Food Protection Trends, Vol. 30, No. 9, Pages 580–587
Copyright© 2010, International Association for Food Protection
6200 Aurora Ave., Suite 200W, Des Moines, IA 50322-2864

Safe Endpoint Temperature for Cooking Whole Raw Poultry: Health Canada Recommendation

GOSIA K. KOZAK,[1] HÉLÈNE COUTURE,[1] THOMAS GLEESON,[1] KIM HOPKINS,[2] PAULETT MEIKLE,[2]
THUY PHAN[2] and JEFFREY M. FARBER[1*]
[1]Bureau of Microbial Hazards, Sir F.G. Banting Research Centre, 251 Sir F.G. Banting Driveway, Ottawa, Ontario, Canada K1A 0K9; [2]Silliker Canada Co., 90 Gough Road, Markham, Ontario, Canada, L3R 5V5

ABSTRACT

Poultry is a known carrier of *Salmonella*. However, it can be safely consumed when cooked to an appropriate internal temperature. The United States Department of Agriculture and some Canadian provinces recommend 74°C, whereas Health Canada currently recommends 85°C, as a safe internal temperature for cooking raw whole poultry, a difference that can potentially create consumer confusion. To address this, Health Canada evaluated three studies recently performed in Canada to examine the survival of *Salmonella* in raw inoculated whole poultry (stuffed and unstuffed whole chicken and turkey), at six different endpoint temperatures. It was found that 82°C was a safe endpoint cooking temperature for whole unstuffed and stuffed poultry. The studies found that variability exists between and within ovens, and that shorter cooking times typically resulted in positive *Salmonella* tests in poultry. The thickest part of the breast was determined to be the optimum location for temperature measurement, as it was the last to reach the desired endpoint temperature. Thigh readings were often inaccurate and difficult to perform. As a result of the evaluation of these studies, Health Canada will likely be recommending changing its endpoint temperature recommendation for raw whole poultry to 82°C, as measured in the thickest part of the breast.

A peer-reviewed article

---

*Author for correspondence: +1 613.957.0880; Fax: +1 613.954.1198
E-mail: jeff.farber@hc-sc.gc.ca

INTRODUCTION

Each year in Canada, approximately 6,000 cases of salmonellosis are reported to health authorities *(9)*. This number represents only a fraction of the actual salmonellosis cases, as the disease is often mistaken for stomach flu because of the similarity of symptoms, including vomiting, diarrhea and abdominal cramping. For every reported case of salmonellosis, it is believed that up to 37 cases go unreported *(21)*. *Salmonella* infections can be severe, especially in young children, the elderly and people with an impaired immune system, and in some cases they may require immediate hospitalization. Poultry are major carriers of *Salmonella,* and consequently contaminated poultry products are frequently associated with *Salmonella* infections *(9)*. A recent Canadian study examining human illness attribution as related to historical foodborne outbreak data sets found that between 14 and 23% of foodborne salmonellosis outbreaks could be attributed to poultry *(18)*.

Because of these public health concerns, various studies and surveillance programs throughout the world have evaluated the incidence of *Salmonella* contamination in poultry. In 2006, the Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS) found *Salmonella* in about 13% of the retail chicken samples analyzed *(8)*. A similar frequency was observed in 2002–2006 in the United States (US), where the National Antimicrobial Resistance Monitoring System (NARMS) isolated *Salmonella* from about 11.5% of retail chicken samples *(15)*. While the incidence of *Salmonella* found in poultry is similar in Canada and the United States, incidence rates vary in other parts of the world. For example, a higher *Salmonella* incidence rate was reported in Vietnam, where the bacterium was isolated from about 48.9% of retail chicken *(12)*, while lower incidence rates, i.e., 3.1% and 4.9%, were reported in New Zealand and United Kingdom, respectively *(14, 24)*. Because of extensive control measures, Sweden and Denmark have virtually eliminated *Salmonella* contamination in their poultry products *(23)*.

Although the presence of *Salmonella* in poultry is relatively common, poultry can be safely consumed when it is cooked to a safe internal endpoint temperature. While there is general consensus between governments and industry that an internal temperature of 74°C *(4, 10, 22)* is sufficient to inactivate *Salmonella* in raw poultry parts (e.g., chicken breasts, chicken thighs), disagreement remains as to what constitutes a safe endpoint temperature when cooking whole stuffed and unstuffed raw poultry. In Canada, for the past 25 years, Health Canada (HC) has recommended that an internal temperature of 85°C, measured in the thickest part of the breast or thigh muscle, not touching the bone *(10)*, would be sufficient to inactivate any *Salmonella* present in raw whole stuffed and unstuffed poultry. However, other Canadian and international government organizations, as well as members of the poultry industry, have recommended different endpoint temperatures. For example, for the inactivation of *Salmonella*, the Canadian Turkey Marketing Agency (CTMA) has recommended 74°C for stuffing in turkeys, and 77°C in the breast and 82°C in the thigh for whole raw turkey *(3)*. In the USA, the National Chicken Council and U.S. Poultry and Egg Association recommend 82°C as a safe endpoint cooking temperature, while the United States Department of Agriculture (USDA) and the governments of the Canadian provinces of British Columbia and Alberta recommend the lower endpoint temperature of 74°C *(1, 2, 16, 22)*.

These differences in endpoint temperature recommendations can confuse consumers as to what truly constitutes a safe endpoint temperature for cooking raw whole poultry. To address these uncertainties, two Canadian poultry industry associations, the Chicken Farmers of Canada (CFC) and CTMA, performed *Salmonella* survival studies on poultry to try to add to the body of scientific evidence for what constitutes a safe endpoint cooking temperature. Subsequent to these studies, Health Canada commissioned an investigation to assess the validity of its current recommendation of 85°C. In each of the three studies, whole raw poultry (stuffed and/or whole chicken and/or turkey) was inoculated with various strains of *Salmonella,* which included commonly observed strains such as *S.* Typhimurium, as well as the less common but known heat-resistant strain of *S.* Senftenberg. The endpoint Celsius temperatures used in these studies were specifically chosen to be equivalent to the Fahrenheit temperatures used in various US recommendations. The temperatures of 73.9, 76.7, 79.4 and 82.2°C used in the Canadian studies are equivalent to 165, 170, 175 and 180°F, respectively.

In the current investigation, Health Canada's objective was to examine the results of these three independent studies and make a recommendation on the safe endpoint temperature for cooking raw whole poultry.

MATERIALS AND METHODS

Although commissioned by different organizations over a 13-year span, all of the studies were conducted by the same independent testing facility "Diversified Research Laboratories Limited," now "Silliker Canada Co.," in Markham, Canada. The studies were performed between 1994 and 2007 with a common purpose: to determine the safe endpoint cooking temperature for raw whole poultry.

Canadian Turkey Marketing Agency

A study was commissioned in 1994 by CTMA to determine a safe endpoint cooking temperature for raw stuffed and unstuffed whole turkey. In this study, whole turkeys separated into four weight classes, ranging in weight from 4 kg to 10 kg, were inoculated with *S.* Typhimurium NAL+ (Table 1). The skin was inoculated with the target inocula, which ranged from 10^3 to 10^4 CFU/cm^2 (Table 1). The stuffing was prepared as recommended by the manufacturer, using 1 part commercial dry stuffing to 1.5 parts water, so as to have the lowest moisture content to ensure a slow heat transfer and to mimic potential in-home cooking conditions. After preparation, the stuffing was subsequently inoculated with *S.* Typhimurium NAL+ at a concentration of 10^2 to 10^3 CFU/g (Table 1). The turkeys were cooked in one of four commercially available consumer type ovens to one of three specific endpoint temperatures, i.e., 76.7°C, 79.4°C and 82.2°C (Table 1). All treatments were repeated for each weight class in each oven. The endpoint temperature

TABLE 1. Summary of materials and methods for the three poultry studies analyzed in this review

Study	Inoculum	Inoculation	Cooking	Sampling	Birds in study	Final internal temperature tested
CTMA 1994	*S.* Typhimurium NAL+	Placed in an autoclave bag with inoculum for 5 min and then dried for 5 min Inoculation: 10^2 to 10^3 CFU/g in stuffing; 10^3 to 10^4 CFU/cm^2 on skin Inoculum not equilibrated overnight	Temperature measured in inner thigh Standing time 15 min after cooking	Skin samples taken from turkey sides; 1 from thigh 1 from breast 3 stuffing samples Followed modified HC procedure MFHPB-20	30 stuffed turkeys Weight class 4 kg, 5.5 kg 6.5 kg and and 10 kg	Stuffed turkeys cooked to: 76°C, 79.4°C 82°C
CFC 2000	*S.* Typhimurium (ATCC # 13311) *S.* Senftenberg (ATCC # 43845)	Injected 1/8" following a previously established protocol *(7)*; deep into thigh, wing breast, oyster at target 10^7 CFU/site Stuffing inoculated at 1.1×10^7 and 6.0×10^7 *Salmonella*/g chicken Chicken equilibrated at 4°C for 24 h (not the stuffing)	Temperature measured in thigh, wing, breast, and oyster but away from inoculation site Waited until all probes reached the desired end-point temp Allowed to stand for 15 min At least 5 chickens tested at each temperature	Followed modified HC procedures MFHPB-20 and MFLP-49 (replaced by MFHPB-24, 2001)	25 unstuffed whole chickens 20 stuffed chickens Weight approx. 2 kg	Stuffed and whole chickens cooked to 73.9°C, 76.7°C, 79.4°C and 82.2°C
HC 2003–2007	*S.* Typhimurium PT104 *S.* Heidelberg *S.* Enteritidis PT4 *S.* Senftenberg 775W	Target inoculum of 10^7 CFU was swabbed on the chicken Chicken equilibrated for 24 h at 4°C	2 probes/breast 1 probe/thigh 1 probe/in oven 1 probe/in roasting pan Waited until all probes reached desired end point temperature Allowed to stand for 10 min; chicken tested in triplicate	Carcass rinse and enrichment of chickens Followed modified HC procedure MFHPB-20	54 whole unstuffed chickens Weight approx. 1.5 kg	73.9°C, 76.7°C 79.4°C, 82.2°C 85°C, 87°C

TABLE 2. Canadian Turkey Marketing Agency's study of *Salmonella* spp. survival from stuffed raw whole turkeys of four different weight classes cooked to three different endpoint temperatures

	Temperatures tested		
CTMA	76.7°C	79.4°C	82.2°C
Stuffed Turkeys	3/12^{a,b}	3/8^{a,b}	0/10^{a}

[a] Total number of *Salmonella*-positive turkeys out of total number of turkeys tested.

[b] *Salmonella* isolated from turkeys at 76.7 and 79.4°C were isolated only from the stuffing.

was recorded at the inner thigh muscle close to the hip joint of the turkey. After the required endpoint temperature was reached in the thigh muscle, the cooked turkey was subjected to a hold time of 15 min before sampling for *Salmonella.* Two skin samples, one from the breast and one from the thigh, consisting of an area of 10 cm^2 and, where applicable, three stuffing samples of undetermined weight from different points of the turkey cavity, were tested for the presence/absence of *Salmonella*, using a modified Health Canada method MFHPB-20 *(19)*.

Chicken Farmers of Canada

The CFC study performed between 1999 and 2000 examined safe endpoint temperatures for raw whole unstuffed and stuffed broiler chickens weighing between 1.5 and 2 kg. A cocktail of *S.* Typhimurium (ATCC #13311) and *S.* Senftenberg (ATCC #43845) was used to inoculate whole broilers. The target inoculum was 10^7 CFU/inoculation site and 10^7 CFU/g in the stuffing (Table 1). The whole and stuffed chickens were inoculated following previously published guidelines *(7)*, at a depth of 1/8" at four locations, i.e., the breast, thigh, wing and oyster (two small round pieces of dark meat, on the back of the poultry near the thigh). Care was taken to inoculate both the fat and lean portions of the chicken.

Additionally, for the stuffed chickens, the stuffing was inoculated (Table 1). Inoculated birds were stored at 4°C for 24 h to mimic storage conditions in a typical household. During cooking, the temperature of all chickens was monitored in the uninoculated wing, thigh and breast; in the stuffed chicken, an additional location (in the center of the stuffing) was monitored. The stuffing mixture was prepared according to manufacturer's instructions, with one part commercial dry stuffing mix and 1.5 parts water, so as to have a low moisture content and mimic possible cooking conditions with a slow heat transfer. The chickens were cooked to the following endpoint temperatures: 73.9°C, 76.7°C, 79.4°C and 82.2°C (Table 1). At least five chickens of similar size were cooked to each endpoint temperature in three different consumer type ovens (Table 1). After the endpoint temperature was reached at each of the monitored endpoints, the chickens were removed from the oven and allowed to stand for 15 min. Injected sites were aseptically removed with a sterile scalpel and placed in cold-buffered peptone at a 1/10 dilution to stop the cooking process. Stuffing was removed and allowed to cool to stop the cooking, and all the test samples were tested for the presence/absence of *Salmonella*, using the Health Canada cultural methods MFHPB-20 and MFLP-49 (replaced by MFHPB-24 2001) *(5, 19)*.

Health Canada

To expand upon the data from the two previously mentioned studies, Health Canada initiated another investigation through a contract with Silliker Laboratories between 2003 and 2007, to determine a microbiologically safe endpoint cooking temperature for raw whole broiler chickens. In this investigation, a cocktail of four *Salmonella* strains consisting of *S.* Typhimurium (PT104), *S.* Senftenberg (775W), *S.* Heidelberg, and *S.* Enteritidis, was used for the inoculation. The inoculum cocktail of 10^7 salmonellae per whole chicken was prepared by suspending 0.1 ml of each of the four *Salmonella* cultures (10^8 cells/ml) in 3.6 ml of sterile peptone water. The cell suspension was swabbed over the surface of the chicken. The inoculated chickens were stored at 4°C for 24 h. The temperature of the chicken was measured by using thermocouples. The thermocouples were calibrated weekly in boiling and ice water. Two probes were positioned in each chicken breast, one probe in each thigh, one probe in the oven beside the roasting pan, and one probe attached to the rack, between the roasting pan and the chicken. Triplicate inoculated chickens were subjected to each of six-endpoint temperatures i.e., 73.9°C, 76.7°C, 79.4°C, 82.2°C, 85°C, 87°C, in three different consumer-type ovens. To confirm the heat resistance of *S.* Senftenberg used in the study, 9 inoculated chickens cooked to 68°C were used as a positive control, to verify that *S.* Senftenberg could survive at this temperature. Once all the probes had reached the desired endpoint temperature, the chickens were removed from the oven and allowed to stand for 10 min before sampling. The chickens were tested for *Salmonella*, using the Health Canada culture method MFHPB-20 *(19)*. Presumptive *Salmonella* isolates were confirmed serologically with polyvalent and single grouping somatic (O) and flagellar (H) antisera (Difco, Becton Dickinson, Sparks, MD, and PRO-LAB Diagnostics, Austin, TX). Appropriate positive and negative controls were included in each experimental trial.

RESULTS AND DISCUSSION

The studies examined in this manuscript used various poultry types, *Salmonella* serovars and final temperatures to determine a recommended endpoint internal temperature that consumers could use to safely cook their raw whole unstuffed and stuffed poultry. Commissioned by three different organizations, all three studies were performed at Silliker Canada Co. in Markham, following similar protocols so as to minimize concern over procedural uniformity and allow direct comparison of the results. In total, 8 different consumer type ovens were used in these studies; the same oven was used twice, once in the Chicken Farmers of Canada study and once in the

TABLE 3. Chicken Farmers of Canada's study of *Salmonella* recovery from stuffed and unstuffed raw whole chickens weighing between 1.5 and 2.0 kg, cooked to four different inoculated endpoint temperatures

	Temperature tested				*Salmonella* serovar isolates	Location(s) where *Salmonella* were isolated
CFC	73.9°C	76.7°C	79.4°C	82.2°C		
Stuffed Chicken	0/5[a]	3/5	0/5	0/5	*S.* Senftenberg	[c]stuffing; [c]stuffing; [c]stuffing + wing + thigh
Whole Chicken	2/5	0/8	1/5	1/7	*S.* Senftenberg	[b]breast + wing; [b]wing + oyster [d]breast; [e]wing

[a]Total number of *Salmonella*-positive chicken out of total number of chickens tested.

[b]*Salmonella* isolated at 73.9°C.

[c]*Salmonella* isolated at 76.7°C.

[d]*Salmonella* isolated at 79.4°C.

[e]*Salmonella* isolated at 82.2°C.

TABLE 4. Health Canada's study of *Salmonella* survival from inoculated unstuffed raw whole chickens weighing between 1.5 and 2.0 kg, cooked to six different endpoint temperatures

	Temperature tested							*Salmonella* serovar(s) isolated
	68°C	73.9°C	76.7°C	79.4°C	82.2°C	85°C	87°C	
Unstuffed whole chicken	9/9[a]	3/9	3/9	2/9	0/9	0/9	0/9	[b]*S.* Senftenberg [b]*S.* Typhimurium

[a]Total number of *Salmonella*-positive chicken out of total number of chickens tested.

[b]*Salmonella* isolated at 73.9, 76.7 and 79.4°C.

Health Canada study. The final endpoint temperatures in all three studies were between 73.9°C and 82.2°C. Temperatures common to all the studies were 76.7°C, 79.4°C and 82.2°C (Table 1), while the CFC and HC studies also used the lower temperature of 73.9°C and the HC study used the higher temperatures of 85°C and 87°C (for which raw data was unavailable). The studies used equivalent methods to test poultry for the presence/absence of *Salmonella* at each temperature, but did not attempt to quantify the surviving bacteria.

In the CTMA study, *Salmonella* was not recovered from the skin of the turkeys cooked to any of the endpoint temperatures, indicating that the skin was cooked thoroughly (Table 2). However, six inoculated stuffed turkeys of three different weights (5.5, 6.5 and 10.0 kg) contained *Salmonella* in the stuffing after cooking, i.e., three at 79.4°C and three at 76.7°C (Table 2).

In the Chicken Farmers of Canada study, *S.* Senftenberg was isolated from whole chicken at all test temperatures, with the exception of 76.7°C (Table 3). In stuffed chickens, *Salmonella* were recovered only at 76.7°C and not at any other temperature (Table 3). It is difficult to understand why *Salmonella* were not isolated in whole unstuffed chickens at 76.7°C, while they were recovered at the higher temperatures of 79.4°C and 82.2°C.

The Health Canada study was done with the purpose of expanding upon the data that had been generated by the CFC study and through a duplication of test temperatures, to possibly explain why

TABLE 5. Aggregate results from three poultry studies examining the survival of *Salmonella* on inoculated stuffed and unstuffed whole poultry cooked to various endpoint temperatures

Endpoint cooking temperature rounded to the nearest whole number (°C)	Inoculum contained *S.* Senftenberg	Number of poultry tested	Number of poultry with *Salmonella* survivors	Percentage with *Salmonella* survivors	Percentage (total) of survivors
68[a]	Yes	9	9	100%	100%
74	Yes	19	5	26%	26%
77	Yes	22	6	27%	27%
	No	12	3	25%	
79	Yes	19	3	16%	22%
	No	8	3	38%	
82	Yes	21	1	5%	3%
	No	10	0	0%	
85	Yes	9	0	0%	0%
87	Yes	9	0	0%	0%

[a] *S.* Senftenberg was the only inoculum used.

positives were obtained at 79.4°C and 82.2°C but not at 76.7°C (Table 4). In the Health Canada study, only whole unstuffed broiler chickens were tested. *Salmonella* Senftenberg and *S.* Typhimurium were isolated at all temperatures except 82.2°C, 85°C and 87°C (Table 4).

The cooking times required to reach a set endpoint temperature differed considerably. Temperature probes at different locations in the same bird, for example, reached the set point at different times. Similarly, cooking times differed between individual poultry in the same class and cooked in the same oven. Factors most likely contributing to the variability both between and within individual poultry include differences in shapes, proportions of white and dark meat and fat distribution. Furthermore, the position of the poultry in the cooking pans could have impacted the rate of cooking in various regions of the poultry. Previous Health Canada studies (HC unpublished data), indicate that the side of the poultry closest to the edge of the metal cooking pan in which it had been placed, has a tendency to cook faster and to a higher temperature than the side further from the pan, likely because of the heat conduction by the pan. Alternatively, the variability in the times to reach endpoint temperatures could have resulted from inconsistent placement of temperature probes with respect to position and depth in the bird. In the CFC and HC studies, improper probe placement was addressed by repositioning the probe in the muscle as needed, when temperature spikes were observed.

Apart from duplicating the depth, having to reproduce the exact location of the probe in various muscle groups provided additional challenges. The CTMA study used endpoint temperature measurements from the thigh, but these readings were generally inconsistent, as consistent positioning of the probes into the thigh muscle was found to be very difficult to perform, even by experienced personnel. This finding was also confirmed in the CFC study, which reported that the endpoint temperature was consistently higher in the thigh muscle than in the rest of the chicken. The higher thigh temperatures may have been due to the pooling of liquid fat in the area. All three studies pointed to the observation that in order to record representative muscle temperatures, the poultry breast was the optimum placement for a temperature probe. The breast is the thickest part of a bird's body and therefore requires the longest time to reach the desired endpoint temperature, ensuring that other parts have reached the required temperature. Furthermore, the breast provides temperature readings that are close to that of the wing, which was found to be the slowest heating part in these studies.

Different poultry parts were found to cook at different rates. For 68% of the poultry, the wing was the slowest to reach the desired endpoint temperature under study. In fact, in the CFC study, the one *Salmonella* isolated (out of 31 birds) from poultry cooked to 82.2°C was found in the wing. It is possible that due to biological differences between the wings or poultry placement in the pan, the inoculated wing did not reach the same internal temperature as the uninoculated wing (which contained the temperature probe). In addition, improper probe placement (close to the bone or a fat pocket which conduct heat more readily than muscle) may have resulted in higher and inaccurate readings.

The slowest rate of temperature increase occurred in the stuffing of stuffed poultry. This was likely due to the stuffing's low moisture content, a factor that hinders good heat transfer, suggesting that heat transfer is less efficient between chicken meat and stuffing than in chicken meat itself. Since stuffing is the slowest part to cook in stuffed poultry, consumers should monitor the temperature of the stuffing as well as that of the bird. Because of inefficient heat transfer between stuffing and poultry meat, Health Canada recommends that stuffing be cooked separately and that the temperature be monitored independently, in order to prevent cross-contamination with *Salmonella*.

Salmonella Senftenberg was the most heat resistant of the *Salmonella* species used (Table 3). Research has shown that *S.* Senftenberg 775W (used in CFC and HC study) is about 30 times more heat resistant than *S.* Typhimurium *(17)* and 10 times more resistant than other *Salmonella* species *(20)*. *Salmonella* Senftenberg is not frequently isolated from poultry; in fact, a recent study found *S.* Senftenberg to be present in only 6% of the non-clinical (routine flock and slaughter surveillance) *Salmonella* chicken isolates. However, the same study identified this species as the top *Salmonella* serovar isolated in turkeys, i.e., it comprised 36% and 16% of the clinical and non-clinical *Salmonella* turkey isolates, respectively *(6)*. *Salmonella* Senftenberg was isolated from one of the chickens cooked to 82°C in the CFC study (about 3% of the total chickens cooked to 82°C) (Table 5). It is possible that the very high inoculum level (10^7 CFU/site), combined with the injection 1/8" deep into the muscle, provided additional protection to the already heat-resistant organism. This situation is not likely to be representative of a typical household, where *Salmonella* would be present on the surface of the poultry and in lower numbers.

In all three studies, the different ovens tested required different final endpoint temperatures to achieve *Salmonella*-negative results in cooked poultry. In the CFC study, for example, the survival of *S.* Senftenberg at 82.2°C occurred in oven #1, an oven from which a positive result was also obtained at a temperature of 79.4°C, whereas none of the three other ovens yielded positive results at either temperature. In total, 4/7 of the *Salmonella* positive chickens in the CFC study were cooked in oven 1. In the HC study, *S.* Typhimurium and *S.* Senftenberg were consistently isolated from oven 1 (a different oven from oven 1 in the CFC study) at temperatures up to 79.4°C, whereas in no other ovens were *Salmonella* detected after an internal temperature of 73.9°C was reached. In the Health Canada study, oven 1 was the oldest oven, having been manufactured in 1990, and, according to the results, it required higher endpoint temperatures to achieve total kill (82.2°C for oven 1, compared with 73.9°C for the other two ovens). The other variables between the ovens were self cleaning vs. non-self cleaning, digital vs. hand dials, and variation in the width/amplitude of the heating profile, all of which could have accounted for the differences observed between the ovens.

In both the CFC and HC studies, significant differences were observed in the time required to reach a given endpoint temperature for poultry of similar size. For example, within a single oven, in the HC study, in one trial it took a chicken 109 min to reach 76.7°C, while in a different trial only 80 min were needed for a chicken of a similar size to reach 79.4°C in the same oven. These results could be attributed either to inconsistent performances of individual ovens or to probes not being placed in the exact same locations/depths in each bird.

In all three studies, the inactivation of *Salmonella* in poultry was dependent on the amount of cooking time the poultry spent in the oven, as well as the final endpoint temperature and weight class. The cook times for *Salmonella*-positive turkeys to reach the required endpoint temperature were 29 to 89 min less than for *Salmonella*-negative turkeys. This difference may have been due to variations in turkey structure, oven heating or probe placement. The time/temperature data from the CTMA and the CFC study showed that all the turkeys and chickens from which *Salmonella* was isolated were heavier, had lower stuffing temperatures, and required a shorter cook time to reach the desired endpoint temperature. However, even with all these considerations, there was only 1 positive out of 31 when raw whole poultry was cooked to an endpoint temperature of 82.2°C.

In the CTMA and the CFC studies, when *Salmonella* was isolated from a stuffed poultry, it was always present in the stuffing. However, in none of the stuffed poultry was any *Salmonella* isolated from the stuffing or the body when the internal temperature of the turkey or chicken had reached 82.2°C.

All three studies ensured a thorough and even cooking of the poultry by introducing a 10–15 min "hold/resting time" after cooking. It was observed that the hold time contributed to the total microbial inactivation (data not shown). During this time, the temperature of the poultry itself, as well as the stuffing, continued to increase at a steady rate before tapering off, thus ensuring more even cooking and the elimination of cold spots.

Based on these studies, Health Canada recommends a target endpoint cooking temperature of 82°C, as measured in the thickest part of the breast, for cooking raw whole stuffed and unstuffed poultry. Although tested in conventional ovens, this temperature recommendation also applies to convection ovens, although increased air circulation, may decrease the poultry cooking time in convection ovens. No significant difference in organism lethality should be observed when poultry is cooked to an endpoint temperature of 82°C, regardless of the shorter cooking time. In the three studies, only one out of 31 birds cooked to 82°C was positive for *Salmonella.* The strain isolated, *S.* Senftenberg 775W, is a heat-resistant strain, and the inoculum was injected at a higher level than would be normally expected (1/8" deep into the muscle), likely providing the bacterium additional heat protection. This situation is also not representative of a typical household, in which the majority of *Salmonella* would be present on the surface of the poultry. Therefore, the recommendation of 82°C still satisfies the requirement for a conservative margin of safety. Furthermore, the oven (oven 1 in CFC study) used to cook the bird from which *Salmonella* was recovered, had a lower wattage but a shorter cooking time than the other ovens used in the study**.**

CONCLUSIONS

The Health Canada recommended endpoint temperature of 82°C is different from some provincial and industry recommendations, most notably the USDA recommendation of 74°C *(22)*. The data from the present three studies show that at the final endpoint temperatures of 74°C, 77°C and 79°C, *Salmonell*a, including *S.* Senftenberg, were recovered. A previous study performed for the USDA found *S.* Senftenberg in the stuffing of 25% of turkeys cooked to 82°C *(13)*. However, another study found that an endpoint temperature of 74°C, with a hold time of less than 10 min for both chicken and turkey, could achieve a 7-log reduction of *Salmonella,* although *S.* Senftenberg was not included *(11).* In conclusion, this study demonstrated that 82°C is a safe endpoint temperature to use when cooking raw whole poultry.

ACKNOWLEDGMENTS

We thank the Chicken Farmers of Canada and the Canadian Turkey Marketing Agency for their help in conducting these studies. We also acknowledge the great efforts of Dr. Jean-Yves D'Aoust in coordinating these studies.

REFERENCES

1. Alberta Health and Wellness. Common Foodborne Illness; Salmonellosis. Available at http://www.health.alberta.ca/health-info/foodborne-illness-common.html. Accessed 30 October 2008.
2. British Columbia Health Files. 2001. Salmonellosis. Available at http://www.healthlinkbc.ca/healthfiles/hfile17.stm. Accessed 30 October 2009.
3. Canadian Turkey Marketing Agency. 2005. Preparation — cooking times and temperatures. Available at http://www.turkeyfarmersofcanada.ca/preparation/cooking-Times. Accessed 18 November 2009.
4. Chicken Farmers of Canada (CFC). Chicken Cooking Times. Available at http://www.chicken.ca/DefaultSite/index.aspx?ArticleID=51&lang=en-CA. Accessed 30 October 2008.
5. D'Aoust, J. Y. 2001. MFLP-49 Detection of *Salmonella* species in foods by the VIDAS SLM™ method. Health Products and Food Branch. Ottawa, ON. Available at http://www.hc-sc.gc.ca/fn-an/res-rech/analy-meth/microbio/volume2/mfhpb24-01-eng.php. Accessed 30 October 2008.
6. Foley, S. L., A. M. Lynne, and R. Nayak. 2007. *Salmonella* challenges: Prevalence in swine and poultry and potential pathogenicity of such isolates. *J. An. Sci.* 86 (14 Suppl):E149–62.
7. Goodfellow, S. J., and W. L. Brown. 1978. Fate of *Salmonella* inoculated into beef for cooking. *J. Food Prot.* 41:598–605.
8. Government of Canada. Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS) 2006. Guelph, ON: Public Health Agency of Canada, 2009.
9. Health Canada. 2006. *Salmonella*. Available at http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/food-aliment/salmonella-eng.php. Accessed 12 January 2009.
10. Health Canada. 2007. Cooking poultry, when is it done? Available at http://www.hc-sc.gc.ca/fn-an/securit/ill-intox/info/poultry-volaille-cooking-cuisson-eng.php. Accessed 30 October 2008.
11. Juneja, V. K., B. S. Eblen, and H. M. Marks. 2001. Modeling non-linear survival curves to calculate thermal inactivation of *Salmonella* in poultry of different fat levels. *Int. J. Food Microbiol.* 70:37–51.
12. Luu, Q. H., L. Q., R. Fries, P. Padungtod, T. T. Hanh, M. N. Kyule, M. P. O. Baumann, and K. H. Zessin. 2006. Prevalence of *Salmonella* in retail chicken meat in Hanoi, Vietnam. *Ann. N.Y. Acad. Sci.* 1081:257–261.
13. McIntyre, S. M., and D. Olds. 1996. Effectiveness of turkey cooking procedures against *Salmonella* Senftenberg. Technical report submitted to Volk Enterprises, Inc., 26 April.
14. Meldrum, R. J., R. M. M. Smith, and I. G. Wilson. 2006. Three-year surveillance program examining the prevalence of *Campylobacter* and *Salmonella* in whole retail raw chicken. *J. Food. Prot.* 69:928–931.
15. National antimicrobial resistance monitoring system – enteric bacteria (NARMS): 2006 NARMS Retail Meat Annual Report. United States Food and Drug Administration (FDA), Washington, D.C.
16. National Chicken Council & U.S Egg and Poultry Association. 2008. Cooking chart. Available at http://www.eatchicken.com/cooking_tips/cooking_chicken.cfm. Accessed 30 October 2008.
17. Ng, H., H. G. Bayne, and J. A. Garibaldi. 1969. Heat resistance of *Salmonella:* the uniqueness of *Salmonella* Senftenberg 775W. *J. Appl. Microbiol.* 17:78–82.
18. Ravel, A., J. Greig, C., Tinga, E. Todd., G. Campbell, M. Cassidy, B. Marshall, and F. Pollari. 2009. Exploring historical Canadian foodborne outbreak data sets for human illness attribution. *J. Food Prot.* 72:1963–1976.
19. Reid, A. 2009. MFHPB-20. Methods for the isolation and identification of *Salmonella* from foods and environmental samples. Health Products and Food Branch Ottawa. Available at http://www.hc-sc.gc.ca/fn-an/res-rech/analy-meth/microbio/volume2/mfhpb20-01-eng.php. Accessed 10 Dec 2009.
20. Smith, S. E., J. L. Maurer, A. Orta-Ramirez, E. T. Ryser, and D. M. Smith. 2001. Thermal inactivation of *Salmonella* spp., *Salmonella* Typhimurium DT104, and *Escherichia coli* O157:H7 in ground beef. *J. Food Sci.* 66:1164–1168.
21. Thomas, M. K., S. E. Majowicz, P. N. Sockett, A. Fazil, F. Pollari, K. Doré, J. A. Flint, and V. L. Edge. 2006. Estimated numbers of community cases of illness due to *Salmonella*, *Campylobacter* and verotoxigenic *Escherichia coli*: Pathogen-specific community rates. *Can. J. Infect. Dis. Med. Microbiol.* 17:229–234.
22. United States Department of Agriculture (USDA). 2007. Safe Food Handling. Available at http://www.fsis.usda.gov/Factsheets/Keep_Food_Safe_Food_Safety_Basics/index.asp. Accessed 30 October 2008.
23. Wegener, H. C., T. Hald, D. L. F. Wong, M. Madsen, H. Korsgaard, F. Bager, P. Gerner-Smidt, and K. Molbak. 2003. *Salmonella* control programs in Denmark. *Emerg. Infect. Dis.* 9:774–780.
24. Wong, T. L., C. Nicol, R. Cook, and S. MacDiarmid. 2007. *Salmonella* in uncooked retail meats in New Zealand. *J. Food Prot.* 70:1360–1365.