Essay

# Epidemiological behavior of *Salmonella* sp. in plant-based foods by intercontinental region

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## Abstract

The epidemiological behavior and specific serotypes of *Salmonella* sp. in plant-based foods are represented by state, country, and intercontinental region. Histograms show incidences of outbreaks in the population of Africa, Europe and North America, spatial distribution of serotypes and the cumulative relative frequency curve. The foodborne diseases were due to *Salmonella* Infantis, *S.* Derby, *S.* Enteritidis, *S.* 1,4,[5],12:i:-, *S.* Agona, *S.* Panama, *S.* Typhi, *S.* Braenderup, *S.* Typhimurium, *S.* Newport, *S.* Saintpaul, *S.* Poona, *S.* Abony, *S.* Urbana, *S.* Adelaide and *S.* Uganda. On the African continent, the epidemiological behavior of *S. enterica* showed significant statistical differences ($p \leq 0.0001$), with cumulative prevalence for North Africa (49.9%), East Africa (12%), South Africa (3%), and West and Central Africa (13%), in contrast to the incidence observed for non-typhoid *S.* In Europe, the epidemiological behavior of *Salmonella* sp. by year of study showed statistically significant differences ($p \leq 0.0001$) in the observed incidence among 28 countries, also, the Fi of outbreaks of *Salmonella* sp. was higher in the last year. Between the United States and Mexican states, significant differences ($p \leq 0.0001$) were also observed in the incidence of the number of epidemiological outbreaks by year. However, as of 2019, a decrease in the epidemiological curve was observed. Among the regions of Africa, Europe and North America, the epidemiological behavior of *Salmonella* sp. presented incidences of 4.08, 30.82 and 65.1% respectively, due to the consumption of contaminated plant-based foods.

**Keywords:** cross-contamination, enterobacteria, foodborne disease, risk analysis.

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## Contamination of plant foods of agricultural origin

In 2014, the World Health Organization (WHO) defined foodborne diseases (FBDs) as a major public health problem in the world and the main index of mortality in infants under five years of age (1.5 million per year) in developing countries. Epidemiological outbreaks caused by FBDs in humans can be due to consumption of plant-based foods, contaminated with pathogenic bacteria transmitted during primary production, until the harvest of food (Hernández *et al*., 2011), due to incorrect use of water for irrigation, cross-contamination during harvest practices, vegetable washing process after harvest and food handling in packaging, transport and shelf life (ICMSF, 2005; Jung *et al*., 2014).

Also, due to the interaction of pathogenic microorganisms of the families *Enterobacteriaceae* and *Vibrionaceae*, Gram-negative bacteria, *Staphylococcus* sp., Gram-positive bacteria (Soto *et al*., 2016). The main genera and species are *Vibrio* sp., *Campylobacter* sp., *Yersinia enterocolitica*, *Shigella flexneri*, *Listeria monocytogenes*, *Escherichia coli* and *Salmonella* sp., the latter is the main precursor of FBDs in animals and humans (50%) (OMS, 2005; Betancor *et al*., 2006; Barreto *et al*., 2016; Andrews *et al*., 2021), which presents epidemiological impact in the world due to the effects on public health (Alam, 2014; Anderson *et al*., 2016; Soodb *et al*., 2018).

## Epidemiological behavior and spatial distribution of *Salmonella* sp. by region

In 2021, the US. Food & Drug Administration (FDA) recognizes that gastroenteritis and typhoid fever have an epidemiological effect of global distribution and are periodically expressed in developed and developing countries (Andrews *et al*., 2021). Annually there are 153 million epidemiological outbreaks caused by *Salmonella*, 91.28% is transmitted by food and 8.72% due to an unknown cause. Fifty-seven thousand cases end in deaths from non-typhoid *Salmonella* (NTS) (Majowicz *et al*., 2010; Healy and Bruce, 2018). The severity caused by *Salmonella* sp., with respect to human infections, varies depending on the serotype involved which affects children under five years of age, the elderly (Nair *et al*., 2015) and immunosuppressed patients (Majowicz *et al*., 2010).

## Distribution of *Salmonella* sp. in the African continent

In Africa, *Salmonella* sp. affects the public health of inhabitants by region (Majowicz *et al*., 2010; Reddy *et al*., 2010). From 1984 to 2006, human epidemiological outbreaks caused by *Salmonella* species were monitored among the five regions of the continent (Table 1). The epidemiological behavior of *S. enterica* in the regions of the continent showed significant statistical differences ($p\leq$ 0.0001) in the cumulative prevalence in North Africa (49.9%), East Africa (12%), South Africa (3%) and West and Central Africa (13%) (Reddy *et al*., 2010).

The increase in outbreaks of *S. enterica* contamination among regions of the continent may be due to population growth, who demands food products without safety and hygiene measures, availability of drinking water, application of good agricultural practices to produce safe foods and viability of international trade to offer healthy foods (Mtove *et al*., 2010; FAO, 2017). In Algeria, Egypt, Jordan, Lebanon, Libya, Morocco, Iraq, Pakistan, Palestine, Saudi Arabia, Sudan, Tunisia, Oman, Palestine and the United Arab Emirates, percentages of *S.* Enteritidis (29.8%), *S.* Typhimurium (23.6%), *S.* Kentucky (20.3%) and other salmonella (26.3%) were detected (Al-Rifai *et al*., 2019). The incidence of *Salmonella* sp. was due to the percentage in salads and sandwiches (25%), fresh fruits and vegetables (5.8%), meat products, dairy, egg and seafood (69.2%) (Al-Rifai *et al*., 2019).

**Table 1**. **Incidence of *Salmonella* sp. due to consumption of contaminated plant-based foods in the African continent from 1984 to 2006.**

| Region | Serotype | No. of cases | Infected population | Incidence (%) |
|---|---|---|---|---|
| North Africa | *S. enterica* | 10 230 | 5 105 | 49.9 ±0.75 a |
| East Africa | | 21 317 | 2 558 | 12 ±0.55 c |
| South Africa | | 23 893 | 717 | 3 ±0.25 d |
| West and Central Africa | | 5 887 | 765 | 13 ±0.8 b |
| North Africa | *S. no* typhoid | 10 230 | 5 125 | 50.1 ±0.15 c |
| East Africa | | 21 317 | 18 759 | 88 ±0.5 b |
| South Africa | | 23 893 | 23 176 | 97 ±0.5 a |
| West and Central Africa | | 5 887 | 5 122 | 87 ±0.5 b |

Levels not connected by the same letter are significantly different. Data extracted and analyzed from Reddy *et al*. (2010).

## Status of *Salmonella* sp. in Europe

In 2017, the European Food Safety Authority (EFSA) and the European Centre for Disease Prevention and Control (ECDC) reported cases of *Salmonella* sp. infection, in 28 countries from 2012 to 2016 (94 278, 87 753, 92 012, 94 597 and 94 530, respectively) (Table 2) (EFSA and ECDC, 2017). By year, the incidence on the epidemiological behavior of *Salmonella* sp. among the countries of the continent showed significant statistical differences ($p \leq 0.0001$).

**Table 2. Epidemiological behavior of *Salmonella* sp. due to consumption of contaminated plant-based foods among regions of the European continent.**

| Country | Year/Incidence (%) | | | | |
|---|---|---|---|---|---|
| | 2012 | 2013 | 2014 | 2015 | 2016 |
| Austria | 1.88 ±0.01 m | 1.6 ±0.1 m | 1.8 ±0.1 k | 1.63 ±0.01 l | 1.5 ±0.1 h |
| Belgium | 3.29 ±0.01 j | 2.88 ±0.01 k | 2.93 ±0.01 i | 3.35 ±0.01 i | 2.97 ±0.01 g |
| Bulgaria | 0.89 ±0.01 o | 0.87 ±0.01 q | 0.79 ±0.01 p | 1.14 ±0.01 n | 0.76 ±0.01 ij |
| Croatia | 0 ±0 w | 0 ±0 w | 1.62 ±0.01 m | 1.68 ±0.01 kl | 1.31 ±0.01 hi |
| Cyprus | 0.1 ±0.01 v | 0.09 ±0.01 vw | 0.1 ±0.01 t | 0.07 ±0.01 t | 0.08 ±0.01 k |
| Czech Republic | 10.67 ±0.01 b | 11.16 ±0.01b | 14.41 ±0.01 b | 13.12 ±0.01 b | 12.28 ±0.01 b |
| Denmark | 1.28 ±0.01 n | 1.3 ±0.1 o | 1.22 ±0.01 n | 0.98 ±0.01 o | 1.14 ±0.01 hi |
| Estonia | 0.26 ±0.01 t | 0.21 ±0.01 t | 0.1 ±0.01 t | 0.12 ±0.01 t | 0.37 ±0 jk |
| Finland | 2.34 ±0.01 l | 2.26 ±0.01 l | 1.76 ±0.01 kl | 1.74 ±0.01 k | 1.6 ±0.1 h |
| France | 9.23 ±0.01 d | 10.17 ±0.01 c | 9.65 ±0.01 c | 10.89 ±0.01 c | 9.39 ±0.01 d |
| Germany | 21.74 ±0.01 a | 21.31 ±0.01 a | 17.39 ±0.01 a | 14.45 ±0.01 a | 13.6 ±0.1 a |
| Greece | 0.43 ±0.01 r | 0.47 ±0.01 r | 0.38 ±0.01 r | 0.49 ±0.01 p | 0.78 ±0.01 ij |

| Country | Year/Incidence (%) | | | | |
|---|---|---|---|---|---|
| | 2012 | 2013 | 2014 | 2015 | 2016 |
| Hungary | 5.79 ±0.01 f | 5.64 ±0.01 g | 5.7 ±0.1 f | 5.17 ±0.01 g | 5 ±0.1 e |
| Ireland | 0.33 ±0.01 s | 0.37 ±0.01 s | 0.28 ±0.01 r | 0.29 ±0.01 s | 0.32 ±0.01 jk |
| Italy | 5.12 ±0.01 g | 5.75 ±0.01 f | 4.85 ±0.01 g | 4.04 ±0.01 h | 4.37 ±0.01 f |
| Latvia | 0.58 ±0.01 q | 0.44 ±0.01 rs | 0.3 ±0.1 r | 0.4 ±0.1 qr | 0.48 ±0.01 jk |
| Lithuania | 1.87 ±0.01 m | 1.37 ±0.01 o | 1.24 ±0.01 n | 1.14 ±0.01 n | 1.14 ±0.01 hi |
| Luxembourg | 0.14 ±0.01 uv | 0.14 ±0.01 tuv | 0.12 ±0.01 t | 0.11 ±0.01 t | 0.11 ±0.01 k |
| Malta | 0.09 ±0.01 v | 0.1 ±0.01 v | 0.14 ±0.01 st | 0.13 ±0.01 t | 0.17 ±0.01 jk |
| Holland | 2.33 ±0.01 l | 1.12 ±0.01 p | 1.05 ±0.01 o | 1.03 ±0.01 u | 1.22 ±0.01 hi |
| Poland | 8.44 ±0.01 e | 8.34 ±0.01 e | 8.74 ±0.01 d | 8.72 ±0.01 f | 10.28 ±0.01 c |
| Portugal | 0.2 ±0.01 tu | 0.19 ±0.01 tu | 0.27 ±0.01 rs | 0.34 ±0.01 rs | 0.4 ±0.1 jk |
| Romania | 0.74 ±0.01 p | 1.48 ±0.01 n | 1.64 ±0.01 lm | 1.41 ±0.01 m | 1.56 ±0.01 h |
| Slovakia | 4.91 ±0.01 h | 4.34 ±0.01 i | 4.43 ±0.01 h | 5.12 ±0.01 g | 5.61 ±0.01 e |
| Slovenia | 0.42 ±0.01 r | 0.36 ±0.01 s | 0.65 ±0.01 q | 0.42 ±0.01 q | 0.33 ±0.01 jk |
| Spain | 4.48 ±0.01 i | 5.17 ±0.01 h | 7.21 ±0.01 e | 9.53 ±0.01 e | 10.39 ±0.01 c |
| Sweden | 3.1 ±0.1 k | 3.24 ±0.01 j | 2.4 ±0.1 j | 2.44 ±0.01 j | 2.38 ±0.01 g |
| United Kingdom | 9.35 ±0.01 c | 9.65 ±0.01 d | 8.8 ±0.1 d | 10.03 ±0.01 d | 10.47 ±0.01 c |

Levels not connected by the same letter are significantly different. Data extracted and analyzed from EFSA-ECDC (EFSA and ECDC, 2017).

Figure 1 shows the epidemiological behavior of *Salmonella* sp. in a histogram with incidence of outbreaks in the population of 28 countries in Europe from 2012 to 2016. The cumulative relative frequency (Fi) curve is presented, which was obtained based on the following formula: $Fi=\frac{Ni}{n}$. Where: Fi= cumulative relative frequency; Ni= cumulative absolute frequency; and n= absolute frequency. The arithmetic mean was calculated with the average number of epidemiological outbreaks obtained from data extracted and analyzed from EFSA-ECDC (2017).

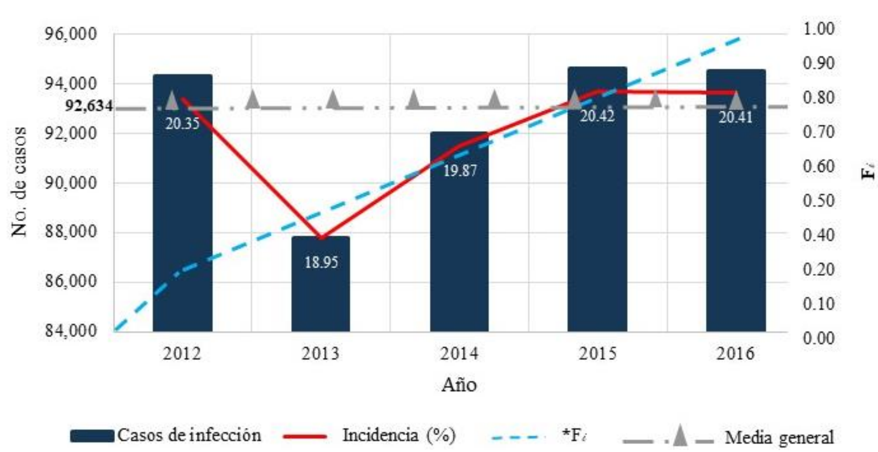


**Figure 1. Histogram of incidence of *Salmonella* sp. in 28 countries in Europe due to consumption of contaminated plant-based foods.** Data extracted and analyzed from EFSA-ECDC (2017).

The histogram showed that the Fi of outbreaks of *Salmonella* sp. was higher in the last year. In the same period, the epidemiological behavior of *Salmonella* sp. present in fresh fruits and vegetables was 28 512, 10 684, 10 652, 7 370 and 8 013 cases respectively, with serotypes *S.* Enteritidis, *S.* Typhimurium monophasic, *S.* Typhimurium, *S.* Infantis and *S.* Derby (EFSA and ECDC, 2016; EFSA and ECDC, 2017).

**Situation of *Salmonella* sp. in North America**

The US. Centers for Disease Control and Prevention (CDC) reported 1.35 million *Salmonella* sp. infections per year in humans due to consuming contaminated foods, of the total cases 420 end in death (CDC, 2021). From 2010 to April 2021, the epidemiological behavior of salmonellosis in the population of the United States of America (USA), 3 246 reported cases due to the consumption of fresh plant-based foods contaminated with *Salmonella* sp. were studied. By year, the epidemiological behavior of *Salmonella* sp. serotypes among the states showed significant statistical differences ($p \leq 0.0001$) in incidence (Table 3).

**Table 3. Incidence and spatial distribution of *Salmonella* serotypes due to consumption of contaminated plant-based foods by US. state from 2010 to April 2021.**

| Year | State | Food | Serotype | Incidence (%) |
|---|---|---|---|---|
| 2010 | CA y NV | Mamey pulp | *S*. Typhi | 0.28 ±0.01 o |
| | IL, MO, IN, PA, WI, MA, NY, TN, VA, CT, AR, CA, CO, DC, GA, HI, IA, KY, LA, MD, NE, NV, NJ, NC, OR, SC y SD | Alfalfa sprouts | *S*. 1,4, [5], 12 i: | 4.31 ±0.01 d |
| 2011 | NY | Turkish pine nuts | *S*. Enteritidis | 1.32 ±0.01 l |
| | TX, IL, NY, CA, GA, WA, AZ, MN, MO, NM, NE, VA, WI, LA, PA, AR, CO, IN, KY, MA, NV, NJ, OH, OK, y TN | Papaya | *S*. Agona | 3.27 ±0.01 g |
| | OR, WA, CA, AZ, CO, MD, MT, NV, UT y PA | Melon | *S*. Panama | 0.62 ±0.01 n |
| 2012 | WA, HI, NY, TX, IL, DE, ID, ME, MI, MT, NE, NJ, OR y WI | Daniela mango | *S*. Braenderup | 3.91 ±0.01 e |
| | KY, IL, IN, AL, MO, GA, IA, WI, MI, TN, MS, AR, OH, NC, SC, MN, NJ, PA, TX, FL, MD, MT, OK y VA. | Melon | *S*. Typhimurium y *S*. Newport | 8.04 ±0.01 c |
| 2013 | CA, AZ, MN, TX, IL, NC, VA, OH, CO, ID, NM, SD, WI, OR, LA, MD, MA y NV | Cucumbers | *S*. Saintpaul | 2.59 ±0.01 i |

| Year | State | Food | Serotype | Incidence (%) |
|---|---|---|---|---|
| 2014 | MA, NY, PA, CT, RI, MD, NH, ME, OH, VT, MT y VA | Soybean sprouts | *S*. Enteritidis | 3.54 ±0.01 f |
| 2015 | Without registration | Cucumbers | *S*. Poona | 27.94 ±0.01 b |
| 2016 | CO, KS, NE, WY, MN, MO, NY, OR y TX | Alfalfa sprouts | *S*. Abony | 1.11 ±0.01 m |
| 2017 | NJ, NY y PA | Maradol papaya | *S*. Urbana | 0.22 ±0.01 p |
| 2018 | MI, IN, MO, IL, OH, AR, FL, KY y TN | Melon | *S*. Adelaide | 2.37 ±0.01 k |
| 2019 | NY, NJ, CT, MA, PA, FL, DE, RI y TX | Papaya | *S*. Uganda | 2.5 ±0.01 j |
| 2020 | WA, CA, UT, OR, MT, IL, MI, ID, AZ, CO, IA, WY, PA, AK, SD, MN, NY, NV, GA, MO, OH, WI, NJ, NE, VA, ND, FL, MD, TN, ME, NC, MS, IN, HI, KS, KY, NM, RI, WV, AL, AR, CT, DE, MA, TX, NH, OK y SC | Onion | *S*. Newport | 34.72 ±0.01 a |
| | MN, MI, NY, IA, NJ, WI, PA, VA, MO, CA, CT, IL, KS, KY, MD, OH y VT | Peaches | *S*. Enteritidis | 3.11 ±0.01 h |
| 2021 | FL, CA y TN | Plant-based products | *S*. Duisburg | 0.15 ±0.01 q |

AL= Alabama; AK= Alaska; AZ= Arizona; AR= Arkansas; CA= California; NC= North Carolina; SC= South Carolina; CO= Colorado; CT= Connecticut; ND= North Dakota; SD= South Dakota; DE= Delaware; DC= District of Columbia; FL= Florida; GA= Georgia; HI= Hawaii; ID= Idaho; IL= Illinois; IN= Indiana; IA= Iowa; KS= Kansas; KY= Kentucky; LA= Louisiana; ME= Maine; MD= Maryland; MA= Massachusetts; MI= Michigan; MN= Minnesota; MS= Mississippi; MO= Missouri; MT= Montana; NE= Nebraska; NV= Nevada; NH= New Hampshire; NJ= New Jersey; NY= New York; NM= New Mexico; OH= Ohio; OK= Oklahoma; OR= Oregon; PA= Pennsylvania; RI= Rhode Island; TN= Tennessee; TX= Texas; UT= Utah; VT= Vermont; VA= Virginia; WV= West Virginia; WA= Washington; WI= Wisconsin; WY= Wyoming. Levels not connected by the same letter are significantly different. Data extracted and analyzed from CDC and FDA (2010; 2011a; 2011b; 2011c; 2011d; 2012a; 2012b; 2013; 2014; 2015; 2016; 2017; 2018; 2019; 2020a; 2020b; 2021).

Figure 2 shows the epidemiological behavior of *Salmonella* sp. in a histogram with the incidence of serotypes and the Fi curve present in the USA from 2010 to April 2021. In this country, the epidemiological impact of *Salmonella* sp. that occurs throughout history is due to the diversity of serotypes, in addition to the expression and typing of virulence genes by serotype. In 2015 and 2020, the highest peak of epidemiological outbreaks due to *Salmonella* sp. was observed, it was also observed that, due to health management measures, the disease was flattened and controlled. However, in recent years the incidence and the F*i* curve may be indicators of the epidemiological behavior of *Salmonella* serotypes, which interact with the population due to the consumption of contaminated foods.

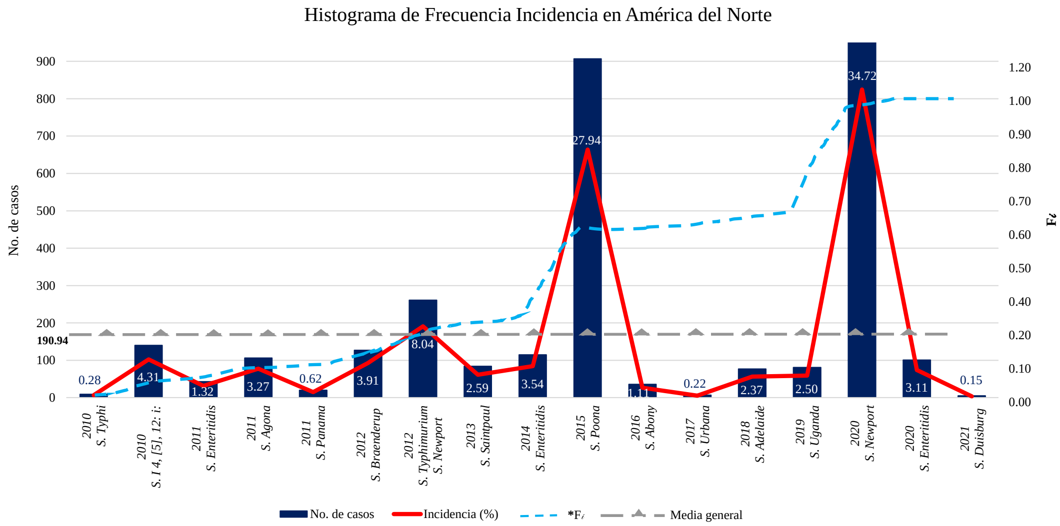


**Figure 2. Histogram of Incidence of *Salmonella* sp. serotypes in the United States of North America due to consumption of contaminated plant-based foods.** Data extracted and analyzed from CDC and FDA (2010-2021).

## Epidemiological behavior of *Salmonella* sp. in Mexico

The National Epidemiological Surveillance System of the General Directorate of Epidemiology (SINAVE-DGE), for their acronyms in Spanish of the Secretariat of Health of Mexico, from 2010 to April 202, reported 975 321 infections by *Salmonella* sp. in humans for consuming contaminated plant-based foods (SINAVE-DGE-SSM, 2021a and 2021b). Table 4 shows by state the epidemiological behavior of *Salmonella* sp. present in plant-based foods. By year, the incidence of epidemiological behavior of *Salmonella* sp. showed significant statistical differences ($p\leq 0.0001$) between states.

**Table 4. Epidemiological behavior of *Salmonella* sp. due to consumption of contaminated plant-based foods by state in Mexico from 2010 to April 2021.**

| State | Year/incidence (%) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
| Aguascalientes | 2.35 $\pm 0.01^{n}$ | 2.19 $\pm 0.01^{k}$ | 2.25 $\pm 0.01^{j}$ | 2.11 $\pm 0.01^{m}$ | 0.93 $\pm 0.01^{r}$ | 1.48 $\pm 0.01^{q}$ | 1.88 $\pm 0.01^{m}$ | 1.25 $\pm 0.01^{o}$ | 0.62 $\pm 0.01^{r}$ | 0.7 $\pm 0.01^{q}$ | 0.44 $\pm 0.01^{t}$ | 0.48 $\pm 0.01^{s}$ |
| Baja California | 1.68 $\pm 0.01^{p}$ | 1.49 $\pm 0.01^{n}$ | 1.52 $\pm 0.01^{o}$ | 1.47 $\pm 0.01^{q}$ | 2.06 $\pm 0.01^{l}$ | 2.66 $\pm 0.01^{j}$ | 2.26 $\pm 0.01^{k}$ | 1.36 $\pm 0.01^{n}$ | 1.24 $\pm 0.01^{n}$ | 0.84 $\pm 0.01^{p}$ | 0.8 $\pm 0.01^{q}$ | 0.33 $\pm 0.01^{t}$ |
| Baja California Sur | 0.35 $\pm 0.01^{z}$ | 0.29 $\pm 0.01^{w}$ | 0.25 $\pm 0.01^{x}$ | 0.27 $\pm 0.01^{x}$ | 0.18 $\pm 0.01^{y}$ | 0.21 $\pm 0.01^{y}$ | 0.23 $\pm 0.01^{z}$ | 0.24 $\pm 0.01^{w}$ | 0.21 $\pm 0.01^{w}$ | 0.16 $\pm 0.01^{v}$ | 0.16 $\pm 0.01^{yz}$ | 0.25 $\pm 0.01^{u}$ |
| Campeche | 1.28 $\pm 0.01^{r}$ | 1.25 $\pm 0.01^{q}$ | 1.11 $\pm 0.01^{p}$ | 1.65 $\pm 0.01^{o}$ | 1.38 $\pm 0.01^{o}$ | 1.8 $\pm 0.01^{n}$ | 1.55 $\pm 0.01^{q}$ | 0.71 $\pm 0.01^{r}$ | 0.42 $\pm 0.01^{t}$ | 0.09 $\pm 0.01^{wx}$ | 0.15 $\pm 0.01^{z}$ | 0.23 $\pm 0.01^{u}$ |
| Coahuila | 9.22 $\pm 0.01^{d}$ | 7.74 $\pm 0.01^{d}$ | 8.43 $\pm 0.01^{d}$ | 8.57 $\pm 0.01^{d}$ | 7.86 $\pm 0.01^{d}$ | 4.12 $\pm 0.01^{f}$ | 1.67 $\pm 0.01^{p}$ | 6.14 $\pm 0.01^{e}$ | 2.34 $\pm 0.01^{i}$ | 3.35 $\pm 0.01^{g}$ | 2.2 $\pm 0.01^{k}$ | 1.68 $\pm 0.01^{k}$ |

| State | Year/incidence (%) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
| Colima | 0.26 ±0.01[∞] | 0.12 ±0.01[x] | 0.11 ±0.01[y] | 0.13 ±0.01[z] | 0.19 ±0.01[y] | 0.22 ±0.01[y] | 0.18 ±0.01[∞] | 0.16 ±0.01[x] | 0.19 ±0.01[w] | 0.11 ±0.01[w] | 0.2 ±0.01[x] | 0.33 ±0.01[t] |
| Chiapas | 18.16 ±0.01[a] | 20.35 ±0.01[a] | 21.21 ±0.01[a] | 23.06 ±0.01[a] | 28.55 ±0.01[a] | 26.17 ±0.01[a] | 27.03 ±0.01[a] | 24.31 ±0.01[a] | 25.73 ±0.01[a] | 25.54 ±0.01[a] | 29.99 ±0.01[a] | 32.07 ±0.01[a] |
| Chihuahua | 5.1 ±0.01[e] | 4.74 ±0.01[e] | 4.17 ±0.01[e] | 4.44 ±0.01[e] | 2.66 ±0.01[j] | 3.27 ±0.01[g] | 3.55 ±0.01[f] | 4.04 ±0.01[f] | 4.18 ±0.01[e] | 4.2 ±0.01[f] | 2.98 ±0.01[h] | 3.11 ±0.01[f] |
| Mexico City | 0.91 ±0.01[v] | 1.43 ±0.01[o] | 0.64 ±0.01[t] | 0.91 ±0.01[s] | 0.55 ±0.01[w] | 0.55 ±0.01[u] | 0.62 ±0.01[w] | 0.44 ±0.01[u] | 0.98 ±0.01[p] | 1 ±0.01[o] | 0.71 ±0.01[r] | 0.85 ±0.01[p] |
| Durango | 0.02 ±0.01[δ] | 0.03 ±0.01[y] | 0.03 ±0.01[z] | 0.04 ±0.01[∞] | 0.12 ±0.01[z] | 0.01 ±0.01[z] | 0.04 ±0.01[β] | 0.02 ±0.01[y] | 0.03 ±0.01[x] | 0.01 ±0.01[y] | 0.03 ±0.01[∞] | 0.05 ±0.01[w] |
| Guanajuato | 0.51 ±0.01[y] | 0.53 ±0.01[v] | 0.53 ±0.01[u] | 0.87 ±0.01[t] | 0.66 ±0.01[u] | 0.56 ±0.01[u] | 1.09 ±0.01[r] | 1.15 ±0.01[p] | 0.95 ±0.01[p] | 1.35 ±0.01[n] | 1.25 ±0.01[p] | 1.32 ±0.01[n] |
| Guerrero | 3.47 ±0.01[i] | 3.04 ±0.01[i] | 3.49 ±0.01[h] | 3.73 ±0.01[g] | 0.87 ±0.01[s] | 1.64 ±0.01[p] | 2.2 ±0.01[l] | 1.8 ±0.01[m] | 1.81 ±0.01[l] | 1.76 ±0.01[m] | 1.96 ±0.01[m] | 1.55 ±0.01[m] |
| Hidalgo | 0.11 ±0.01[β] | 0.14 ±0.01[x] | 0.11 ±0.01[y] | 0.23 ±0.01[y] | 0.3 ±0.01[x] | 0.26 ±0.01[x] | 0.27 ±0.01[y] | 0.26 ±0.01[vw] | 0.32 ±0.01[u] | 0.34 ±0.01[t∣] | 0.19 ±0.01[xy] | 0.23 ±0.01[u] |
| Jalisco | 4.51 ±0.01[f] | 4.42 ±0.01[f] | 3.76 ±0.01[g] | 3.47 ±0.01[h] | 1.88 ±0.01[n] | 3.1 ±0.01[h] | 3.04 ±0.01[g] | 2.98 ±0.01[i] | 2.37 ±0.01[i] | 2.17 ±0.01[k] | 3.28 ±0.01[g] | 2.82 ±0.01[g] |
| State of México | 2.75 ±0.01[l] | 2.41 ±0.01[j] | 2.09 ±0.01[k] | 1.94 ±0.01[n] | 2.49 ±0.01[k] | 2.53 ±0.01[k] | 2.29 ±0.01[k] | 1.89 ±0.01[l] | 1.91 ±0.01[k] | 2.25 ±0.01[j] | 2.37 ±0.01[i] | 2.02 ±0.01[i] |
| Michoacán | 2.55 ±0.01[m] | 2.18 ±0.01[k] | 1.94 ±0.01[l] | 1.55 ±0.01[p] | 1.96 ±0.01[m] | 2.27 ±0.01[m] | 2.61 ±0.01[j] | 2.18 ±0.01[j] | 2.36 ±0.01[i] | 2.47 ±0.01[i] | 2.26 ±0.01[j] | 1.86 ±0.01[j] |
| Morelos | 0.51 ±0.01[y] | 0.75 ±0.01[t] | 0.46 ±0.01[v] | 0.33 ±0.01[w] | 0.63 ±0.01[uv] | 0.49 ±0.01[v] | 0.28 ±0.01[y] | 0.24 ±0.01[w] | 0.25 ±0.01[v] | 0.21 ±0.01[u] | 0.19 ±0.01[xy] | 0.01 ±0.01[x] |
| Nayarit | 1.06 ±0.01[u] | 1.04 ±0.01[r] | 1.71 ±0.01[m] | 2.35 ±0.01[l] | 4.35 ±0.01[f] | 4.7 ±0.01[e] | 2.94 ±0.01[h] | 2.02 ±0.01[k] | 3.3 ±0.01[f] | 5.01 ±0.01[e] | 5.02 ±0.01[e] | 2.55 ±0.01[h] |
| Nuevo León | 1.1 ±0.01[t] | 1.3 ±0.01[p] | 1.13 ±0.01[p] | 0.65 ±0.01[v] | 1.05 ±0.01[q] | 0.4 ±0.01[w] | 0.61 ±0.01[w] | 0.5 ±0.01[t] | 0.49 ±0.01[s] | 0.42 ±0.01[s] | 0.29 ±0.01[w] | 0.16 ±0.01[v] |
| Oaxaca | 2 ±0.01[o] | 1.99 ±0.01[l] | 2.06 ±0.01[k] | 2.08 ±0.01[m] | 1.99 ±0.01[m] | 1.71 ±0.01[o] | 1.78 ±0.01[o] | 1.35 ±0.01[n] | 2.06 ±0.01[j] | 2.14 ±0.01[k] | 2.04 ±0.01[l] | 1.63 ±0.01[l] |
| Puebla | 4.43 ±0.01[h] | 4.39 ±0.01[f] | 4.05 ±0.01[f] | 4.24 ±0.01[f] | 6.57 ±0.01[e] | 7.29 ±0.01[d] | 6.55 ±0.01[d] | 6.27 ±0.01[d] | 6.17 ±0.01[d] | 5.46 ±0.01[d] | 5.45 ±0.01[d] | 5.78 ±0.01[d] |
| Querétaro | 0.68 ±0.01[x] | 0.66 ±0.01[u] | 0.42 ±0.01[w] | 0.24 ±0.01[xy] | 0.12 ±0.01[z] | 0.29 ±0.01[x] | 0.4 ±0.01[x] | 0.28 ±0.01[v] | 0.19 ±0.01[w] | 0.06 ±0.01[x] | 0.03 ±0.01[∞] | 0.03 ±0.01[wx] |
| Quintana Roo | 3.16 ±0.01[j] | 3.46 ±0.01[h] | 3.43 ±0.01[i] | 2.9 ±0.01[j] | 2.86 ±0.01[i] | 2.44 ±0.01[l] | 2.94 ±0.01[h] | 3.61 ±0.01[g] | 3.14 ±0.01[g] | 1.97 ±0.01[l] | 1.52 ±0.01[o] | 1.86 ±0.01[j] |
| San Luis Potosí | 0.69 ±0.01[x] | 0.83 ±0.01[s] | 0.71 ±0.01[s] | 0.88 ±0.01[st] | 1.11 ±0.01[p] | 1.29 ±0.01[r] | 0.86 ±0.01[t] | 1.15 ±0.01[p] | 1.34 ±0.01[m] | 1.02 ±0.01[o] | 0.69 ±0.01[r] | 0.46 ±0.01[s] |
| Sinaloa | 4.47 ±0.01[g] | 4.25 ±0.01[g] | 4.04 ±0.01[f] | 2.61 ±0.01[k] | 3.71 ±0.01[g] | 2.94 ±0.01[i] | 2.78 ±0.01[i] | 3.38 ±0.01[h] | 2.95 ±0.01[h] | 2.98 ±0.01[h] | 4.07 ±0.01[f] | 4.4 ±0.01[e] |
| Sonora | 1.19 ±0.01[s] | 1.25 ±0.01[q] | 1.06 ±0.01[q] | 0.62 ±0.01[v] | 0.76 ±0.01[t] | 0.97 ±0.01[s] | 1 ±0.01[s] | 0.81 ±0.01[q] | 0.65 ±0.01[r] | 0.36 ±0.01[t] | 0.37 ±0.01[v] | 0.65 ±0.01[q] |

| State | Year/incidence (%) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
| Tabasco | 9.8 ±0.01$^{c}$ | 10.88 ±0.01$^{c}$ | 10.21 ±0.01$^{c}$ | 11.34 ±0.01$^{b}$ | 8.6 ±0.01$^{c}$ | 10.17 ±0.01$^{c}$ | 10.53 ±0.01$^{c}$ | 9.64 ±0.01$^{c}$ | 9.89 ±0.01$^{c}$ | 9 ±0.01$^{c}$ | 7.22 ±0.01$^{c}$ | 6.85 ±0.01$^{c}$ |
| Tamaulipas | 2.86 ±0.01$^{k}$ | 3.04 ±0.01$^{i}$ | 3.74 ±0.01$^{g}$ | 3.11 ±0.01$^{i}$ | 3.55 ±0.01$^{h}$ | 2.94 ±0.01$^{i}$ | 3.99 ±0.01$^{e}$ | 3.58 ±0.01$^{g}$ | 3.14 ±0.01$^{g}$ | 2 ±0.01$^{l}$ | 1.63 ±0.01$^{n}$ | 1.85 ±0.01$^{j}$ |
| Tlaxcala | 0.77 ±0.01$^{w}$ | 0.68 ±0.01$^{u}$ | 0.84 ±0.01$^{r}$ | 0.79 ±0.01$^{u}$ | 0.62 ±0.01$^{v}$ | 0.79 ±0.01$^{t}$ | 0.71 ±0.01$^{u}$ | 0.65 ±0.01$^{s}$ | 0.82 ±0.01$^{q}$ | 0.62 ±0.01$^{r}$ | 0.4 ±0.01$^{uv}$ | 0.55 ±0.01$^{r}$ |
| Veracruz | 12.01 ±0.01$^{b}$ | 11.03 ±0.01$^{b}$ | 12.35 ±0.01$^{b}$ | 10.24 ±0.01$^{c}$ | 9.8 ±0.01$^{b}$ | 10.73 ±0.01$^{b}$ | 11.62 ±0.01$^{b}$ | 15.07 ±0.01$^{b}$ | 17.55 ±0.01$^{b}$ | 20.34 ±0.01$^{b}$ | 21.04 ±0.01$^{b}$ | 22.73 ±0.01$^{b}$ |
| Yucatán | 0.5 ±0.01$^{y}$ | 0.5 ±0.01$^{v}$ | 0.56 ±0.01$^{u}$ | 1.06 ±0.01$^{r}$ | 0.52 ±0.01$^{w}$ | 0.56 ±0.01$^{u}$ | 0.67 ±0.01$^{v}$ | 1.23 ±0.01$^{o}$ | 1.24 ±0.01$^{n}$ | 1.35 ±0.01$^{n}$ | 0.43 ±0.01$^{tu}$ | 0.3 ±0.01$^{t}$ |
| Zacatecas | 1.54 ±0.01$^{q}$ | 1.61 ±0.01$^{m}$ | 1.61 ±0.01$^{n}$ | 2.09 ±0.01$^{m}$ | 1.14 ±0.01$^{p}$ | 1.46 ±0.01$^{q}$ | 1.82 ±0.01$^{n}$ | 1.26 ±0.01$^{o}$ | 1.14 ±0.01$^{o}$ | 0.71 ±0.01$^{q}$ | 0.59 ±0.01$^{s}$ | 1.03 ±0.01$^{o}$ |

Levels not connected by the same letter are significantly different. Data extracted and analyzed from SINAVE-DGE-SSM (2021a and 2021b).

Figure 3 shows the epidemiological behavior of *Salmonella* sp. in a histogram with incidence of salmonellosis and the Fi curve present in Mexico from 2010 to 2021. In the histogram, the Fi of *Salmonella* sp. outbreaks declined 43.75% in 2020 with respect to 2019. The epidemiological behavior in the first four-month period of 2021, the percentage of cases presented a trend of 13.24% in contrast to 2019, Chiapas, Veracruz, Tabasco, Durango, Puebla and Coahuila were the states with the highest incidence.

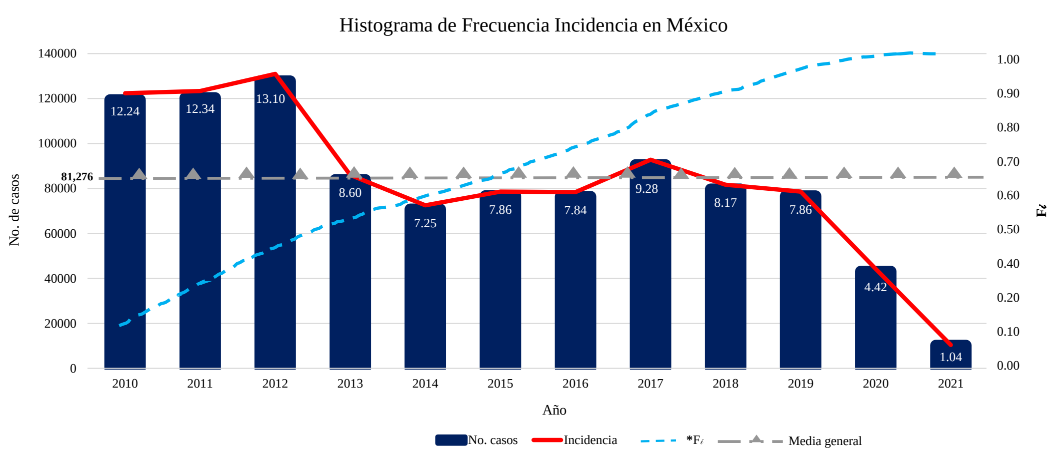


**Figure 3. Histogram of Incidence of *Salmonella* sp. in Mexico due to consumption of contaminated plant-based foods.** Data extracted and analyzed from SINAVE-DGE-SSM (2021a and 2021b).

The epidemiological behavior of *Salmonella* sp. among regions of Africa, Europe and North America presented incidences of 4.08, 30.82 and 65.1%, respectively. Figure 4 shows the histogram of salmonellosis incidence in the population by region, due to the consumption of contaminated plant-based foods, plus the Fi curve (Reddy *et al*., 2010; CDC-FDA, 2011c; EFSA-ECDC, 2017; SINAVE-DGE-SSM, 2021a and 2021b).

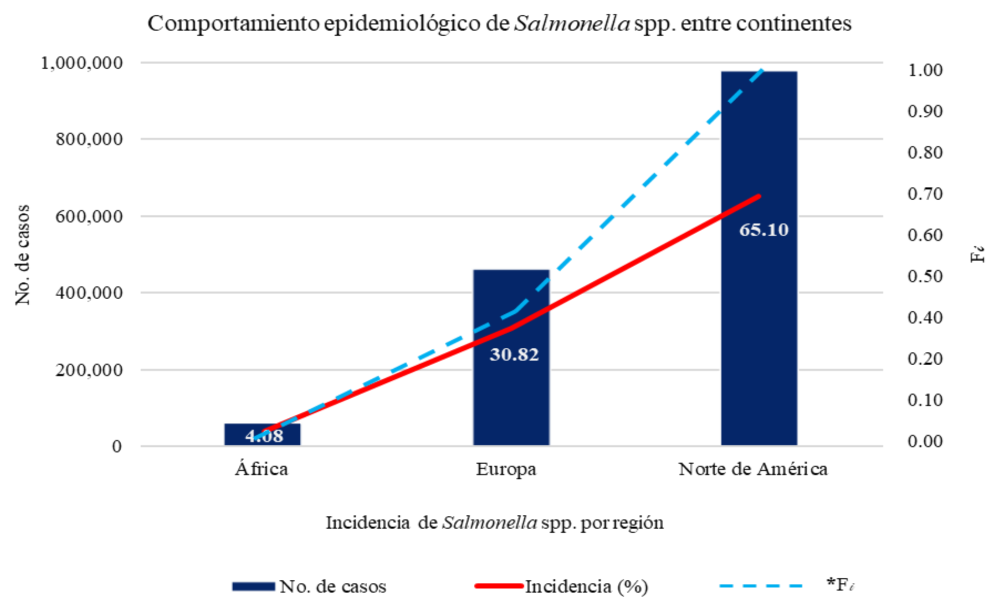


**Figure 4. Histogram of Incidence of *Salmonella* spp. among the population of the regions of Africa, Europe and North America, due to consumption of contaminated plant-based foods.** Data extracted and analyzed from Reddy *et al*. (2010), CDC-FDA (2011c), EFSA-ECDC (2017), SINAVE-DGE-SSM (2021a and 2021b).

## Conclusions

The epidemiological behavior of *Salmonella enterica* in plant-based foods showed the highest prevalence (49.9%) in the North African region. On the European continent, the epidemiological status of *Salmonella* sp. increased in 2015. In 2021, the states of the United States and Mexico showed a radical decrease in the epidemiological curve. Among the regions of Africa, Europe and North America, the epidemiological behavior of *Salmonella* sp. in plant-based foods presented incidences of 4.08, 30.82 and 65.1% respectively, due to the consumption of contaminated plant-based foods.

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