US Open Agriculture & Food Technology Journal
Vol. 1, No. 1, March 2014, pp. 1 - 5
Available online at http://arepub.com/Journals.php

Short Communication

Microbial Contamination in Poultry Chillers Estimated by Monte Carlo Simulations

Ronald A. Holser

Russell Research Center, USDA-ARS, 950 College Station Rd., Athens, Georgia 30605 USA

+1 706-546-3520

E-mail: Ronald.Holser@ars.usda.gov

Abstract

The risk of microbial contamination during poultry processing may be reduced by the operating characteristics of the chiller. The performance of air chillers and immersion chillers were compared in terms of pre-chill and post-chill contamination using Monte Carlo simulations. Three parameters were used to model the cross-contamination that occurs during chiller operation. Results were calculated for 30%, 50%, and 80% levels of contamination in pre-chill carcasses. Air chilling showed increased risk of contamination in post-chill carcasses. Immersion chilling with 50 mg/L chlorine or 5% trisodium phosphate added to the chiller water as antimicrobial treatments reduced contamination to negligible levels in post-chill carcasses. Simulations of combination air/immersion chiller systems showed reductions of microbial contamination but not to the extent of immersion chillers attributed to the reduced exposure time to antimicrobial treatments.

Keywords: contamination, poultry, probability, processing, risk

Introduction

Recent bacterial outbreaks in fresh and processed foods have increased awareness of food safety among consumers, regulatory agencies, and the food industry. The risk of contamination exists in meat processing facilities where bacteria that are normally associated with the animal are transferred to the product. If the product is not stored, handled, or cooked properly the results range from mild food poisoning to potential life threatening health conditions [3]. In the United States the Center for Disease Control collects data on the incidence of food poisoning and estimates nearly 50 million cases occur annually [2]. The United States government has responsibility for food safety and implements regulatory standards through food inspection programs [4]. The purpose of these regulations is to protect the consumer by establishing limits on bacteria that are responsible for food spoilage and illness.

Salmonella and Campylobacter are two common human pathogens prevalent in poultry with Salmonella posing the greater risk of illness. One strategy to manage risk during production is the practice of Hazard Analysis and Critical Control Points (HACCP). This approach has gained acceptance by the United States Food and Drug Administration (US FDA) and includes identification and control of hazards from raw materials through production and delivery of the finished product. In keeping with the principles of HACCP a key processing step to control bacterial growth occurs at the chiller. Common practice is to reduce the temperature of the bird carcass to near freezing by direct immersion in a tank of chilled water. In large production facilities the chiller tanks are designed to move the carcasses continuously through the chill water with sufficient residence time to achieve a target temperature of less than 5^{0}C [7]. Bacterial growth is reduced at these temperatures and the addition of antibacterial agents can further reduce bacterial populations as noted by Blank et al. [1]. Immersion chilling provides rapid heat transfer and is widely used among poultry processors.

Alternative methods such as air chilling were promoted to reduce the possibility for contamination between carcasses that can occur in immersion chilling. However, studies such as those conducted by James et al. [5] indicate that air chilling may not be as effective in reducing bacteria compared to immersion chilling when antimicrobial treatments are added to the chiller water. Other chilling systems have been developed that incorporate characteristics of both air immersion and water immersion chillers, e. g., the Combi In-Line Air Chilling System (TopKip BV, Enschede, Netherlands). This system offers microbiological control and reduced water consumption, energy cost, and process time. The current investigation examined the performance of these poultry chilling systems and evaluated the probability of contamination in post-chill carcasses. The application of Monte Carlo techniques described by van der Voet & Slob [10] and Williams et al. [11] is gaining acceptance for risk analysis calculations in food safety and quality.

Materials and Method

Monte Carlo simulations were used to estimate the likelihood of contamination in a facility processing 10,000 birds/day. Models were prepared and analyzed with @Risk version 6 (Palisade Corp., Ithaca, New York, USA). One model parameter estimated the probability of contact between birds, a second parameter estimated the probability of contamination, and a third parameter estimated the impact of antimicrobial treatments [6] Model parameters were selected based on published reports of bacteria on pre-chill and post-chill carcasses. The influence of parameter values on the model results was evaluated by sensitivity analysis. Summary statistics were based on calculations after 1000 iterations.

Results and Discussion

Contamination in the chiller can occur by contact of non-contaminated carcasses with contaminated carcasses, suspended microbes, or microbial biofilms that adhere to process equipment surfaces. The basic model used one

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parameter to estimate the likelihood of contact and a second parameter to estimate the likelihood of contamination resulting from that contact [7]. A third parameter was included to represent the influence of antimicrobial treatments to reduce bacterial populations. This parameter was used for immersion chilling and combination air/immersion simulations but not for air chilling simulations where the opportunity to introduce antibacterial agents is limited. Table 1 shows the results for air chilling simulations for a range of pre-chill contamination levels, e. g., 30%, 50%, and 80%. There is no reduction in bacterial populations although the growth is reduced compared to higher temperature conditions. The carcasses would need to enter the chiller sterile or have some antimicrobial intervention to reduce the contaminant level to near zero in the post-chill carcasses. Currently, neither of these are technically or economically practical approaches.

Table 1: Post-chill contamination from air chilling without antimicrobial treatment.

Pre-chill	Post-chill		
% contaminated	Mean	Min	Max
30	53.7370	51.9400	55.2900
50	73.0668	71.8500	74.3700
80	91.5721	90.6100	92.3200

Results for immersion chilling simulations are presented in Table 2. The use of chlorine in the chiller water provides a very effective antimicrobial treatment at 50 mg/L. The reduction in microbial activity is significant even at the highest contamination levels in the pre-chill carcasses. Chlorine treatment of chiller water was demonstrated in the 1950’s and is generally accepted practice.

Table 2: Post-chill contamination from immersion chilling with 50 mg/L chlorine.

Pre-chill	Post-chill		
% contaminated	Mean	Min	Max
30	1.69e-5	0	0.05
50	2.37e-5	0	0.03
80	2.6e-5	0	0.03

Results for combination air/immersion chilling simulations are presented in Table 3 where some reduction in microbial activity is observed. Again chlorine was used at 50 mg/L but the contact time with the treated water is less than in the immersion chiller so the treatment is not as effective.

Table 3: Post-chill contamination from air/immersion chilling with 50 mg/L chlorine.

Pre-chill	Post-chill		
% contaminated	Mean	Min	Max
30	7.5775	6.4800	8.7100
50	10.2447	9.1400	11.4200
80	12.4710	11.5600	13.3700

The risk of microbial contamination of the post-chill carcasses increases from immersion chilling to air chilling with the combination system exhibiting intermediate values. The differences between these systems are primarily due to the impact of antimicrobial treatments that can be applied in the process water. The effectiveness of treatment varies with several factors including the amount of antimicrobial agent added, the exposure time, the particular bacteria species and whether the microbe is suspended (planktonic) or attached (biofilms) as described by Somers et al. [9]

and Parveen et al. [8]. For example, 5% trisodium phosphate (TSP) was shown to be effective against *Escherichia coli*, *Campylobacter jejuni*, and *Salmonella typhimurium* while *Listeria monocytogenes* exhibited resistance. The model can account for this variability when detailed information for each microbial population is available. Results of simulations performed with parameters obtained from dose-response and survival data reported by Somers et al. [9] and Yang et al. [12] appear in Table 4 and Table 5 for treatment with TSP and chloride, respectively.

Table 4: Post-chill contamination from immersion chilling with 5% trisodium phosphate.

Pre-chill		Post-chill		
% contaminated	**Bacteria**	**Mean**	**Min**	**Max**
30	***Salmonella typhimurium***	**1.73e-5**	**0**	**0.03**
50	***Salmonella typhimurium***	**2.32e-5**	**0**	**0.04**
30	***Campylobacter jejuni***	**1.96e-5**	**0**	**0.03**
50	***Campylobacter jejuni***	**2.15e-5**	**0**	**0.03**

Treatment with 5% trisodium phosphate is similarly effective for Salmonella and Campylobacter at the 30% and 50% pre-chill levels of contamination. The chlorine treatment is also effective but with greater sensitivity shown by Campylobacter than Salmonella.

Table 5: Post-chill contamination from immersion chilling with 50 mg/L chlorine treatment.

Pre-chill		Post-chill		
% contaminated	**Bacteria**	**Mean**	**Min**	**Max**
30	***Salmonella typhimurium***	**6.64e-5**	**0**	**0.05**
50	***Salmonella typhimurium***	**9.04e-5**	**0**	**0.06**
30	***Campylobacter jejuni***	**1.64e-5**	**0**	**0.04**
50	***Campylobacter jejuni***	**2.45e-5**	**0**	**0.03**

These results show that the risk of cross contamination during immersion chilling can be more effectively reduced by antimicrobial treatments compared to air chilling. The antimicrobial treatments can also be exploited in the combination chiller systems provided adequate contact time is maintained with the treated process water. Immersion chilling allows more rapid heat transfer than air chilling due to the larger heat capacity of water versus air. In addition to the reduction in microbial activity achieved in the chiller the chilling rate is an important operating characteristic that can influence product quality, e. g., tenderness and color.

Conclusion

The normal operation of poultry chillers presents a significant risk of microbial contamination in the fresh product. Different chiller designs offer the ability to effectively reduce microbe growth with antimicrobial treatments. The water used in immersion chillers can be treated with chlorine, for example, to reduce the risk of contamination to near zero. The application of risk-based models with Monte Carlo simulations provides a useful approach to compare the performance of chillers. The method can also be extended to estimate the microbial contamination in the waste water produced by the chillers.

Acknowledgement

The author is grateful for the assistance of B. Tobias in conducting this investigation.

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