**Epidemiology and Infection**

Estimated reduction in human salmonellosis incidence in Canada from a new government requirement to reduce *Salmonella* in frozen breaded chicken products

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**Supplementary Material**

**Supplementary Appendix (SA) 1**

**Supplementary Table S1.1** Timeline of key events and studies leading to identification of raw frozen breaded chicken products as a risk factor for salmonellosis, as well as the government and industry collective actions and interventions undertaken to control foodborne FBCP-related *Salmonella* in Canada, 2003-2019.

|  |  |
| --- | --- |
| Time | Key event or action |
| February – April 2003 | **STUDY**: Raw frozen chicken nuggets identified as source of *Salmonella* Heidelberg for first time, resulting in joint press release by the British Columbia Centre for Disease Control and the Canadian Food Inspection Agency (CFIA) warning consumers in British Columbia to fully cook frozen processed chicken products [1]. |
| January 2011 | **SURVEILLANCE**: FoodNet Canada began collection of retail frozen breaded chicken products (FBCP) samples. |
| August 2014 | **FBCP INTERVENTION**: Health Canada issued guidance document for industry on safe cooking and handling labelling for raw ground poultry products intended for sale to consumers [2]. |
| January – July 2015 | **OUTBREAK & RECALL**: First national outbreak (51 cases) investigation of *S.* Enteritidis illnesses linked to raw FBCP exposure resulting in 1 recall issued by the CFIA to 3 raw FBCP [3]. |
| September 2015 | **PATHOGEN REDUCTION**: Government-Industry Working Group (Joint WG) on the Control of *Salmonella* and *Campylobacter* in Poultry established [4]. |
| 2015 | **FBCP INTERVENTION**: Industry voluntarily developed additional labelling on raw FBCP adding prominent messaging, and cooking instructions on inner-packaging bags [5]. |
| May 2017 | **SURVEILLANCE**: Whole genome sequencing introduced for all human and retail *Salmonella* isolates [6]. |
| September 2017 | **STUDY**: Public Health Agency of Canada (PHAC) published the Foodbook study findings about consumer food safety practices and knowledge related to raw frozen chicken nuggets [7]. |
| April 2017 – September 2018 | **OUTBREAK & RECALL:** 12 outbreaks (378 cases) between April 2017 and September 2018 directly linked to raw FBCP exposure resulting in 9 separate recalls issued by the CFIA to various raw FBCP [3, 8] |
|  | **Apr-Jul 2017**: There were 25 cases of illness due to *S*. Enteritidis in seven provinces. Raw retail chicken exposure, including raw FBCP, identified as source of outbreak. No product recall issued. |
|  | **Apr-Jun 2017:** There were 13 cases of illness due to *S*. Enteritidis in five provinces. Raw FBCP were identified as source of outbreak. Recall issued by CFIA to chicken nuggets on July 12, 2017. |
|  | **Apr-Jul 2017:** There were 9 cases of illness due to *S*. Heidelberg in six provinces and one territory. Raw FBCP exposure identified as source of outbreak. No product recall issued. |
|  | **Jun-Oct 2017:** There were 22 cases of illness due to *S*. Enteritidis in six provinces. Raw FBCP exposure identified as source of outbreak. Recall issued by CFIA to chicken burgers and popcorn chicken on October 17, 2017. |
|  | **Apr-Dec 2017:** There were 54 cases of illness due to *S*. Enteritidis in nine provinces. Raw retail chicken exposure, including raw FBCP, identified as source of outbreak. No product recall issued. |
|  | **May 2017-Mar 2018:** There were 33 cases of illness due to *S*. Enteritidis in six provinces. Raw retail chicken exposure, including raw FBCP, identified as source of outbreak. Recall issued by CFIA to chicken nuggets on March 28, 2018. |
|  | **Mar-Jul 2018:** There were 90 cases of illness due to *S*. Enteritidis in ten provinces and two territories. Raw retail chicken exposure, including raw FBCP, identified as source of outbreak. Recall issued by CFIA to chicken burgers on June 2, 2018.  |
|  | **Nov 2017-Feb 2018:** There were 12 cases of illness due to *S*. Enteritidis in four provinces. Raw FBCP exposure identified as source of outbreak. No product recall issued. |
|  | **Jun-Aug 2018**: There were 27 cases of illness due to *S*. Enteritidis in eight provinces. Raw FBCP exposure identified as source of outbreak. Recall issued by CFIA to chicken fries on July 21, 2018. |
|  | **Jun-Sep 2018:** There were 55 cases of illness due to *S*. Enteritidis in eight provinces. Raw FBCP exposure identified as source of outbreak. Recall issued by CFIA to chicken nuggets on July 20, 2018.  |
|  | **Jul-Sep 2018:** There were 12 cases of illness due to *S*. Enteritidis in six provinces. Raw FBCP exposure identified as source of outbreak. Recall issued by CFIA to chicken fries on October 2, 2018. |
|  | **Dec 2017-Sep 2018:** There were 26 cases of illness due to *S*. Enteritidis in nine provinces. Raw FBCP exposure identified as source of outbreak. Recall issued by CFIA to chicken burgers on October 26, 2018, and to chicken strips on November 2, 2018. |
| April 2017 – May 2019 | **FBCP INTERVENTION:** Risk communication through public health notices and social media messaging regarding raw FBCP by PHAC and Health Canada [8-11]. |
| March 2018 | **FBCP INTERVENTION**: The CFIA issued a notice advising industry that *Salmonella* in raw FBCP must be addressed in their Preventive Control Plan (“soft implementation study period”) [6]. |
| May 2018 | **STUDY**: Publication of the public opinion research report with questions regarding handling and cooking raw FBCP by Health Canada [12]. |
| June 2018 – April 2019 | **OUTBREAK & RECALL:** 4 outbreaks (109 cases) between June 2018 and April 2019 directly linked to raw FBCP exposure resulting in 4 separate recalls issued by the CFIA to various raw FBCP and 1 raw FBCP voluntarily removed by retailer [3, 8]. |
|  | **Jun 2018-Mar 2019:** There were 64 cases of illness due to *S.* Enteritidis in ten provinces and one territory. Raw FBCP exposure identified as source of outbreak. Two recalls issued by CFIA to chicken nuggets on January 25 and February 27, 2019. |
|  | **Dec 2018-Mar 2019:** There were 30 cases of illness due to *S*. Enteritidis in six provinces. Raw FBCP exposure identified as source of outbreak. One retailer voluntarily removed chicken nuggets on February 8, 2019 from its retail chains across Canada due to the potential risk of illness associated with raw FBCP. |
|  | **Feb-Apr 2019:** There were 4 cases of illness due to *S*. Enteritidis in two provinces. Raw FBCP exposure identified as source of outbreak. Recall issued by CFIA to chicken nuggets on March 21, 2019. |
|  | **Sep 2018-Apr 2019:** There were 11 cases of illness due to *S*. Enteritidis in seven provinces. Raw FBCP exposure identified as source of outbreak. Recall issued by CFIA to chicken strips on May 24, 2019. |
| July 2018 | **FBCP INTERVENTION:** The CFIA announced that new raw FBCP requirement will come into effect on 1 April 2019 [13]. |
| September 2018 | **FBCP INTERVENTION**: Statement by Council of Chief Medical Officers of Health regarding raw FBCP health risks [14]. |
| 2018 – 2019 | **FBCP INTERVENTION**: Targeted FBCP consumer marketing campaign by Health Canada [15]. |
| April 2019 | **FBCP INTERVENTION**: The CFIA requirement to reduce *Salmonella* in FBCP to below a detectable amount came into effect on April 1 [13]. |

**Supplementary Appendix (SA) 2**

**Supplementary Methods**

**2.1 FoodNet Canada salmonellosis cases**

FoodNet Canada (FNC) is a sentinel site surveillance system coordinated by the Public Health Agency of Canada in collaboration with provincial and local health authorities that collects information on four components – farm animals, retail foods, raw water sources, and human cases of enteric illness – in order to identify food and environmental sources of contamination causing enteric illness [14].

Endemic salmonellosis cases reported from 1 January 2015 to 29 February 2020 that also had an onset date from 1 January 2015 to 29 February 2020 were included from three FNC sentinel sites located in the provinces of Alberta (Alberta Health Services), British Columbia (Fraser Health), and Ontario (Middlesex-London Health Unit) [15]. The Quebec sentinel site was excluded, as it was officially established in July 2019 and did not have any pre-intervention data points. Case data were transformed into weekly time series. Salmonellosis symptom onset dates were used to assign each observation a unique week number. For asymptomatic cases, the sample collection date was captured by the sentinel sites as the theoretical onset date.

**2.2 Seasonality adjustment**

As salmonellosis incidence exhibits seasonal variation, with higher rates in warmer months [16], controlling for seasonality is important. This was especially needed in this study since the pre-intervention period was much longer than the post-intervention period and demonstrated seasonal spikes and valleys, whereas the post-intervention period did not include months with highest and lowest seasonal spikes, which could lead to overestimation of the intervention effect. Seasonality was removed by generating a season variable with 26 categories, representing 2-week blocks, which was used in a linear regression model with salmonellosis incidence rate as the response variable and the season as the explanatory variable. The season categories were assessed for significance (p ≤ 0.1), using the category with the mean incidence rate closest to the overall mean in the pre-intervention period as the referent. This allows the seasonal dummy variables to fit both peaks and valleys from the mean. A new linear regression model with only significant season categories was fit, and model-predicted values were generated. Finally, seasonality was removed from the human salmonellosis incidence rate by subtracting the fitted values from the unadjusted human salmonellosis incidence rate. The same method was used to assess and remove seasonality from the retail FBCP and CBM *Salmonella* prevalence series.

**2.3 Determination of the intervention periods**

Since the date of the CFIA requirement implementation was 1 April 2019, the pre-intervention period was from May 2014 until March 2019. The post-intervention period was determined by first visually inspecting the FBCP prevalence plot over time, and estimating the first week when the prevalence reached 0% after policy implementation. A series of linear regressions were performed to generate a line of best fit to determine the earliest week when *Salmonella* prevalence reached the point of 0%, which was the week of 14 October 2019. The period between 1 April and 13 October 2019 was considered the intervention period, during which the intervention was expected to have an effect on the *Salmonella* prevalence in FBCP. We refer to the official requirement deadline of 1 April 2019 as the hard implementation, and we use the term soft implementation to refer to the period when the CFIA released an industry notice about the new raw FBCP control measures in March 2018, granting the industry a 12-month implementation period.

**2.4 Interrupted time series analysis methods**

**Generalized linear model regression.**A segmented regression-based interrupted time series analysis was performed, following the methods described by Bernal et al. [17] to ensure the robustness of the pre-post intervention methodology results. Negative binomial regression models accounted for the excess variance in the salmonellosis case count series. A dummy variable indicating the pre-intervention, the intervention, and post-intervention periods was included in the models with the pre-intervention period used as the referent. A linear time variable was included in the models to adjust for a potential underlying temporal trend. The time variable was centered at the mid-point of the pre-intervention period. Salmonellosis case counts were used as the outcome and population estimates were included as the offset. Seasonality was adjusted by including the significant seasonal dummy variables in the models.

The following equation describes the segmented regression model that was used:

Y = $β\_{0}$+ $β\_{1}$T + $β\_{2}$X+ $β\_{3}$S

Where :

Y is the salmonellosis incidence rate; T is the time variable; X is the vector of dummy variables representing the intervention periods; and S is the vector of dummy variables representing seasonality.

Univariate autoregressive integrated moving average (ARIMA) models were also used to assess the robustness of the results generated by the negative binomial models after adjusting for residual autocorrelation of the outcome series. The results were robust after adjusting for residual autocorrelation (results not shown).

**2.5 Pre- and post-intervention difference in salmonellosis incidence rate estimation and the difference-in-differences estimator example calculation**

Values used in the example calculations are taken from Table 2 of the Results section of the paper:

1) Subtract the seasonally adjusted mean salmonellosis incidence rate in the post-intervention period from the mean rate in the pre-intervention period of the overall group:

21 – 16 = 5 cases per 100,000 population[[1]](#footnote-1)

2) Subtract the seasonally adjusted mean salmonellosis incidence rate in the post-intervention period from the mean rate in the pre-intervention period of the comparison group:

4.2 – 4.1 = 0.10 cases per 100,000 population

3) Calculate the difference-in-differences estimator by subtracting the comparison group pre-post difference in salmonellosis incidence rate from the overall group pre-post difference:

5 – 0.1 = 4.9 cases per 100,000 population

**2.6 Policy impact and source attribution equations and example calculations**

**Policy impact**. To calculate the percent drop in the human salmonellosis rate due to the CFIA requirement using the pre-post intervention methodology, the seasonally adjusted difference-in-differences estimates were divided by the seasonally adjusted percentage drop in the FBCP *Salmonella* prevalence between the pre-intervention and post-intervention periods, and then divided by the seasonally adjusted salmonellosis incidence rate before the intervention, and converted into a percentage, using the equation:

$$Policy impact= \frac{\left(\frac{DID}{FBCP\_{pre}-FBCP\_{post}} \right)x (FBCP\_{pre}-FBCP\_{post}\*)}{IR\_{pre}}$$

Where:

*Policy impact* = the proportion of salmonellosis cases attributed to the CFIA FBCP requirement

*DID* = difference-in-differences estimate

$FBCP\_{pre}$ = frozen breaded chicken products *Salmonella* prevalence in pre-intervention period

$FBCP\_{post}$ = frozen breaded chicken products *Salmonella* prevalence in post-intervention period

$IR\_{pre}$ = salmonellosis incidence rate per 100,000 population in pre-intervention period

\*For policy impact calculation the actual post-intervention FBCP *Salmonella* prevalence was used, which leads the two ($FBCP\_{pre}-FBCP\_{post})$ expressions to cancel out and reduces the equation to:

*Policy impact = DID /* $IR\_{pre}$

For source attribution calculation, 0 is substituted in place where the post-intervention FBCP *Salmonella* prevalence was used in the policy impact calculation, which is marked with the asterisk

**Example calculation:**

Values used in the example calculations are taken from Tables 1 and 2 of the Results section of the paper:

1. Subtract difference between seasonally adjusted pre- (4.2) and post-intervention (4.1) mean salmonellosis rate in comparison series from difference in pre- (21) and post-intervention (16) periods in overall series:

(21 – 16) – (4.2 – 4.1) = 4.9 cases per 100,000 (difference-in-differences (D-I-D) estimate)

1. Calculate drop in salmonellosis due to drop in FBCP *Salmonella* prevalence from CFIA requirement by dividing D-I-D by difference in pre (28%) and post (2.9%) in FBCP:

4.9 / (28 – 2.9) = 0.19 cases per 100,000 / % point drop in FBCP

1. Multiply by the mean FBCP *Salmonella* prevalence and calculate the difference between pre (28%) and post (2.9%) periods:

(0.19\*28) – (0.19\*2.9) = 4.8 cases per 100,000

1. Divide by salmonellosis rate in pre-intervention period to calculate the percentage drop in the human salmonellosis rate due to the CFIA requirement:

(4.8 / 21)\*100% = 23%

**Source attribution.** For source attribution calculations, where the effect of the entire exposure on the salmonellosis rate needs to be considered, a similar formula is used though we substitute the post period prevalence on FBCP with 0 in step 3 of the above example calculation, which is what would be the case if the entire exposure is removed.

1. Multiply by the mean FBCP *Salmonella* prevalence and calculate the difference between pre- (28%) and post-intervention (0%) periods:

(0.19\*28) – (0.19\*0) = 5.3 cases per 100,000

1. Divide by salmonellosis rate in pre-intervention period to calculate the percentage of the salmonellosis rate attributed to FBCP exposure:

(5.3 / 21)\*100% = 25%

**Supplementary Appendix (SA) 3**

**Supplementary Results**

**3.1 Pre-post intervention analysis results using FoodNet Canada data**

**Supplementary Table S3.1a.** Unadjusted and seasonally adjusted *Salmonella* prevalence in retail samples of frozen breaded chicken products and chicken breast meat during the pre- and post-intervention periods, and the pre-post intervention differences using FoodNet Canada data, 2015-2020.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Mean *Salmonella* prevalence | Pre-intervention Unadj. | Pre-interventionSeas. adj. | Post-interventionUnadj. | Post-interventionSeas. adj. | Pre-post differenceUnadj. | Pre-post differenceSeas. adj. |
|  |  | Prevalence percent (95% confidence interval) |
| Hard impl. | Frozen breaded chicken products | 28(26, 30) | 28(26, 29) | 3.3(0.85, 5.8) | 3.3(0.85, 5.8) | 25(22, 28) | 24(21, 27) |
| Chicken breast meat | 21(19, 23) | 20(18, 22) | 19(15, 23) | 19(15, 23) | 1.9(-2.4, 6.3) | 1.0(-3.3, 5.4) |
| Soft impl. | Frozen breaded chicken products | 27(25, 29) | 26(25, 28) | 3.3(0.85, 5.8) | 3.3(0.85, 5.8) | 23(20, 27) | 23(20, 26) |
| Chicken breast meat | 22(20, 24) | 22(20, 24) | 19(15, 23) | 19(15, 23) | 3.0(-1.4, 7.5) | 2.7(-1.8, 7.1) |

Unadj., unadjusted; Seas. adj., seasonally adjusted; Hard impl., hard implementation – using 1 April 2019 as beginning of intervention period; Soft impl., soft implementation – using 1 April 2018 as beginning of intervention period.

**Supplementary Table S3.1b.** Unadjusted and seasonally adjusted endemic human salmonellosis incidence rates of overall and comparison groups during the pre- and post-intervention periods, and the pre-post intervention differences using FoodNet Canada data, 2015-2020.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Mean salmonellosis incidence rate | Pre-intervention Unadj. | Pre-intervention Seas. adj. | Post-intervention Unadj. | Post-intervention Seas. adj. | Pre-post difference Unadj. | Pre-post difference Seas. adj. | D-I-DUnadj. | D-I-DSeas adj. |
|  |  | Cases per 100,000 population (95% confidence interval) |
| Hard impl. | Overall group | 13(12, 14) | 13(12, 13) | 7.5(5.8, 9.2) | 8.2(6.2, 10) | 5.9(3.9, 7.9) | 4.3(2.1, 6.6) | 6.2(4.7, 7.8) | 4.8(2.9, 6.7) |
| Comparison group | 2.2(1.9, 2.6) | 2.2(1.9, 2.5) | 2.6(1.4, 3.7) | 2.6(1.4, 3.7) | (-0.34)(-1.5, 0.84) | (-0.43)(-1.6, 0.75) |
| Soft impl. | Overall group | 14(13, 15) | 13(12, 14) | 7.5(5.8, 9.2) | 8.2(6.1, 10) | 6.8(4.7, 8.8) | 5.1(2.8, 7.3) | 7.2(5.5, 8.9) | 5.6(3.7, 7.5) |
| Comparison group | 2.2(1.8, 2.5) | 2.1(1.7, 2.4) | 2.6(1.4, 3.7) | 2.6(1.4, 3.7) | (-0.40)(-1.6, 0.79) | (-0.50)(-1.7, 0.69) |

Unadj., unadjusted; Seas. adj., seasonally adjusted; D-I-D, difference-in-differences; Hard impl., hard implementation – using 1 April 2019 as beginning of intervention period; Soft impl., soft implementation – using 1 April 2018 as beginning of intervention period.

**3.2 Policy impact and source attribution results using FoodNet Canada data**

**Supplementary Table S3.2.** Frozen breaded chicken products policy impact and food source attribution of endemic human salmonellosis percentages using FoodNet Canada data, 2015-2020.

|  |  |  |
| --- | --- | --- |
|  | Policy impact / Source attribution | Percent (95% CI) |
| Hard impl. | Policy impact. Reduction in human salmonellosis incidence rate attributable to the drop in FBCP *Salmonella* prevalence after new FBCP requirement | 38(24, 52) |
| Source attribution. Extrapolated reduction in human salmonellosis incidence rate if FBCP exposure completely removed | 43(27, 60) |
| Soft. Impl. | Policy impact. Reduction in human salmonellosis incidence rate attributable to the drop in FBCP *Salmonella* prevalence after new FBCP requirement | 42(29, 56) |
| Source attribution. Extrapolated reduction in human salmonellosis incidence rate if FBCP exposure completely removed | 48(32, 64) |

FBCP, frozen breaded chicken products; Hard impl., hard implementation – using 1 April 2019 as beginning of intervention period; Soft impl., soft implementation – using 1 April 2018 as beginning of intervention period; 95% CI, 95% confidence interval.

**3.3 Interrupted time series analysis results**

**Supplementary Table S3.3.** Reduction in human salmonellosis incidence rate resulting from the frozen breaded chicken products requirement using the interrupted time series approach utilizing the negative binomial regression, NESP, 2014-2020.

|  |  |  |
| --- | --- | --- |
|  | Model | Percent (95% CI) |
| Hard impl. | Reduction in human salmonellosis incidence, adjusted for seasonality | 36(31, 41) |
| Reduction in human salmonellosis incidence, adjusted for seasonality and time trend | 26(19, 32) |
| Soft. impl. | Reduction in human salmonellosis incidence, adjusted for seasonality | 38(34, 43) |
| Reduction in human salmonellosis incidence, adjusted for seasonality and time trend | 31(25, 37) |

NESP, National Enteric Surveillance Program; Hard impl., hard implementation - using 1 April 2019 as beginning of intervention period; Soft impl., soft implementation - using 1 April 2018 as beginning of intervention period; 95% CI, 95% confidence interval.

**Supplemental Material References**

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1. Estimates in these example calculations differ slightly from those in the Results section due to rounding. [↑](#footnote-ref-1)