Reducing Risk of Campylobacteriosis from Poultry: A Mini Review

Nion Sukted[1,2], Pravate Tuitemwong[2], Larry E. Erickson[1,*], Taradon Luangtongkum[3], Nipa Chokesajjawatee[4], and Kooranee Tuitemwong[5]

[1]*Department of Chemical Engineering, Kansas State University, Manhattan, KS 66506, USA*

[2]*Department of Microbiology, King Mongkut's University of Technology Thonburi, Bang Mod, Thung Khru, Bangkok 10140, Thailand*

[3]*Department of Veterinary Public Health, Chulalongkorn University, Pathumwan, Bangkok 10330, Thailand*

[4]*National Center for Genetic Engineering and Biotechnology (BIOTEC), National Science and Technology Development Agency, Khlong Nueng, Khlong Luang, Pathum Thani 12120, Thailand*

[5]*Department of Microbiology, Kasetsart University, Ladyaow, Chatuchak, Bangkok 10900, Thailand*

Abstract: The worldwide annual cost of campylobacteriosis is at least several billion dollars. Risk analysis is being used to reduce the magnitude of the problem and to support regulations and voluntary actions that are successful in that the number of cases of illness is decreasing. The new regulations in the U.S. have resulted in commercial products with fewer *Campylobacter*. During the last 16 years there has been significant progress in New Zealand because of new regulations that have resulted in reduced numbers of *Campylobacter* on marketed products. While some progress has been made in reducing cross contamination, it remains an important issue. Food safety education on the general principles of food hygiene and food handling as well as applications of hazard analysis and critical control point (HACCP) principles in food safety management are recommended to address the challenges associated with cross contamination. Economic analysis of campylobacteriosis and the poultry meat industry shows that there are significant benefits of addressing the challenges associated with *Campylobacter* in poultry products. Freezing has been shown to be an excellent cost-effective method to reduce the number of viable *Campylobacter* and the number of cases of campylobacteriosis.

Keywords: *Campylobacter*, Communication, Food safety, Regulations, Risk reduction.

INTRODUCTION

Campylobacteriosis is of concern in many parts of the world and there is much that can be done to reduce the number of infections [1-100]. *Campylobacter* is a zoonotic pathogen that is often present in poultry as a commensal organism [1, 2]. The optimum growth temperature is 41-42°C and the optimum atmosphere is 5% oxygen, 10% carbon dioxide, and 85% nitrogen [3]. *Campylobacter* colonize and grow in the cecum part of the intestine of poultry and are released in the feces. In 2013, the estimated cost of the food-borne illness campylobacteriosis in the USA was approximately $1.9 billion [2, 4]. Many individuals in many countries have experienced diarrhea, cramping, abdominal pain, and fever for 2 to 5 days because of ingestion of *Campylobacter*. In many countries, campylobacteriosis is the most frequently reported zoonotic disease in humans [5-7]. The world campylobacteriosis cases during 2005 to 2013 are shown in Table **1**. In some cases campyobacteriosis leads to Guillain-Barre syndrome (GBS), reactive arthritis (ReA), or irritable bowel syndrome (IBS), which affect health and care requirements for a longer period of time [38]. The highest risk groups of severe symptoms are young children and older adults because of weak immune systems [38-40]. Other people with weak immune systems, pregnant women, and cancer patients are among those with increased risk [38-40].

In Thailand, *Campylobacter jejuni* and *Campylobacter coli* are found most commonly in production and processing [41-43]. Antimicrobial resistance is present in many cases [41]. Cross-contamination has been found in processing plants where broilers are slaughtered [41]. *Campylobacter* spp. were isolated from 5 of 129 farmers who were working with production of chickens [42]. There are efforts to reduce *Campylobacter* in poultry in both production and processing in Thailand [43]. Genetic profiles of *Campylobacter* spp, in production and processing have been reported [43].

A special issue of Microbial Risk Analysis on *Campylobacter* was published recently [44]. It includes a comprehensive review of quantitative risk assessment models and consumer process models that have been developed for *Campylobacter* risk

*Address correspondence to this author at the Department of Chemical Engineering, Kansas State University, Manhattan, KS 66506, USA;
Tel: (+1) 785-532-4313; Fax: (+1) 785-532-7372;
E-mail: lerick@ksu.edu;

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Table 1: Certain Epidemiology of Campylobacteriosis Worldwide in Recent Years

Period	Country	Incidences or Outbreaks	References
		Africa	
2005-2009	South Africa	40% of children's stools with diarrhea at the Red Cross Children's Hospital in Cape Town were isolated as *C. jejuni* (of these, 32.3% *C. jejuni* subsp. *jejuni* and 7.7% *C. jejuni* subsp. *doylei*), and following by *C. concisus* (24.6%)	[8]
May 2011-May 2012	Kenya	5.8% (9/156 samples) of samples from patients with diarrhea were detected *Campylobacter* species	[9]
		Europe	
2005-2011	Hesse, Germany	53.4 to 81.4 campylobacteriosis cases per 100,000 population annually	[10]
2007	Germany	81 campylobacteriosis cases per 100,000 population	[11]
Apr 2008-Aug 2009	United Kingdom	9.3 campylobacteriosis cases per 1,000 person-years in the community, with an estimated total of 500,000 cases and 80,000 general practitioner consultations across the United Kingdom annually	[12]
2009	27 European Union state members	29.9 to 13,500 per 100,000 population or equated to 9.2 million cases of *Campylobacter* infections	[13]
2009	Netherlands	5.8 campylobacteriosis cases per 1,000 person-years	[14]
2009 and 2010	Denmark	35 cases per 100,000 population were reported to be annually incidence of *C. concisus* infection	[15, 16]
2009-2012	Ireland	1.15 to 1.30% were positive for *C. ureolyticus* DNA in gastroenteritis cases	[17, 18]
Mar and Apr 2011	Netherlands	71.4% of 493 gastroenteritis cases were PCR positive for *Campylobacter* DNA (*C. jejuni*-associated cases (4.1%), *C. concisus* (4.1%), *C. concisus* or *C. curvus* (0.8%), *C. ureolyticus* (0.6%), *C. gracilis* (0.6%), *C. showae* or *C. rectus* (0.4%), *C. upsaliensis* (0.4%), *C. hominis* (0.2%), and *C. sputorum* (0.2%)	[19]
2011	Germany	70,560 campylobacteriosis cases	[20]
2012	Poland	1.12 campylobacteriosis cases per 100,000 population	[21, 22]
2013	Austria	67.7 campylobacteriosis cases per 100,000 population	[23]
2013	Denmark	67.3 campylobacteriosis cases per 100,000 population	[23]
2013	Estonia	28.9 campylobacteriosis cases per 100,000 population	[23]
2013	Finland	74.9 campylobacteriosis cases per 100,000 population	[23]
2013	Germany	77.3 campylobacteriosis cases per 100,000 population	[23]
2013	Iceland	31.4 campylobacteriosis cases per 100,000 population	[23]
2013	Lithuania	38.3 campylobacteriosis cases per 100,000 population	[23]
2013	Norway	65.2 campylobacteriosis cases per 100,000 population	[23]
2013	Slovenia	49.9 campylobacteriosis cases per 100,000 population	[23]
2013	Sweden	84.9 campylobacteriosis cases per 100,000 population	[23]
2013	United Kingdom	104 campylobacteriosis cases per 100,000 population	[23]
		Asia	
2005-2006	Miyagi Prefecture of Japan	1,512 per 100,000 population per year were estimated for the numbers of acute gastroenteritis episodes associated with *Campylobacter*	[24]
2007 and 2009	Nahariya, Israel	61% of 99 hospitalized children with gastroenteritis were positive for *Campylobacter* species	[25]
Jan 2008-Dec 2010	India	7.0% of 3,186 hospitalized patients with gastroenteritis were culture positive for *Campylobacter* species (70% of positive culture were identified as *C. jejuni*	[26]
2010	Israel	90.99 campylobacteriosis cases per 100,000 population	[27]
		North America	
2006	United State	1.3 million campylobacteriosis cases in 2006 or 4.4 cases per 1,000 persons	[14]

2006-2007	Maxico	15.7% of 5,459 cases of acute gastroenteritis in infants and preschoolers were cause by *Campylobacter*	[28]
2006-2012	Canada	30.6, 29.1, 28.5, 25.9, 26.5, 27.6 and 29.3 campylobacteriosis cases per 100,000 population in 2006, 2007, 2008, 2009, 2010, 2011, 2012, respectively	[29]
South America			
Nov 2010-Mar 2012	Peru	41.3% of 150 children with gastroenteritis were detected *C. jejuni/C. coli* and including *C. hyointestinalis* subsp. *lawsonii*, *C. troglodytis*, and *C. upsaliensis*, in children with gastroenteritis in 33%	[30]
2013	southern Chile	11.4% and 10.7% of 140 fecal sample of gastroenteritis patients were tested positive for *C. concisus* DNA and *C. jejuni* DNA, respectively	[31]
Oceania			
2007 and 2009	New Zealand	46.9% of gastroenteritis patients were tested positive for *C. concisus,* and other species; *C. ureolyticus* (10.9%), *C. hominis* (8.6%), and *C. gracilis* (14.1%)	[32]
2008	New Zealand	161.5 campylobacteriosis cases per 100,000 population	[33]
2010	Australia	112.3 campylobacteriosis cases per 100,000 cases of notified foodborne infection	[34-36]
2013	New Zealand	152.9 campylobacteriosis cases per 100,000 population	[37]

analysis [46]. Since, this review by Chapman *et al*. [46] is new, the content of their paper is not reviewed in this manuscript.

This review manuscript is an effort to present information that can be used to improve food safety and reduce the number of cases of campylobacteriosis. Risk analysis, which includes risk assessment, risk management, and risk communication, has been applied to reduce the number of cases of campylobacteriosis. The focus of this review will be on activities after process chilling that reduce risk, including 1) methods to reduce the number of viable *Campylobacter* associated with poultry products after chilling, 2) methods to reduce risk in food markets, 3) methods to reduce cross contamination by consumers and food service workers, and 4) public food safety risk reduction education.

There are several important processes that may result in ingestion of *Campylobacter*: 1) consumption of raw poultry products, 2) consumption of under cooked poultry products, and 3) cross contamination of food that results in ingestion of *Campylobacter*. In addition, person-to-person transmission, contact with animals, overseas travel, and contact with contaminated environment or recreational activities in nature may also result in ingestion of *Campylobacter* [47]. Processes or opportunities that may result in ingestion of *Campylobacter* are shown in Figure **1**.

Under cooking can result in serving foods that contain viable *Campylobacter*. Cross contamination can result in *Campylobacter* in ready-to-eat foods.

There is significant evidence that cross contamination occurs in areas where raw poultry is prepared for cooking in home kitchens and food service establishments [48-53].

The development and applications of modern principles for the conduct of microbiological risk assessment research has been beneficial during the last 20 years [47, 54, 55]. The results of several studies have been reported; however, the quality and extent of available data must be considered in a review of the conclusions that are presented [55, 56]. For the present review, the application of these risk assessment principles leads to the conclusions that risk can be reduced by 1) Reducing the number of *Campylobacter* in the marketed products, 2) Cooking these poultry products so that there are no viable *Campylobacter* in the prepared food, and 3) Reducing cross contamination as much as possible

METHODS TO REDUCE *CAMPYLOBACTER* POPULATIONS

The number of *Campylobacter* per chicken in the market is an important factor in campylobacteriosis risk management. In the review by Keener *et al*. [57], values of 1,000 to 1,000,000 CFU per chicken are reported. In several studies cited, more than 90% of samples of chickens in food markets test positive for *Campylobacter*. This contrasts with new data; in Scotland, 50% of samples tested positive for *Campylobacter*, which was down from 71% in the time period from December 2014 to February 2015 [58]. Recent data in the U.S. shows that most processors are meeting the new USDA performance requirements

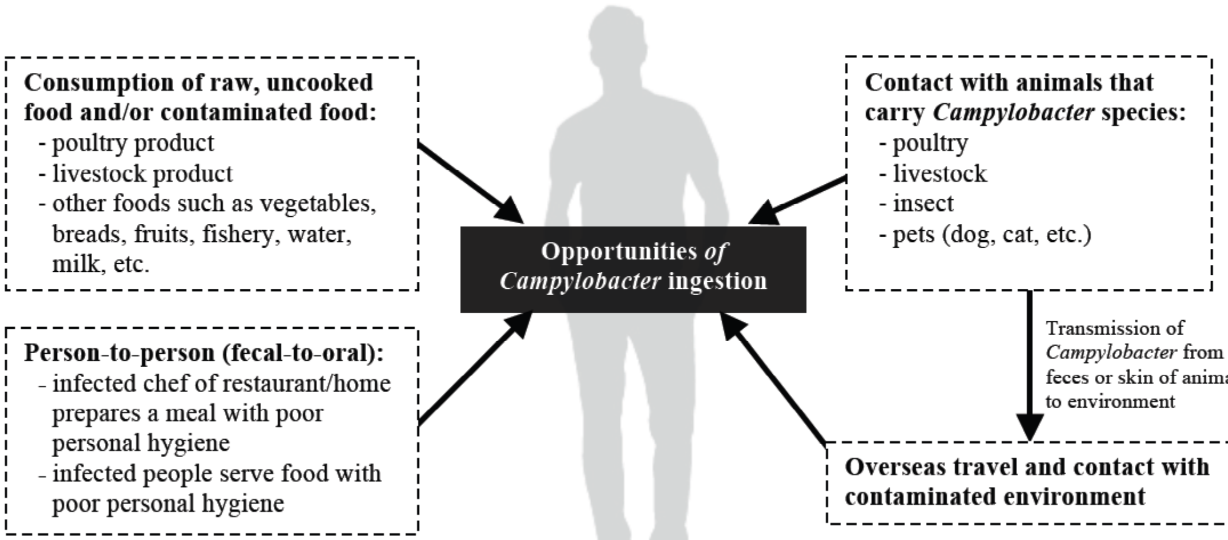

Figure 1: Human opportunities to ingest *Campylobacter.*

to market more than 80% of their chickens without measurable numbers of *Campylobacter* [59, 60].

Post-Chill Chemical Inactivation Processes

One of the methods to reduce the number of *Campylobacter* on chicken carcasses after chilling is to immerse the carcass in a chemical solution such as sodium hypochlorite or peracetic acid. Because the carcasses are clean and free of fecal material, blood, and other contaminating solids, immersion for a short time can be very effective [61]. Wideman [62] reported that peracetic acid was the most effective chemical in immersion post-chill industrial applications. When immersion and spray application methods were compared, immersion was superior [2]. In this same study, peracetic acid was found to be superior to sodium hypochlorite with immersion for 60 s in 200 ppm of peracetic acid solution [2]. Nagel *et al*. [63] reported that immersion in either 400 ppm or 1,000 ppm of peracetic acid for 20 s was more effective compared to 40 ppm total chlorine or 5,000 ppm lysozyme. Acidified sodium chlorite has also been shown to be effective in 15 s post-chill immersion applications with 500-1,200 ppm sodium chlorite at pH 2.3 to 2.9 [64]. In the study of Chen *et al*. [65], peracetic acid at 700 and 1,000 ppm was found to be superior to 3,500 or 6,000 ppm cetylpyridinium chloride (CPC). Risk of campylobacteriosis is reduced signify-cantly by application of these post-chill technologies.

Sensory analysis studies have been conducted with chickens subjected to post-chill immersion in 1,000 ppm peracetic acid and other post-chill chemicals, and no deleterious impacts on sensory quality were reported [63]. Peracetic acid is being used as one of the effective post-chill immersion applications to reduce risk [62].

Consumers should be informed of the chemicals that are used to inactivate the *Campylobacter* by adding this information to the product label.

Freezing

Research has shown that *Campylobacter* are inactivated by freezing [66-69]. Freezing reduces the number of viable *Campylobacter*, but it does not result in a sterile product free of viable *Campylobacter*. In Denmark studies in Danish slaughter operations showed a reduction of 1.38 log CFU/g on average due to freezing the chickens [71]. In the research in Iceland, there was a reduction from 116 cases of campylobacteriosis per 100,000 people to 33 per 100,000 when there was a voluntary effort by the Iceland poultry industry to freeze the chickens and market them in the frozen state [67]. This reduction of risk is related to the reduction in the number of viable *Campylobacter* and the greater safety associated with frozen chicken because there are no fluids with *Campylobacter* to cause contamination. Viable *Campylobacter* numbers decrease during refrigerated storage also; refrigerated storage followed by freezing and frozen storage resulted in the largest reduction of viable *Campylobacter* [66]. Ritz *et al*. [72] report that *Campylobacter* that are on skin are impacted more by freezing than those that are associated with muscle.

Harrison *et al*. [73] have reported that chicken livers with *Campylobacter* can be frozen to reduce viable numbers significantly and that freezing, thawing, and freezing a second time reduces viable numbers further. Before freezing there were about 6,300 CFU/g; after the first freezing, about 32 CFU/g, and about 6 CFU/g after the second freezes. The process of freezing in which water becomes a solid appears to be lethal for some of the organisms.

Lindqvist and Lindblad [55] have reported quantitative risk assessment results that include estimated risk reduction associated with freezing chickens. Their analysis of risk shows that the estimated number of cases of campylobacteriosis would be 43% of the baseline number if all chicken flocks testing positive for *Campylobacter* were frozen and marketed in the frozen state. The authors report that the risk per 20,000 mishandlings of chicken was 5.4 times greater for fresh compared to frozen chicken [55].

It is clear that risk can be reduced by decreasing the number of viable *Campylobacter* that are present on poultry carcasses [55, 74]. Quantitative microbiological risk assessment can be used to estimate the public health impact of new food safety regulations [75].

Regulatory Processes

One way to reduce risk of campylobacteriosis is through regulations that are intended to reduce *Campylobacter* numbers in marketed products. The USDA changed the regulations related to *Campylobacter* in marketed chickens in February, 2016 [60]. The maximum acceptable percent positive is now 15.7% for chicken broiler carcasses, 5.4% for turkey carcasses, 7.7% for chicken parts, and 1.9% for comminuted chicken and comminuted turkey [60]. Recent performance data show that most of the U.S. industrial companies that are processing chickens and turkeys are meeting the new regulations [59].

The new regulations in the U.S. are in response to the application of a science-based, data-driven, risk-based approach to address *Campylobacter* infections associated with chickens that are marketed [76]. Poultry slaughter plants have the responsibility to implement risk-based pathogen reduction programs that meet the new regulations. The Food and Agriculture Organization of the United Nations and the World Health Organization have helped to develop a risk assessment framework and risk assessment model for *Campylobacter* spp. in broiler chickens [47]. The Food Safety and Inspection Service (FSIS) of the USDA have developed a guidance publication for poultry slaughter establishments to help them comply with regulatory requirements [74].

The European Food Safety Agency (EFSA) and agencies in European countries such as the Food Standards Agency in the United Kingdom are working cooperatively to attempt to reduce risk associated with *Campylobacter*. In Europe campylobacteriosis is a major problem with estimates of 9 million human cases per year and total annual costs of 2.4 billion Euros [5]. Recent data show that there is a reduction in the number of carcasses with detected *Campylobacter* on them and the number of viable *Campylobacter* per gram in the United Kingdom [77]. The survey data included the percentage of skin samples positive for *Campylobacter*, the percentage of skin samples with measured values of more than 1,000 viable *Campylobacter* per gram, and the percentage of outer packaging samples positive for *Campylobacter.* In the most recent 3 months, 9.3% of the samples tested positive for the 1,000 viable cells per gram compared to 21.8% a year earlier, and 50% of the samples tested positive for *Campylobacter* compared to 71% a year earlier. About 6% of the samples tested positive for *Campylobacter* on the outer surface of the package [77]. The progress shows that the campaign "Acting on *Campylobacter* Together" has had positive outcomes.

The EFSA Panel on Biological Hazards identifies a number of options to reduce risk of campylobacteriosis in their report. Irradiation to inactivate all *Campylobacter* is one of the options; freezing to reduce the number of viable *Campylobacter* is another option [5]. Risk reduction is estimated to be 100% with irradiation and 50-90% by freezing.

The EU has an integrated approach to food safety that includes both risk assessment and risk management. The EFSA provides scientific support and advice with timely and effective risk communication. In Denmark, a voluntary strategy to reduce *Campylobacter* in broilers has resulted in a decrease from 18% in 2004 to 8% in 2007 in the percent of broilers testing positive for *Campylobacter* [78]. Rosnequist *et al*. [78] also reported that the number of registered cases of campylobacteriosis decreased 12% from 2002 to 2007.

Campylobacteriosis is a significant problem in Australia and New Zealand. In Australia there were about 7,400 cases per million people annually in 2,000 and 8,400 cases per million people in 2010 [79]. A new food safety standard for *Campylobacter* went into effect May 20, 2012 [80]. The standard is to reduce contamination of poultry carcasses and poultry meats by *Campylobacter* by having the processors implement food safety management control measures and provide evidence of their implementation. An integrated model that includes risk management assessment has been introduced by the Food Regulation Implementation Sub-Committee. The Food Standards Australia New Zealand is responsible for the implementation of the new standard which is based on risk based science [81].

New Zealand has made progress with respect to *Campylobacter* through a regulatory program with limits on the measured populations of *Campylobacter* on broiler carcasses [82]. The number of carcasses with no detected *Campylobacter* has increased from about 50% in 2007/2008 to about 66% in 2013/2014. Paulin [83] and Duncan [84] report a 58% reduction in campylobacteriosis because of industry actions to meet the new compliance standards applied in 2007 and 2008. Duncan's cost benefit analysis reports a gain of at least $57.4 million annually because of the efforts to reduce *Campylobacter* numbers [84].

METHODS TO IMPROVE DISTRIBUTION AND SALES PROCESSES

Risk reduction is important in distribution and sales processes during which poultry products move from the slaughtering plant to food distributors and food markets and from there to homes or food service establishments. If the products are in the frozen state, risk is reduced because there are no liquids to manage and the number of viable *Campylobacter* is less. Keener *et al*. [57] has reported that cleaning surfaces with hot water and detergent and drying the surface is sufficient to remove *Campylobacter* from the surface. In the meat department of food markets where both raw and prepared food products are present, cross contamination must be considered and reduced to a minimum. Cutting boards and other surfaces must be cleaned after working with each different product [85]. Risk can be reduced also by using a different cutting board for fresh poultry that may have *Campylobacter* contamination. Machines and equipment used for cutting and packaging may also become contaminated and need to be cleaned. Hand washing and drying is important in working with poultry because cross contamination can be due to handling raw poultry or raw poultry packages and then handling other foods [55, 70, 86].

One of the important cross-contamination possibilities is for cross-contamination in moving products to and from food markets. Customers may not realize that cross contamination may occur in moving the food from the food market to the home because of *Campylobacter* on the surface of a package of chicken or fluids from the poultry package leaking onto other foods. It is good to keep raw poultry separate in the shopping cart and place it in a separate bag for transport home.

The program in the United Kingdom "Acting on *Campylobacter* Together" has included some public education on proper handling, cooking, and package disposal by adding clear information to packages of poultry [77]. This has included providing consumers with methods to cook, cooking time and cooking temperature, safe internal temperature, and adjustments needed for stuffing of whole poultry. Information on cooking temperature and time on packages has been very helpful for roasting turkeys. Public education on proper use of food thermometers to measure internal temperature has been helpful. Since there are both ready to eat products that have been cooked and raw poultry, clear labeling so the consumer knows which products need to be cooked is important. Words such as "uncooked" or "must be cooked for safety" are helpful for consumers. Cooking information to help the consumer who begins with a frozen product is important, also. Cross contamination can be reduced by including written food safety information that is delivered with the purchased poultry products [74, 77].

METHODS TO IMPROVE FOOD PREPARATION PRACTICES

One of the ways to reduce risk is to improve food preparation practices where food is prepared and served in homes and food service establishments [87]. Bearth *et al*. [48, 49] have reported on the need for public education of consumers who work with food preparation. Luber [51] reports that education to prevent cross contamination is important and that risk can be reduced through education and behavior change. Risk information can be distributed with packaged poultry products informing purchasers of the potential for *Campylobacter* to be present, and that food safety practices should be followed.

Food safety risk communication is needed because microbial pathogen hazards are not visible, and youngsters who come to work in food service need to be educated about food safety. The principles of food safety risk communication include openness, transparency, timeliness, and responsiveness [88]. Risk communication should take place in an open environment with opportunity for questions and dialog with presenters who understand the risks and have the ability to communicate effectively. There should be transparency with respect to policies, practices, and procedures. It is important to educate new employees before they begin to work. There is a need to respond to questions and openly discuss concerns that are identified. It is good to have written guidance that can be reviewed by those who wish to make sure they know proper procedures [88, 89].

Public Education About *Campylobacter* Risk

Public education about *Campylobacter* risk has the potential to significantly reduce risk associated with campylobacteriosis. The reduction of numbers of *Campylobacter* on chickens in the market reduces risk. Public education should include cooking of poultry to at least 75℃ and has no longer pink in the middle because the elimination of consumption of under cooked meats reduces risk. Health Canada [90] recommends a temperature of 85℃ for whole poultry because the thermometer may not be in the coolest location. The internal temperature can be measured at several locations to make sure the internal temperature is at or above 75℃ at all locations.

Public education on safe handling of poultry products includes 1) Wash hands, cutting boards, cutlery, utensils, and counter tops after handling raw poultry, 2) Freeze fresh chicken as soon as possible to reduce viable *Campylobacter* numbers and to preserve product quality; it is good to package the chicken so that the entire package will be used when it is removed from the freezer, 3) Raw chicken should be securely packaged so its juices are contained, 4) Frozen poultry can be defrosted in the bottom of the refrigerator, in a microwave oven, or during cooking in a slow cooker (cross contamination can happen during defrosting by juices leaking out of the package), 5) Use a different cutting board, plate, and utensils for raw chicken that may contain *Campylobacter*, 6) Cook refrigerated poultry within 2 to 3 days, 7) Store raw poultry in a package or container in the bottom of the refrigerator so juices from the package do not contaminate other foods, 8) Clean surfaces where chicken has been stored in the refrigerator, 9) Do not wash raw poultry, 10) Do not touch prepared foods (use sterile gloves) [40, 90-93].

Public Health Safety in Food Service Establishments

Food safety is very important in food service establishments, including restaurants, school food lunch programs, food catering, and other places. Risk reduction in food service should include implementation of Hazard Analysis and Critical Control Point (HACCP) principles [94, 95]. Risk is to be reduced through active managerial control of food safety, including implementation of procedures that reduce risk [95]. In New Zealand a new Food Act 2014 is being implemented to address food safety in the food service industry [96].

Brown *et al*. [97] have reported that 61% of foodborne illness outbreaks were associated with restaurants or delicatessens. The survey results of Brown *et al*. show that poor food safety knowledge of some who work in food service contributes to Campylobacteriosis outbreaks. Webb and Monancie [98] have found that many food service workers at a university campus also had poor food safety knowledge. There is good general knowledge in printed publications about food safety for those who work in food service [39, 93-95, 99]; however, there is a need to implement training programs and have better practices in many food service establishments.

Recommended Food Preparation and Food Service Practices

There are several sources of recommended food preparation practices [93-95, 99]. The ten rules for handling food safely include 1) All employees must follow strict personal hygiene policies, 2) Establish safe handling procedures for all hazardous foods, 3) Obtain food from approved suppliers, 4) Time/temperature abuse must be avoided when handling prepared foods, 5) Potentially hazardous raw foods must be kept separate from ready-to-eat foods, 6) Cross contamination must be avoided; establish guidelines and practices for hand washing; wash, rinse, and sanitize all food contact surfaces, 7) Foods must be cooked to recommended internal temperatures, 8) Hot foods should be kept at 57℃ or greater and cold foods should be kept at 5℃ or less, 9) Foods that are to be cooled should be cooled rapidly in 2 hours or less to 21℃ and then to 5℃ in 4 hours or less, 10) Leftover foods must be heated to 75℃, and they should only be reheated once [99].

The application of the 7 HACCP principles for food safety management of *Campylobacter* in poultry in food service establishments has the potential to reduce risk [94]. The following is included to illustrate the process of applying HACCP in a food service operation. 1) Perform a Hazard Analysis. The hazards are under cooking the chicken and cross contamination. 2) Decide on the Critical Control Points. The temperature needs to reach 75℃ in all parts of the chicken when it is cooked. Cross contamination needs to be eliminated during the preparation process through proper food safety management. 3) Determine the Critical Limits. The temperature of 75℃ should be maintained for at least one minute. The preparation surface for raw chicken and sink for washing and sanitizing the utensils should be separate from the location where fresh fruits and vegetable are washed and prepared. After using a surface for raw chicken it should be washed with detergent, rinsed, sanitized, and dried. Utensils should be washed with detergent, rinsed, sanitized, and dried. The person who prepared the chicken should wash his hands with soap, rinse, dry, and sanitize them. Package materials and any trimmings should be disposed of properly also. 4) Establish Procedures to Monitor Critical Control Points. The temperature during cooking can be monitored using a meat thermometer. The food preparation process, cleaning the surfaces, washing the utensils, and hand washing can be monitored with video cameras that allow the manager to review the activities of the food service worker. The video cameras can be motion activated. 5) Establish Corrective Action. If the manager observes the need for corrective action, the employee can be shown the proper method. 6) Establish Verification Procedures. A microbiologist can take samples before and after the food preparation surface is cleaned and the utensils are washed to verify that *Campylobacter* numbers are inactivated by cleaning and washing. The samples can be incubated using methods to detect *Campylobacter* [1]. 7) Establish a Record Keeping System. Records can be kept of the final cooking temperature and the cooking time for each product. Records can be kept of any observed departures from the recommended cleaning and washing procedures.

There are general principles of food hygiene that are important at all food preparation locations [39, 40, 77, 90, 93-95, 99, 100]. In some parts of the world, there are food preparation environments that present food safety challenges. Where raw poultry preparation and ready-to-eat foods are both prepared in the same location, the ready-to-eat foods can be prepared first and be properly stored until eaten. Where transit times are large, an insulated container can be used to keep cold items cold. Flies and other insects can transfer *Campylobacter* from raw chicken to ready-to-eat foods; this can be prevented by keeping products covered and by eliminating insects in the area. *Campylobacter* can move with air flow associated with fans [61]. It is important to keep garbage containers covered and away from food preparation areas.

DISCUSION AND CONCLUSION

Risk of campylobacteriosis is reduced by inactivation of viable *Campylobacter* prior to marketing products, by proper cooking, and by elimination of cross contamination. The process information that is available is sufficient to produce poultry products with small non-detectable numbers of *Campylobacter*, and this is being accomplished in some poultry slaughtering operations. Freezing poultry products and marketing them in frozen form reduces the number of viable *Campylobacter* and number of cases of campylobacteriosis.

Proper cooking of poultry to kill all of the *Campylobacter* prior to serving delicious products is easily accomplished. A final product temperature of at least 75℃ in the coolest region is recommended in many publications.

Cross contamination is an important problem and it has resulted in a significant number of cases of campylobacteriosis. Eliminating cross contamination is difficult because it depends on appropriate food safety education and actions of many individuals who work with raw poultry in home kitchens and food service establishments. HACCP principles can be used to develop improved procedures in food service establishments that reduce risk of campylobacteriosis. Freezing chickens reduces risk of cross contamination, and increase safe storage time. Educational efforts can inform and enlighten those who prepare poultry for cooking. The risk associated with cross contamination can be reduced by using better methods of food preparation and by reducing the number of *Campylobacter* in the raw poultry.

There is economic value associated with risk reduction based on an analysis of costs and benefits associated with campylobacteriosis. Food safety education and good personal hygiene practices to reduce risk have economic and social value.

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