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POULTRY FOOD SAFETY CONTROL INTERVENTIONS IN THE DOMESTIC KITCHEN

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ABSTRACT

Research was undertaken to investigate cross-contamination of the domestic kitchen environment during poultry fillet preparation using a streptomycin-resistant strain of *Pseudomonas fluorescens* as a model organism. The potential role of a cook-in-the-bag technology to control this cross-contamination was also investigated. Poultry fillets were inoculated with *P. fluorescens* (6.06 $\log_{10}$ CFU/cm^2). Six people were challenged to unpack, defrost, cut and cook without contaminating the preparation environment. After preparation, the chopping board, knife blade, dishcloth, refrigerator handle, oven handle, oven buttons, draining board, tap, microwave handle, microwave buttons, plate, tinfoil and press handle were tested for the presence of the *P. fluorescens* strain, before and after washing. The experiment was then repeated with a precut cook-in-the-bag product. In a separate experiment, the effect of freezing and frozen storage (−20C) on *Campylobacter* and the sensory attributes of chicken fillets were investigated. The cook-in-the-bag approach considerably reduced the incidence and levels of cross-contamination in the domestic kitchen. Freezing significantly ($P < 0.05$) reduced the *Campylobacter* counts on inoculated fillets after 7 days at −20C (1.73 $\log_{10}$ CFU/g). While there was no adverse effect on taste, fillets that had been frozen were significantly more "firm" and "less moist" as compared with fresh product.

PRACTICAL APPLICATIONS

It was concluded that using cook-in-the-pack technologies would reduced cross-contamination of the domestic kitchen during poultry preparation and *Campylobacter* could be specifically targeted using freezing/frozen storage.

INTRODUCTION

Poultry are an important source of human pathogens and a significant proportion of poultry-associated illnesses is attributed to poor hygiene practices in the domestic kitchen (Beumer and Kusumaningrum 2003; de Jong *et al.* 2008; van Asselt *et al.* 2008). During the preparation of poultry-based meals, poultry-borne bacteria are transferred from the raw meat to other foods, including ready-to-eat products, via hands, equipment and the kitchen environment (Luber *et al.* 2006; van Asselt *et al.* 2008; Verhoeff-Bakkenes *et al.* 2008; Tang *et al.* 2011). This may reflect a lack of basic safe food preparation knowledge on the part of consumers (Kennedy *et al.* 2005) compounded by a belief that food safety is someone else's responsibility (Redmond and Griffith 2003).

The main human pathogen associated with poultry is *Campylobacter*, especially *Campylobacter jejuni*, (Kozačinski *et al.* 2006; Sampers *et al.* 2010). The symptoms of *Campylobacter* infection range from a mild, self-limiting diarrhea to severe complications including Guillain Barre syndrome, a nervous system disorder characterized by acute neuromuscular paralysis. There are estimated to be 9.2 million cases of campylobacteriosis in the EU27 per annum (European Food Safety Authority [EFSA] 2011) and the incidence of confirmed campylobacteriosis in the Republic

of Ireland has risen steadily from 1885 confirmed cases in 2007 to 2433 in 2011 (Health Protection Surveillance Centre [HPSC] 2013). In addition to morbidity and mortality, there are considerable economic costs associated with campylobacteriosis (Snelling *et al.* 2005).

To date, *Campylobacter* control interventions have been focused mainly on broiler farm biosecurity. However, it is impossible to achieve complete biosecurity all of the time, and many flocks are contaminated by the time the birds are 3 or 4 weeks old (Patriarchi *et al.* 2009). *Campylobacter* are carried into the processing plant in the ceca and cloaca at counts of up to 10^7/g (Berrang and Dickens 2000). Cross-contamination with feces during processing is unavoidable and most carcasses are *Campylobacter* positive when leaving the slaughter plant (EFSA 2010). In the absence of on-farm and processing controls, future control initiatives should therefore focus on the food preparation environment.

Control technologies that are simple to use and require no additional work or cost on the part of the consumer are therefore needed. Cook-in-the-bag and freezing are two such technologies that may reduce and/or prevent bacterial, including *Campylobacter*, cross-contamination (El-Shibiny *et al.* 2009; Habib *et al.* 2010). The effectiveness of the former has not yet been demonstrated. Although it has been established that *Campylobacter* numbers reduce during freezing (Georgsson *et al.* 2006; Sampers *et al.* 2010; Eideh and Al-Qadiri 2011), inoculation studies with poultry *Campylobacter* isolates have not been undertaken and the effect of domestic freezing/frozen storage on the sensory characteristic of the product has not yet been reported. The objectives of this study were to investigate the cross-contamination of the domestic kitchen environment during poultry preparation and to examine the effectiveness of cook-in-the-bag technology and freezing as domestic *Campylobacter* control technologies.

MATERIALS AND METHODS

Pseudomonas fluorescens Inoculum Preparation

P. fluorescens (DSMZ 50090) was obtained from Deutsche Sammlung von Mikroorganismen und Zellkulturen (Leibniz Institute DSMZ). To facilitate recovery, strains with resistant to 1000 μg/mL streptomycin sulfate (Sigma, Dorset, U.K.) were developed using the selection procedures described by Blackburn and Davies (1994) and stored on protect beads (Technical Service Consultant, Heywood, Lancashire, U.K.) at –20C. When required, one bead was aseptically transferred to 50 mL nutrient broth (Oxoid, Basingstoke, Hampshire, U.K.) and incubated aerobically at 30C for 48 h. Inocula were prepared from stationary phase cells, recovered by centrifugation (2,655 × g) for 5 min at 4C (centrifuge 5403; Eppendorf, Hamburg, Germany), washed three times in maximum recovery diluent (MRD; Oxoid) and resuspended in 500 mL MRD.

Pretrial Testing

Prior to each trial, the chicken fillets were tested for the presence of *P. fluorescens* by swabbing an area of 20 cm^2, with a 10 × 10-cm sterile cellulose acetate sponge pre-moistened with 10 mL of MRD. Approximately 90 mL of MRD was then added to each sponge in a stomacher bag and pulsifed (Pulsifier, Microgen Bioproducts, Camberley, Surrey, U.K.) for 15 s. Serial dilutions were prepared in MRD and tested for *P. fluorescens* by plating onto *Pseudomonas* agar base (Oxoid, CM 0559) supplemented with *Pseudomonas* CFC selective supplement (Oxoid, SR103) and incubated at 30C for 24 h. The chopping board, knife blade, fridge handle, oven handle, oven buttons, draining board, tap, microwave handle, microwave buttons, plate, tinfoil and press handle were cleaned with warm water and washing-up liquid prior to the trial commencing and then sampled using the same swabbing technique. The dishcloth was tested directly by adding 90 mL of MRD and processing as described earlier. Finally, the operator's hands were thoroughly washed using warm water and ordinary soap before each hand was sampled as described by Zhao *et al.* (1998).

Sample Preparation

Four previously tested chicken fillets, obtained from a local retailer, were inoculated with *P. fluorescens* by immersion in the 500 mL bacterial suspension for 1 min and stored at room temperature for a further 30 min in a laminar flow cabinet to allow for bacterial attachment. Two of these inoculated fillets were diced into cubes (approximately 1 × 1 × 1 cm) and packaged in a cook-in-the-pack bag (Versatile Packaging, Monaghan, Ireland). The other two fillets were placed on a foil tray and sealed in a plastic film.

Poultry Preparation Trial

Each participant was initially asked to prepare the cook-in-the-bag chicken fillets. This included performing the process of defrosting in a microwave and cooking. The plate used in the microwave and the raw (10 g) and cooked (10 g) chicken were tested for *P. fluorescens* as described earlier. The plate was then washed in warm water (approximately 40–45C) and washing-up liquid before retesting. The dishcloth was also examined.

The participant was then asked to prepare (defrost, cut into approximate 1 × 1 × 1 cm cubes and cook) fillets from the conventional pack. A sample of the raw chicken was tested for *P. fluorescens*. Once the poultry preparation was

completed, the chopping board, knife blade, fridge handle, oven handle, oven buttons, draining board, tap, microwave handle, microwave buttons, plate, tinfoil, press handle and the operator's hands were tested for *P. fluorescens*. The participant was then asked to wash each of these with warm water and washing-up liquid after which each was retested. The cooked product was also examined. Each trial was performed on six separate occasions with different participants.

Freezing Experiment: *Campylobacter* Inoculum Preparation

Five *Campylobacter* strains isolated from poultry, three strains of *C. jejuni* and two strains of *C. coli* from the Teagasc culture collection were used in the study. Strains were stored at –80C on ceramic beads (TSC, Heywood, Lancashire, U.K.) and cultured by aseptically transferring one bead from stock cultures to 30 mL Hunts broth (nutrient broth [Oxoid, Basingstoke, U.K.] and yeast extract [Oxoid], 5% lysed horse blood and 0.4% *Campylobacter* growth supplement ferrous sulphate, sodium metabisulphite and sodium pyruvate [FBP]) and then incubated at 42C for 48 h under microaerobic (5% O_2, 10% CO_2 and 85% N_2) conditions using gas generating kits (Biomerieux, Marcy l'Etoile, France). The *Campylobacter* cells were then harvested by centrifugation for 10 min at 2,655 × g, washed three times in MRD (Oxoid), and resuspended in 500 mL of MRD. Cell suspension concentrations were assessed by preparing a 10-fold dilution series and plating 0.1 mL dilutions onto modified charcoal cefoperazone deoxycholate agar medium (mCCDA, Oxoid) plates in duplicate.

Sample Preparation

A total of 21 chicken breast fillets were collected from the poultry processing plant immediately after chilling for the freezing intervention study. In the laboratory all fillets were immersed into the freshly prepared *Campylobacter* suspension for 15 s and left at room temperature in the laminar flow cabinet for 30 min to allow for attachment. *Campylobacter* were enumerated on three fillets using mCCDA, incubated at 42C for 48 h under microaerobic conditions and the remainder were stored in a freezer at –20C. Samples, (three fillets) were withdrawn every week for 6 weeks and surviving *Campylobacter* cells were enumerated as earlier.

Sensory Analysis

Sensory analysis was carried out by a panel of eight assessors, selected and recruited according to international standards (International Standards Organisation [ISO] 1993). The frozen samples were defrosted at refrigeration temperatures for 24 h prior to the assessment and were then treated in the same way as the fresh samples.

At the start of each experiment, the panel took part in the development of a descriptive vocabulary to describe the sensory characteristics of the test samples. During a discussion group, the panel examined the full range of samples in the study. A list of attributes describing the raw odor and appearance, and the cooked odor, flavor and taste, and texture characteristics of the samples was generated. Descriptive sensory analysis was carried out using a final vocabulary of 1 raw odor, 3 raw appearance, 2 cooked odor, 5 cooked flavor and taste, and 5 cooked texture descriptors for fillets (Table 1).

On the day of the assessments and for each sensory session, samples were removed from refrigerated storage at least 1 h prior to cooking. In order to prevent any assessor recognition bias the products were assigned three-digit codes. Raw samples were cut into uniform cubes, placed in lidded polystyrene cups and served to the assessors. Fillets for cooked analysis were subjected to standardized cooking methods. Fillets were tightly wrapped in foil and cooked at a temperature setting of 180C for 30 min in a fan assisted oven and allowed to stand for 10 min before they were cut into uniform cubes and served in coded polystyrene lidded cups to assessors.

Each assessor was provided with deionized water and instructed to cleanse their palate between tastings. Each assessor was also provided with a list of the defined vocabulary. The order of tasting was balanced to account for the order of presentation and carry-over (from one sample to the next) effects (MacFie *et al.* 1989).

All assessments were conducted in individual booths in a specifically designed sensory analysis unit, which complies with international standards for the design of test rooms (ISO 1988). Samples were scored for attributes on unstructured 100-mm line scales labeled at both ends with extremes of each attribute.

Statistical Analysis

All bacterial counts obtained from each sample were averaged and converted to $\log_{10}$ CFU/cm^2. Cross-contamination studies from six participants were performed in the domestic kitchen. Three separate replications were performed on the freezing experiment, with all analysis conducted in duplicate. A least significant difference analysis was performed using GENSTAT ver. 12.1 (VSN International, Ltd., Hemel Hempstead, U.K.).

For the sensory analysis experiment, the intensity of each of the descriptive terms was recorded for each sample using the Compusense five V. 4.0 sensory data acquisition programme (Guelph, ON, Canada). The mean panel scores from the duplicate descriptive sensory analysis were then

TABLE 1. DESCRIPTIVE VOCABULARY AND DEFINITIONS USED BY THE TRAINED ASSESSORS TO EVALUATE THE SENSORY CHARACTERISTICS OF THE CHICKEN DRUMSTICKS AND FILLETS

Odor attributes of raw fillet	
Intensity of raw poultry odor	Intensity of raw poultry odor from "low" to "high".
Appearance attributes of raw fillet	
Color of the flesh	Color of the flesh of the fillet. Ranging from "Light" to "typical" to "dark".
Shine of meat	The degree of shine on the fillet or drum. Ranging from "dry" to "typical" to "moist".
Residual moisture	The amount of liquid in the cup. Ranging from "low" to "high".
Odor attributes of cooked fillet	
Intensity of chicken odor	Low to high.
Intensity off odor	Intensity of off odor ranging from "low" to "high".
Flavor and taste attributes of cooked fillet	
Poultry flavor	Intensity of poultry flavor from "low" to "high".
Sweet	Fundamental taste elicited by sugars.
Sour	A sour tangy, citrus-like taste. The fundamental taste sensations of which lactic acids and citric acids are typical.
Salty	Fundamental taste sensation of which sodium chloride is typical.
Bitter	The fundamental taste sensations of which caffeine and quinine are typical.
Texture attributes of cooked fillet	
Firmness	The extent of resistance offered by the chicken. Judged in the first half of chewing using the front teeth. Ranging from "a little" to "a lot".
Moist	The perceived moisture content of the chicken. Ranging from "a little" to "a lot".
Dry	Degree to which the chicken feels dry when in the mouth. Ranging from "a little" to "a lot".
Chewy	The effort needed to break down the structure of the chicken. Ranging from "a little" to "a lot".
Sticky/gluey	Degree to which the chicken coats the palate and the teeth during mastication.

subjected to one-way analysis of variance (ANOVA, SPSS v 18.0 SPSS., Inc., Chicago, IL) to determine which terms were effective at providing discrimination among the samples. The acceptable significance level was set at $P < 0.05$.

RESULTS

Cross-Contamination During Conventional Poultry Preparation

At the outset of the experiment all sampled sites were *P. fluorescens* negative while the *P. fluorescens* count on the inoculated raw fillets was 6.06 $\log_{10}$ CFU/cm^2. Preparing the poultry supplied in a conventional pack resulted in *P. fluorescens* transfer from the inoculated fillets to the operators hands (3.3 $\log_{10}$ CFU/cm^2), chopping board (5.24 $\log_{10}$ CFU/cm^2), knife handle (2.81 $\log_{10}$ CFU/cm^2), knife blade (2.76 $\log_{10}$ CFU/cm^2), dishcloth (1.5 $\log_{10}$ CFU/cm^2), refrigerator handle (0.65 $\log_{10}$ CFU/cm^2), microwave handle (0.91 $\log_{10}$ CFU/cm^2), microwave buttons (1.54 $\log_{10}$ CFU/cm^2), press handle (0.57 $\log_{10}$ CFU/cm^2), oven handle (0.71 $\log_{10}$ CFU/cm^2), plate (4.45 $\log_{10}$ CFU/cm^2), tinfoil (0.94 $\log_{10}$ CFU/cm^2) and the draining board (0.28 $\log_{10}$ CFU/cm^2). After washing/cleaning these with warm water containing washing-up liquid, *P. fluorescens* was still detected on the chopping board (2.78 $\log_{10}$ CFU/cm^2), knife handle (0.52 $\log_{10}$ CFU/cm^2), dishcloth (0.67 $\log_{10}$ CFU/cm^2) and on the draining board (0.17 $\log_{10}$ CFU/cm^2) (Table 2).

Cook-in-the-Bag as a Control Intervention

Using the cook-in-the-bag method *P. fluorescens* was only detected (0.91 $\log_{10}$ CFU/cm^2) on the plate used during defrosting in the microwave (Table 2).

Freezing as a Control Intervention

Immersion of the fillets in the 500 mL of the *Campylobacter* cocktail (8.5 $\log_{10}$ CFU/mL) resulted in an initial concentration of 5.34 $\log_{10}$ CFU/g. After 1 week of storage at –20C the *Campylobacter* count decreased significantly ($P < 0.05$) by 1.73 $\log_{10}$ CFU/g (Table 3). Thereafter the rate of decline decreased and counts of 3.24, 3.03, 2.81, 2.35 and 1.88 $\log_{10}$ CFU/g were obtained after 2, 3, 4, 5 and 6 weeks, respectively.

Sensory Analysis

The results of the sensory analysis experiments are shown in Table 4. There was a significant difference between some of the attributes measured in the raw and frozen chicken fillets. Raw chicken fillets that had been frozen and defrosted had a significantly higher "shine" that that of raw fresh fillets. While freezing chicken fillets did not affect flavor, significant differences in texture were recorded. Cooked chicken fillets that had been frozen were significantly more "firm," less "moist" and more "dry" than that of cooked fresh chicken fillets.

TABLE 2. TRANSFER OF *P. FLUORESCENS* FROM THE RAW FILLET TO HANDS, EQUIPMENT AND THE KITCHEN ENVIRONMENT AND THE EFFECT OF CLEANING/WASHING WITH WARM WATER AND WASHING UP LIQUID

	Mean counts after conventional preparation (log_{10} CFU/cm^2)		Mean counts after cook-in-the-bag preparation (log_{10} CFU/cm^2)	
Sampling site	Before washing	After washing	Before washing	After washing
Hands	3.30	ND	ND	ND
Chopping board	5.24	2.78	NT	NT
Knife handle	2.81	0.52	NT	NT
Knife blade	2.76	ND	NT	NT
Dishcloth	1.5	0.67	NT	NT
Refrigerator handle	0.65	ND	ND	ND
Microwave handle	0.91	ND	ND	ND
Microwave buttons	1.54	ND	ND	ND
Press handle	0.57	ND	NT	NT
Oven handle	0.71	ND	ND	ND
Plate	4.45	ND	0.91	ND
Tinfoil	0.94	ND	NT	NT
Tap	ND	ND	ND	ND
Draining board	0.28	0.17	ND	ND

ND, not detected; NT, not tested because this equipment was not used with the cook-in-the-bag technology.

DISCUSSION

Using *P. fluorescens*, the spread of bacterial contamination from poultry to hands, the chopping board, knife handle, knife blade, dishcloth, fridge handle, microwave handle, microwave buttons, press handle, oven handle, plate, tinfoil and the draining board was readily demonstrated in this study. Gorman *et al*. (2002) have previously demonstrated cross-contamination of hands, oven handles, counter tops and draining boards with bacteria from poultry and secondary spread in the home. Other studies have also demonstrated the transfer of *Campylobacter* from poultry to hands, kitchen utensils and ready-to-eat foods directly or via the cutting board (Luber *et al*. 2006; van Asselt *et al*. 2008; Fravalo *et al*. 2009; Tang *et al*. 2011). Indeed, Luber (2009) concluded that cross-contamination events during food preparation presented a greater risk of illness than the risk associated with undercooking poultry meat.

Our data show a clear distinction between the bacterial counts obtained on primary (direct) contamination sites such as hands, chopping boards, knives and plates (2.76–5.24 log_{10} CFU/cm^2), and secondary sites such as the dishcloth, fridge, microwave, press and oven handles, tinfoil,

TABLE 3. THE REDUCTION IN *CAMPYLOBACTER* INOCULATED ONTO POULTRY FILLETS AND STORED AT –20C OVER A PERIOD OF 6 WEEKS

	Campylobacter CFU/g	
Storage (weeks)	After freezing	SE†
0	5.34[a]	0.11
1	3.61[b]	0.09
2	3.24[c]	0.15
3	3.03[c,d]	0.08
4	2.81[d]	0.11
5	2.35[e]	0.13
6	1.88[f]	0.17

Comparisons were made between storage week stage. The same letter indicates not statistically different at the 5% level ($P > 0.05$).
† SE, standard error.

TABLE 4. MEAN SENSORY SCORES FOR CHICKEN FILLETS AFTER SIX WEEKS OF STORAGE AT –20C

	Mean panel score†	
Attributes	Fresh	Frozen
Raw fillet attributes		
Intensity of raw poultry odor	35.4[a]	40.8[a]
Color of the flesh	43.3[a]	47.2[a]
Shine of meat	40.2[a]	51.8[b]
Residual moisture	2.2[a]	8.0[a]
Cooked fillet attributes		
Intensity of chicken odor	50.8[a]	52.5[a]
Intensity of off odor	0.7[a]	0.4[a]
Poultry flavor intensity	49.1[a]	50.6[a]
Sweet	2.4[a]	2.7[a]
Salty	0.7[a]	0.7[a]
Sour/Acidic	1.6[a]	1.2[a]
Bitter	0.7[a]	0.8[a]
Firmness	18.4[a]	23.8[b]
Moist	21.4[a]	12.4[b]
Dry	29.8[a]	38.9[b]
Chewy	15.0[a]	18.5[a]
Sticky/gluey	22.3[a]	23.1[a]

† Average score of eight assessors and measuring attributes on a defined 100-mm line scale. The same letter indicates not statistically different at the 5% level ($P > 0.05$).

microwave button and draining board where the counts ranged from 0.28 to 1.54 log_{10} CFU/cm^2. Such high loading on surfaces in direct contact with the chicken was also observed by Humphrey (2001).

Cleaning with warm soapy water reduced both the detectable incidence and levels of contamination, but the chopping board, knife handle, dishcloth and the draining board were still contaminated with *P. fluorescens*. Previous studies have shown that warm water and washing-up liquid are not sufficient to effectively decontaminate kitchen surfaces and equipment (Scott and Bloomfield 1990, 1993; Cogan *et al.* 1999, 2002; Kusumaningrum *et al.* 2002; Barker *et al.* 2003; Thormar and Hilmarsson 2010). One possible explanation for this is provided by Humphrey *et al.* (2001) who noted that contrary to consumer perception, washing-up water (soapy water) is neither sufficiently hot nor clean.

The cook-in-the-bag approach prevented cross-contamination of all sites with the exception of the plate used to defrost the cook-in-the-bag poultry, which was contaminated despite not coming into direct contact with the inoculated raw product. This was probably due to the contamination of the outside of the bag during preparation and packing. Contamination on the outside of packaging has been previously highlighted by Burgess *et al.* (2005), who reported that 3% of the external surfaces of raw chicken packs were contaminated with organisms originating from the poultry. Furthermore, a recent study by the Food Safety Authority of Ireland (FSAI) detected *Campylobacter* on 8.9% of the external surfaces of conventional poultry packaging and 1.6% of leak-proof packs (FOOD SAFETY AUTHORITY OF IRELAND FSAI 2010).

In this study, freezing at −20C for 7 days decreased *Campylobacter* by 1.73 log_{10} CFU/g and by 3.46 log_{10} CFU/g after 42 days of storage. Eideh and Al-Qadiri (2011) reported a 1.0 to 2.7 log_{10} CFU/g *Campylobacter* reduction in inoculated chicken breast samples stored at −18C for 20 days; Sampers *et al.* (2010) a 0.9–3.2 log_{10} reduction after 2 weeks storage at −20C on naturally contaminated chicken skin and muscle, and Zhao *et al.* (2003) a 1.3–1.8 log_{10} CFU/g reduction in *C. jejuni* on chicken wings frozen at −20 and −30C for 72 h, respectively. *Campylobacter* on broiler carcasses were reduced by up to 2.87 log_{10} after 31 days of frozen storage (Georgsson *et al.* 2006). The rate of decline was fastest in the first week of this study in contrast to Huang *et al.* (2012) who observed slow inactivation in the first 20 days of storage at −20C with a rapid decrease in surviving cells between 25 and 45 days. This may be due to the variability in strain sensitivity (Martinez-Rodriguez and Mackey 2005). In our and all the other studies referenced earlier, surviving cells were detected even after 60 days of frozen storage (Sampers *et al.* 2010). However, while freezing does not eliminate *Campylobacter* on poultry, the reductions achieved are sufficient to effect a significant decrease in the risk to the consumer (Lindqvist and Lindblad 2008).

Although freezing offers a cheap and readily available intervention to reduce *Campylobacter* on poultry in the domestic stage of the food chain, it adversely affects the quality of the product at –40C (Patsias *et al.* 2008). This is consistent with our sensory analysis, which found a significant change in the appearance ("shine") and texture firmness, moisture and dryness of the frozen chicken fillets (–20C) as compared with the control (fresh chicken fillets). The decrease in the quality and the commercial value of frozen poultry may therefore prevent widespread application of freezing as a *Campylobacter* control measure.

In conclusion, our study demonstrated the dissemination of bacteria from contaminated poultry to hands and food contact surfaces and showed how cook-in-the-bag methods could reduce cross-contamination. It also suggested that although freezing does not completely eliminate *Campylobacter*, the most significant human pathogen associated with poultry, significant reductions can be obtained. Either or these approaches alone or in combination with improved consumer knowledge of effective hygiene procedures in the kitchen will reduce campylobacteriosis in the future.

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