultry products vastly depends on processes that occur after the bird is harvested from the farm; that includes slaughtering, processing, dressing, packing, and properly cooling at appropriate temperatures during storage and transportation. Frozen products must be maintained in a frozen state from the processing facility to the consumer. Quality of water, specifically noting the presence of coli forms/microbial contamination, used for processing also plays an important role. Quality assurance must be developed in a written form, thoroughly identifying possible food safety contamination points and Standard Sanitation Operating Procedures.

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