



Canadian Food  
Inspection Agency

Agence canadienne  
d'inspection des aliments

# Bacterial Pathogens and Indicators in Raw Non-Soy Plant-based Meat Alternatives - April 1, 2020 to March 31, 2023

## Food microbiology - Targeted surveys - Final report



## Summary

A 3-year targeted survey<sup>1</sup> analysed 954 samples of raw non-soy plant-based meat alternatives for the presence of the pathogens *Escherichia coli* (*E. coli*) O157, and *Salmonella* species (spp.). All samples were also tested for generic *E. coli* which is an indicator of the overall hygienic and sanitary conditions of the food supply chain from production to the point of sale.

Almost all (99.7%) of the samples tested were found to be satisfactory. *E. coli* O157 and *Salmonella spp.* were not found in any of the samples. Generic *E. coli* at elevated levels were found in 3 of the 954 (0.3%) samples. The Canadian Food Inspection Agency (CFIA) conducted appropriate follow-up activities.

Overall, our survey results indicate that raw non-soy plant-based meat alternatives sold in Canada are generally safe for consumption. However, as with all foods, good hygienic practices are recommended for producers, retailers, and consumers.

## Why was this survey conducted

The survey was conducted to generate baseline information on the quality and safety of raw non-soy plant-based meat alternatives sold at retail in Canada. A similar survey was conducted from 2013 to 2014 and 2015 to 2016<sup>2</sup> which included plant-based meat alternatives, however all of the samples were soy-based and ready-to-eat (RTE) while those tested in this survey were raw and derived from other plant-based sources such as peas, beans, grains, and vegetables.

The consumption of plant-based meat alternatives has a long history in many parts of Asia<sup>3</sup>. However, in recent years they have grown in popularity and a wide variety of products is now available on the Canadian retail marketplace<sup>4</sup>. Unfortunately, plant-based meat alternatives have been associated with recalls<sup>5,6</sup>, and foodborne illness outbreaks<sup>7,8,9</sup>.

Contamination with bacterial pathogens can occur at any step in the food supply chain such as during production, processing, packaging, distribution, at retail, and/or during preparation for consumption. Consequently, if pathogens are present, there is a potential for foodborne illness.

## When was the survey conducted

The survey was conducted over a 3-year period from April 1, 2020 to March 31, 2023.

## Where were the samples collected from

Samples were collected from national retail chains and local/regional grocery stores located in the following 11 major cities across Canada:

- Halifax
- Moncton
- Quebec City
- Montreal
- Toronto
- Ottawa
- Vancouver
- Victoria
- Calgary
- Saskatoon
- Winnipeg

The planned number of samples to be collected from each city was based on the population of the province in which the city was located relative to the total population of Canada.

## How many and what kind of samples were collected

A total of 954 refrigerated raw plant-based meat alternative samples were collected. Soy-based products were excluded from this survey and sampling was focused on plant-based burgers, patties, and sausages. All products collected under this survey were labelled with cooking instructions. A sample consisted of a single or multiple consumer sized packages of the same lot weighing at least 250g.

## What were the samples tested for

All samples were tested for *E. coli* O157, *Salmonella* spp. and generic *E. coli*. *E. coli* O157 and *Salmonella* spp. are pathogenic bacteria while generic *E. coli* is an indicator of the overall hygienic and sanitary conditions under which the samples have been produced, processed, stored, and transported.

## What methods were used to test the samples

Samples were analyzed using analytical methods published in Health Canada's *Compendium of Analytical Methods for the Microbiological Analysis of Foods*<sup>10</sup> that were appropriate for the testing of plant-based meat alternatives.

## How were the samples assessed

The samples were assessed using criteria based on the principles of Health Canada's *Health Products and Food Branch (HPFB) Standards and Guidelines for Microbiological Safety of Food – An Interpretive Summary*<sup>11</sup>, *Guidance document for E. coli O157:H7 and E. coli O157:NM in raw beef*<sup>12</sup>, and the *Food and Drugs Act*<sup>13</sup> (Section 4(1)).

**Table 1 - Assessment criteria**

| Bacteria               | Satisfactory            | Investigative           | Unsatisfactory |
|------------------------|-------------------------|-------------------------|----------------|
| <i>E. coli</i> O157    | Not detected            | Not applicable          | Detected       |
| <i>Salmonella</i> spp. | Not detected            | Not applicable          | Detected       |
| Generic <i>E. coli</i> | ≤ 10 <sup>2</sup> CFU/g | > 10 <sup>2</sup> CFU/g | Not applicable |

No assessment guidelines had been established in Canada for the presence of *E. coli* O157, *Salmonella* spp., or indicator organisms in plant-based meat alternatives at the time of writing this report.

As *E. coli* O157 and *Salmonella* spp. are considered pathogenic to humans the presence of either was considered to be a violation of the *Food and Drugs Act*<sup>13</sup> Section 4(1) and assessed as unsatisfactory.

Unlike bacterial pathogens, most strains of generic *E. coli* are harmless. Generic *E. coli* is considered to be an indicator organism as their levels present in a food product are used to assess the overall sanitation conditions throughout the food chain from production to the point of sale. Their presence at some levels is tolerated, however elevated levels were assessed as investigative, possibly resulting in further follow-up actions.

## What were the survey results

Almost all (99.7%) of the samples tested were found to be satisfactory. *E. coli* O157 and *Salmonella* spp. were not found in any of the samples. Generic *E. coli* at elevated levels (>10<sup>2</sup> CFU/g) were found in 3 of the 954 (0.3%) samples.

**Table 2 - Assessment results**

| Bacterial analysis     | Number of samples tested | Satisfactory (%)  | Investigative (%) | Unsatisfactory |
|------------------------|--------------------------|-------------------|-------------------|----------------|
| <i>E. coli</i> O157    | 954                      | 951               | Not applicable    | 0              |
| <i>Salmonella</i> spp. |                          |                   | Not applicable    | 0              |
| Generic <i>E. coli</i> |                          |                   | 3                 | Not applicable |
| <b>Total</b>           | <b>954</b>               | <b>951 (99.7)</b> | <b>3 (0.3)</b>    | <b>0</b>       |

Survey results are also presented by product type (table 3), production practice (table 4), origin (table 5), and main ingredient (table 6).

**Table 3 - Assessment results by product type**

| Product type                  | Number of samples tested (%) | Satisfactory | Investigative |
|-------------------------------|------------------------------|--------------|---------------|
| Raw plant-based bites         | 19 (2.0)                     | 19           | 0             |
| Raw plant-based buffalo wings | 1 (0.1)                      | 1            | 0             |
| Raw plant-based burgers       | 602 (63.1)                   | 599          | 3             |
| Raw plant-based patties       | 65 (6.8)                     | 65           | 0             |
| Raw plant-based sausage       | 264 (27.7)                   | 264          | 0             |
| Raw plant-based ground        | 3 (0.3)                      | 3            | 0             |
| <b>Total</b>                  | <b>954</b>                   | <b>951</b>   | <b>3</b>      |

**Table 4 - Assessment results by production practice**

| Production practice | Number of samples tested (%) | Satisfactory (%)  | Investigative (%) |
|---------------------|------------------------------|-------------------|-------------------|
| Conventional        | 921 (96.5)                   | 918               | 3                 |
| Organic             | 33 (3.5)                     | 33                | 0                 |
| <b>Total</b>        | <b>954</b>                   | <b>951 (99.7)</b> | <b>3 (0.3)</b>    |

**Table 5 - Assessment results by product origin**

| Product origin                             | Number of samples tested (%) | Satisfactory | Investigative |
|--|------------------------------|--------------|---------------|
| Canada                                     | 7 (0.7)                      | 7            | 0             |
| Mexico                                     | 43 (4.5)                     | 43           | 0             |
| United Kingdom                             | 4 (0.4)                      | 4            | 0             |
| United States                              | 272 (28.5)                   | 272          | 0             |
| Unknown <sup>a</sup>                       | 159 (16.7)                   | 157          | 2             |
| Unknown <sup>a</sup> (processed in Canada) | 469 (49.2)                   | 468          | 1             |
| <b>Total</b>                               | <b>954</b>                   | <b>951</b>   | <b>3</b>      |

<sup>a</sup> Country of origin could not be assigned from the product label or available sample information.

**Table 6 - Assessment results by product's main<sup>b</sup> ingredient**

| Product's main <sup>b</sup> ingredient | Number of samples tested (%) | Satisfactory | Investigative |
|--|------------------------------|--------------|---------------|
| Beets                                  | 6 (0.6)                      | 6            | 0             |
| Black beans                            | 23 (2.4)                     | 23           | 0             |
| Carrots                                | 19 (2.0)                     | 19           | 0             |
| Cauliflower                            | 6 (0.6)                      | 6            | 0             |
| Chickpeas                              | 62 (6.5)                     | 62           | 0             |
| Corn                                   | 21 (2.2)                     | 21           | 0             |
| Fava beans                             | 1 (0.1)                      | 1            | 0             |
| Kale                                   | 14 (1.5)                     | 14           | 0             |
| Millet                                 | 30 (3.1)                     | 30           | 0             |
| Mushrooms                              | 2 (0.2)                      | 2            | 0             |
| Pea protein                            | 707 (74.1)                   | 704          | 3             |
| Potatoes                               | 11 (1.2)                     | 11           | 0             |
| Quinoa                                 | 6 (0.6)                      | 6            | 0             |
| Red peppers                            | 1 (0.1)                      | 1            | 0             |
| Rice                                   | 34 (3.6)                     | 34           | 0             |
| Seitan (Water and gluten)              | 10 (1.0)                     | 10           | 0             |
| Walnut                                 | 1 (0.1)                      | 1            | 0             |
| <b>Total</b>                           | <b>954</b>                   | <b>951</b>   | <b>3</b>      |

<sup>b</sup> The first ingredient in the list of ingredients.

## What do the survey results mean

No previously published studies on the microbiological quality or safety of raw non-soy plant-based meat alternatives were found at the time of writing this report. During the same time period, another targeted survey<sup>14</sup> was conducted on the microbiological quality and safety of ready-to-eat (RTE) non-soy plant-based meat alternatives. In both studies, no pathogens were detected in any of the samples, while generic *E. coli* at levels > 10<sup>2</sup> CFU/g were detected in 0.3% (3 of 954) of the raw samples and none (0 of 1026) of the RTE samples.

Overall, our survey results indicate that raw plant-based meat alternatives sold in Canada are generally safe for consumption. However, as with all foods, good hygienic practices are recommended for producers, retailers and consumers.

## What is done with the survey results

All results are used to:

- inform risk management decisions
- support program design and re-design

The investigative samples triggered appropriate follow-up activities which may have included:

- on-site visit of the manufacturer
- review of manufacturer production and sanitation practices
- review of records and inspection of equipment and establishment conditions

## Can I access the survey data

Yes. The data will be accessible on the [Open Government Portal](#).

## References

1. Canadian Food Inspection Agency, [Food chemistry and microbiology](#).
2. Canadian Food Inspection Agency, [2014-2016 Bacterial Pathogens in Soy Products](#). 2017.
3. Shurtleff, W. and A. Aoyagi. [History of Fermented Tofu - A Health NonDairy / Vegan Cheese \(1610-2011\): Extensively Annotated Bibliography and Sourcebook](#). 2011.
4. Agri-food Innovation Council, [Plant-based protein market.Global and Canadian market analysis. March 2019](#). 2022.
5. Canadian Food Inspection Agency, [Lightlife Smart Ground brand Original – Plant-Based Crumbles recalled due to pouch integrity defects](#). 2021.
6. Canadian Food Inspection Agency, [Beyond Meat brand Beyond Burger Plant-based Burgers recalled due to pieces of wood](#). 2022.
7. U.S Food and Drug Administration, [Investigation of Adverse Event Reports: French Lentil & Leek Crumbles \(June 2022\)](#). 2022.
8. Centers for Disease Control and Prevention, [Botulism Associated with Home-Fermented Tofu in Two Chinese Immigrants - New York City, March-April 2012](#). MMWR, 2013. 62(26): 529-532.
9. Centers for Disease Control and Prevention, [Wholesome Soy Products, Inc. Sprouts and Investigation of Human Listeriosis Cases \(Final Update\)](#). 2015.
10. Health Canada, [Compendium of Analytical Methods](#). 2011.
11. Health Canada, [Health Products and Food Branch \(HPFB\) Standards and Guidelines for Microbiological Safety of Food - An Interpretive Summary](#). 2008.
12. Health Canada, [Guidance Document on E. coli O157:H7 and E. coli O157:NM in Raw Beef](#). 2011.
13. Health Canada, [Food and Drugs Act, RSC 1985, c F-27](#). 1985.
14. Canadian Food Inspection Agency, [Bacterial Pathogens and Indicators in Ready-to-eat Non-Soy Plant-based Meat Alternatives - April 1, 2020 to March 31, 2023](#). 2023.