PREVELANCE OF LISTERIA IN PRODUCE. COMPARING THE TOTAL NUMBER OF FOOD RECALLS FROM THE RESULT OF *LISTERIA MONOCYTOGENES, SALMONELLA, AND ESCHERICHIA COLI* IN THE LAST TEN YEARS USING THREE YEAR INTERVALS

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Abstract

Background: Fruits, vegetables, and ready to eat processed produce are vulnerable to bacteria contamination during production, harvesting, transportation, packaging, and distribution. Agencies like the Canadian Food Inspection Agency (CFIA), and the Food and Drug Administration (FDA) regulate and create legislative policies to ensure the food is safe for public consumption. When a product does not meet CFIA or FDA regulations or if the product is tested positive to biological, chemical, or physical contamination the product will be recalled. The main objective of this study is to determine if *Listeria monocytogenes* recalls in produce have increased over the last ten years. Listeria is a food-borne pathogen that is often overlooked and underreported. The diagnosis of Listeriosis can be difficult because symptoms can take up to 70 days to surface. Despite this, it is responsible for 41% of food-borne deaths in Canada.

Methods: To determine if *Listeria* has increased over the last ten years, food recalls were collected from the CFIA, FDA, Food and Safety Inspection Service (FSIS), and Health Canada websites and recorded in Microsoft Excel. All food recalls were counted and analyzed using a one-tailed T-Test conducted in NCSS.

Results: The study concluded that produce recalls due to the pathogen *Listeria* have increased by 60% over the last ten years. During the years of 2016 to 2018 the top pathogen responsible for food recalls was *Listeria* followed by the pathogens *Salmonella* and *Escherichia coli*. The study also concluded that total food recalls during the years of 2016 to 2018 was 45% higher than ten years ago.

Conclusion: The results of this study could indicate that there is a need to increase traceability by obtaining produce through approved sources. This could allow for stricter policies, programs, and legislation regarding the use of irrigation water during production and identify breakdowns in sanitation procedures during processing and distribution.

Key Words: *Listeria*, *Listeria monocytogenes*, recalls, food recalls, *Salmonella, E. coli, Escherichia coli*, CFIA, FDA, FSIS, Health Canada

INTRODUCTION

Traditionally, lettuce has been seen as a low-risk food (35); yet, within the last year, there appears to be an increase in the number of recalls of pre-packaged salads due to a threat of *Listeria monocytogenes* contamination. As of 2018, recalls due to *Listeria monocytogenes* contamination has been occurring more frequently in produce such as microgreens, kale, frozen vegetable products, and spinach (6). The top three pathogens contaminating produce resulting in foodborne illness are *Listeria monocytogenes, Salmonella*, and *Escherichia coli*.

The majority of food recalls in Canada and the United states are due to microbiological contamination (26; 12). In the United states from 2002 to 2011 there were a total of 3,360 food recalls. 42% of recalls were due to microbiological contamination which included 71% recalls due to *Salmonella spp*. and 18% due to *Listeria monocytogenes (*12). In Canada, between 2006 and 2008 there were a total of 942 food recalls. Like the United States, the top two pathogens responsible for food recalls are *Salmonella spp*. and *Listeria* (26). Produce related outbreaks of *Salmonella*, *Listeria*, and *Escherichia coli* are becoming a common phenomenon in today's produce. This is due in part by increased consumption of fruits and vegetables by the public (25). Foodborne illness costs the United States an estimated 4.4 billion for *Salmonella*, 2 billion for *Listeria,* and 607 million for *E. coli* (34). Worldwide, *L. monocytogenes* is responsible for up to 30 percent of deaths due to foodborne illness (2).

In this study, the amount of food recalls due to *L. monocytogenes* contamination will be analyzed between the years of 2016 to 2018 and compared to the previous recalls between the years of 2006 and 2008. This study will help determine if the amount of *Listeria* recalls in produce has actually increased within the past ten years. Then total recalls of *Listeria* will be compared to *Salmonella* and *E. coli* recalls in produce to see if *Listeria* is dominating produce contamination. The total food recalls between the years of 2016 – 2018 will also be compared to total food recalls during the years of 2006 – 2008 to see if food recalls are rising.

LITERATURE REVIEW

A company will issue a food recall if there is a biological, chemical or physical contamination of the product, if the product does not comply with the law or regulations, or if the product does not meet the company's standard of quality (5; 28). Food can be recalled two ways, a voluntary recall by the food processor or by the Canadian Food Inspection Agency (CFIA) during a routine inspection, routine sampling program, or a food borne illness investigation. After a recall has

been ordered, it is the industries responsibility to find and remove all recalled products (5; 6).

Agencies, such as the CFIA and Food and Drug Administration (FDA), help regulate and create legislative policies that companies follow to make sure food is safe for the public. The CFIA conducts over 3000 investigations each year, on customer complaints, recalls, foodborne illness, routine sampling, and food tampering (28). For national recalls, the CFIA will collaborate with the United States Centers for Disease Control (CDC), and FDA in an event of serious threats to public health (6). In the United States, two agencies handle food recalls the FDA, which has a comparable classification system as the CFIA, and the Food and Safety Inspection Services Department (FSIS) that handles only meat recalls (26). In Canada, the CFIA is the main agency that handles recalls and have legislative authority to do food enforcement under the CFIA Act and Food and Drugs Act. (6; 26). Health Canada is also involved in handling product recalls. Health Canadas responsibility is to seta many of the standards used in Canada regarding food recalls. The Department of Agriculture, Food and Fisheries (MAPAQ), located in Quebec, conducts recalls in Quebec (26). All food recalls are made available to the public on CFIA, FDA, FSIS, MAPAQ, and Health Canada websites.

To determine exactly how many recalls have been done each year, a study was conducted by Macquarrie (2009), in conjunction with British Columbia Center of Disease Control (BCCDC), to manually collect recall data from Canadian and American websites including the CFIA, FDA, FSIS, Health Canada, and MAPAQ. It was determined the total number of recalls issued in 2006 to 2008 was 942. 32% of recalls were due to possible or confirmed biological hazards such as *Salmonella, Listeria*, and *E. coli*. The largest contributor of microbiological recalls was *Salmonella* at 35%, followed by *Listeria* a 29%, and *E. coli* at 13% (26).

It is important to ensure the recall system is being managed efficiently and to follow up on recalls preventing contaminated food from reaching the public. As public health officials, it is important to not only be aware of recalls but to help educate and inform the public of the potential health risks. For public health agencies, there are three major pathogens of concern that dominate food recalls. These pathogens are *Listeria monocytogenes, Salmonella*, and *Escherichia coli*.

Listeria monocytogenes

Listeria monocytogenes is the pathogen responsible for the food-borne illness Listeriosis. (1; 29; 15). Symptoms of listeriosis range from pneumonia, septicemia, meningoencephalitis, and death (29; 30; 19; 27). Listeriosis can affect any age with incidence rates that are more predominant in people over sixty, people with weakened immune symptoms, and pregnant women (19). Pregnant women are at a higher

risk as Listeria can be vertically transmitted from the mother to her unborn baby resulting in stillbirths and miscarriages. Unfortunately, the diagnosis of Listeriosis can be difficult since symptoms could take up to 70 days to surface (32). This increases the likelihood that *Listeria* could be making people ill without those affected individuals realizing they have been infected by the bacteria (19).

In Canada alone, Listeriosis is responsible for forty-one percent of food borne deaths (1; 17). Since 2009, the incidence rate of *Listeria* in BC remains unchanged. BCCDC reported that there were seventeen cases of *Listeria* in 2016, with the majority of confirmed cases among people sixty years of age or older (2). The most recent information for the Canada incidence rate of Listeriosis in 2016 is reported rate of 0.53 per 100,000 (29).

Prevalence of Listeria in Produce

After the mass outbreak of *Listeria* in Maple Leaf products in 2008, it appears that *Listeria* recalls in processed meats have decreased; however, *Listeria* is becoming more predominate in produce and pre-packaged lettuce. Its ubiquitous nature allows it to grow everywhere such as soil, water, food, contact surfaces, and it's even found in oxygen low environments (29; 30; 19; 27). Its ability to adapt is credited to several virulence factors that help increase its pathogenicity. Virulence factors such as: its ability to survive in high salt concentrations, ability to multiply in high moisture environments, and its ability to grow in temperatures as low as -0.4℃ making refrigerated food no longer safe (1; 2; 19). *Listeria* is persistent and can survive in farm fields, the pre-packaged anaerobic environment, and within food processing plants.

Bacterial pathogens can find their way on vegetables before they are picked and processed, especially if they have been irrigated with feces-contaminated waters (36). It is estimated that 18% of farms have *Listeria* growing within the soil (35). Soils play an important role in how *Listeria* finds its way into food processors by the collection of fruits and vegetables (27). A study conducted by Shenoy, Oliver, and Deering (2017) revealed that if lettuce is grown in *Listeria*-contaminated soil, the pathogen could potentially contaminate the lettuce itself. If the plant seeds become contaminated with *Listeria*, simply washing lettuce alone, will not eliminate the pathogen (35). So, it is important to control pathogen growth at the farm level.

In a pre-packaged environment, the plastic air-sealed bag or container produce is shipped in will not stop *Listeria* growth. The packaging design of pre-prepared salads is designed to lower oxygen levels to increase shelf life. However, this packaging can favor anaerobic bacteria such as *Clostridium botulism* as well as psychrophiles like *Listeria* (24). So how likely is it that pathogens are

present in pre-packaged salads even if its labeled pre-washed?

There have been studies done to test to see if pathogenic bacteria are present in pre-packaged salads. A study conducted in Sweden tested 153 samples of salads for the pathogens *Listeria, Escherichia coli, Campylobacter, Salmonella*, and *Yersinia enterocolitica*. The results indicated that 1 in 10 of the salads collected contained pathogens. Two of the pre-packaged salads containing pre-cooked meat tested positive for *Listeria* (36).

What makes the presence of *Listeria* in salads more threatening is that there is no kill step, such as cooking, to destroy the pathogen (11; 19). It can take as little as 10^3 CFU/g of *Listeria* to make people seriously ill (19). Although fatality rates associated with Listeriosis are reported, it is believed many Canadians suffer from Listeriosis more often than reported to health authorities (1). The strongest line of defense against *Listeria*-related health risks is to eliminate *Listeria* in food processing environments.

Controlling *Listeria* in food processing is difficult, especially with its high affinity to form biofilms and ability to attach firmly on to surfaces. Any processor with a well-placed Hazard Analysis of Critical Control Points (HACCP) and sanitation program in place still can be regularly invaded by these bacteria (1). The bacteria can be found on any food processing surface, from floors, knives, carts, and countertops to food slicers and other food processing equipment (1; 17; 24). To eliminate *Listeria* from food processors, the company must ensure proper training, regular sanitation, constant monitoring, and conduct regular food testing (1).

After the 2008 Maple Leaf outbreak of *Listeria* in deli meat, the CFIA increased monitoring of *Listeria* in food processing plants. A survey was conducted in 2009 by the BCCDC to determine *Listeria's* presence in BC production facilities. It was found that the highest levels of *Listeria* counts were found in fish processing plants on food contact surfaces. Unfortunately, facilities that produced RTE fruits or vegetables were not included in this study (1).

In addition, after the Maple Leaf Outbreak, Health Canada revised its 2004 policy on *Listeria monocytogenes* in RTE Foods. In this revised policy Health Canada classified foods into categories. Each category classified the risk of *Listeria* contamination into certain types of products. The policy also included that regular testing should be conducted by regulatory authorities and food processors to validate that *Listeria* is not present in finished products. Processors should always assume that all raw products may contain *Listeria* and always use best business practices to eliminate the spread of *Listeria* through maintaining proper sanitation, regular maintenance, implementing a HACCP

plan, and use additives where possible to prevent *Listeria* growth (19).

Salmonella

The bacteria *Salmonella enterica subsp. enterica*, formally known as *S. enteritidis*, is the primary serotype responsible for making people ill (23). The pathogen causes Salmonellosis, which can be transmitted in the environment by fecal oral contact. This results in symptoms of diarrhea, fever, nausea, abdominal pain, and vomiting. It can cause dehydration in immunocompromised individuals, such as the sick, infants, and the elderly. The incubation period of Salmonellosis can occur anywhere between 5 to 72 hours and can last up to sixteen days. The mode of transmission of *Salmonella* is commonly through food, such as poultry and eggs, but can be spread by water, and contact with animals such as turtles and poultry (10; 23). Recent outbreaks of *Salmonella* that resulted in recalls occurred in 2016 and 2018 in the United States and in Canada. First in the United states in 2016, there was 36 cases of Salmonellosis due to alfalfa sprouts that spread across nine states. Also, in the United States in 2018, there was a recall of pre-cut melons that caused an outbreak affecting 77 people across nine states (3). In Canada in 2018, frozen breaded chicken products resulted in 566 lab confirmed cases of Salmonellosis that led to 13 separate food recalls (8).

E. coli

When infected by *E. coli*, a person can experience two types of gastroenteritis conditions, secretory diarrhea, which results in watery stools, and inflammatory diarrhea, which results in fever and bloody stools. Enterohemorrhagic *E. coli* (EHEC*), including E. coli O157:H7* is the most common human pathogens that cause outbreaks world-wide. EHEC include two types of toxins, verotoxigenic and shigatoxigenic toxins. These toxins can cause severe conditions such as hemolytic uremic syndrome (HUS) and Shigella dysentery which can cause kidney failure and death (10; 4; 23). *E. coli* is responsible for several notable outbreaks in produce. In 2006, a 26-state outbreak occurred in the US that resulted in 199 people contracting *E. coli O157:H7*. 102 of the victims were hospitalized and three people died when they consumed contaminated baby spinach (3). Recent outbreaks in Canada and the United States in 2018 involving shiga-toxin *E. coli O157:H7* in romaine lettuce and cauliflower. In the US, contaminated romaine caused 62 reported cases across sixteen states while in Canada there were eighteen confirmed cases in Ontario and Quebec (15; 3). It can be common that *E. coli* contaminated products may not be listed in recall databases. For example, a large *E. coli O:157:H7* outbreak in romaine lettuce, from California, resulted in 29 confirmed cases in Canada, ten of which resulted in contracting HUS (33). In this case, romaine lettuce from this

outbreak was not listed in the CFIA or FDA databases.

MATERIALS AND METHODS

Method used in this report was to collect product recall data from 2016, 2017, and 2018 from the Canadian Food Inspection Agency (CFIA) (http://www.inspection.gc.ca), Health Canada (https://www.healthycanadians.gc.ca), the Food and Drug Administration (FDA) (https://www.fda.gov), and USDA Food Safety and Inspection Service (FSIS) (https://www.fsis.usda.gov) and compare the data to past recalls compiled by Kate Macquarrie in 2006, 2007, and 2008. Recall data was copied and entered into Excel and included the following: the date of the recall, reason for recall (biological, chemical, or physical), the type of food product, and which website the data was collected from. When searching for recalls on the CFIA website, the option "all' was selected when finding the year, reason for the recall, class, and distribution. Under the section listed as public warning, "both" (yes and no) was selected. The majority of Health Canada recalls were exact duplicates of CFIA recalls; therefore, identical recalls were only counted once. Any recalls not found in the CFIA database but found in the Health Canada database was counted and listed. When searching FDA website, filter used for recall type was "food". When searching for recalls at FSIS, the recall case archives were used as well as current recall data for 2018.

All recall data from CFIA, FDA, Health Canada, and FSIS was then given a total for each month and each year. Seasonal recalls were separated accordingly: Winter (December to February), Spring (March to May), Summer (June to August), and Fall (September to November) to match Macquarie's method. The monthly totals were then entered into NCSS and run through a two tailed T-test to get the results of a one-tailed T-Test. Specific pathogens *Listeria monocytogenes, Salmonella*, and *Escherichia coli* (all serotypes listed) were collected separately from all four agency sites and counted in each month and year and was used for descriptive comparisons and for a chi square test.

RESULTS

In analyzing the total number of recalls during the years of 2016 – 2018 there were a total of 2112 food recalls. This is significantly higher than the 942 total food recalls recorded by Macquarrie (2009) between the years 2006 - 2008. When using statistical analysis to determine if food recalls have increased, the one-tailed test results concluded there is a statistically significant increase in the total number of food recalls in the years of 2016 - 2018.

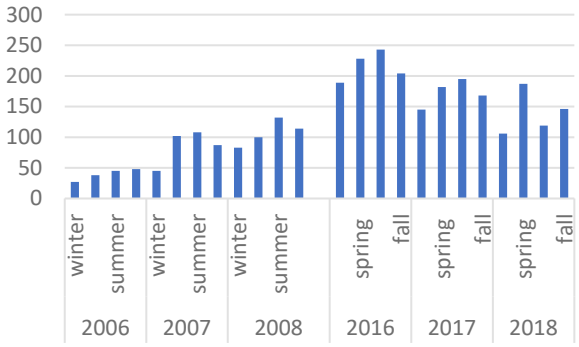

FIGURE ONE: TOTAL SEASONAL FOOD RECALLS BETWEEN THE YEARS OF 2006 - 2008 AND THE YEARS OF 2016 - 2018.

(Note: Winter (December- February), Spring (March-May), Summer (June-August), and Fall (September-November))

As seen in figure one, food recalls increased in spring and summer months and decreased in the fall. The total amount of food recalls between the years of 2006 - 2008 is significantly lower than the years of 2016 - 2018. Overall, there is an increasing trend of recalls during the years of 2006 - 2008, and a decreasing trend of recalls during the years of 2016 – 2018.

The three-year total of *Listeria* recalls during the years of 2016 – 2018 was 359. This is significantly higher than the 129 total food recalls recorded by Macquarrie (2009) between the years 2006 - 2008. When using statistical analysis to determine if *Listeria* recalls have increased, the one-tailed test results concluded there is a statistically significant increase in the total number of *Listeria* recalls in the years of 2016 - 2018.

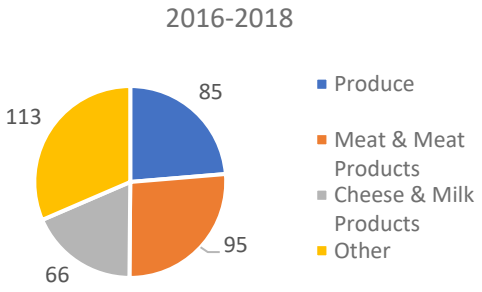

FIGURE TWO: PRODUCT RECALLS BY TYPE RECALLED DUE TO *LISTERIA* BETWEEN THE YEARS OF 2006 -2008 AND BETWEEN THE YEARS OF 2016 – 2018

Of all the products recalled due to *Listeria monocytogenes* contamination between the years 2006 - 2008 included 71 (55%) meat related products, 34 (27%) cheese and milk products, 13 (9%) produce, and 10 (8%) products listed as other (26). As shown in figure two, out of all the products recalled due to *Listeria monocytogenes* between the years of 2016 - 2018, 95 (27%) recalls were meat related products, 85 (24%) recalls were produce (including fruits, vegetables, and lettuce), and 66 (18%) recalls were cheese and milk-based products. There were 113 (31%) products were listed under other. Notable products between the period of 2016 - 2018 listed under other included granola bars, protein bars, hummus, and trail mix.

The three-year total of *Salmonella* recalls during the years of 2016 – 2018 totaled 203. This is significantly higher than the 93 total food recalls recorded by Macquarrie (2009) between the years 2006 - 2008. When using statistical analysis to determine if *Salmonella* recalls have increased,

the one-tailed test results concluded there is a statistically significant increase in the total number of *Salmonella* recalls in the years of 2016 - 2018.

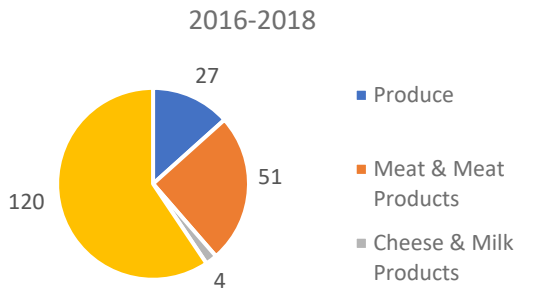

FIGURE THREE: PRODUCT RECALLS BY TYPE RECALLED DUE TO *SALMONELLA* BETWEEN THE YEARS OF 2006 - 2008 AND BETWEEN THE YEARS OF 2016-2018

Out of all the products recalled due to *Salmonella* contamination between the years 2006 - 2008 included 10 (11%) meat related products, 6 (7%) cheese and milk products, 22 (23%) produce, and 55 (59%) products listed as other (26). As shown in figure three, out of all the products recalled due to *Salmonella* between the years 2016 - 2018, 51 (26%) were meat related products, 27 (13%) were produce, and 4 (2%) were cheese and milk-based products. 120 (59%) recalls were listed under other. Some notable examples of products between the years of 2016 - 2018 listed under other were tea, pistachios, potato chips, sesame seeds and coconut.

Finally, the three-year total of recalls due to *E. coli* during the years of 2016 – 2018 totaled 109. This is significantly higher than the 65 total food recalls recorded in by Macquarrie (2009) between the years 2006 - 2008. When using statistical analysis to determine if *E. coli* recalls have increased, the one-tailed test results concluded there is a statistically significant increase in the total number of *E. coli* recalls in the years of 2016 - 2018.

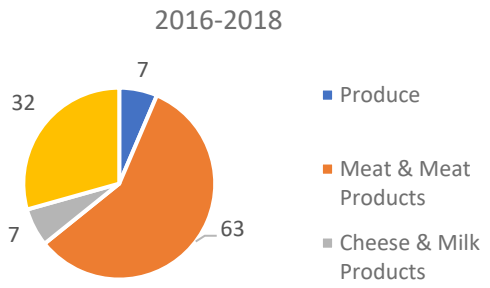

FIGURE FOUR: PRODUCT RECALLS BY TYPE RECALLED DUE TO *E. COLI* BETWEEN THE YEARS OF 2006 -2008 AND BETWEEN THE YEARS OF 2016-2018

Out of all the products recalled due to *E. coli* contamination between the years of 2006 - 2008 included 53 (81%) meat related products, 2 (3%) cheese and milk products, 5 (8%) produce, and 5 (8%) products listed as other (26). As shown in figure four, out of all the products recalled due to *E. coli* between the years of 2016 - 2018, 63 (59%) were meat related products, 7 (6%) were produce, and 7 (6%) were cheese and milk-based products. 32 (29%) recalls were listed under Other. Some notable examples of products between the period of 2016 - 2018 listed under other was flour, pie and tart shells, and cake mix.

DISCUSSION

The data from this study shows there is a significant increase of food recalls in the last ten years. Recalls during the years of 2016 – 2018 are approximately 45 percent higher than recalls during the years of 2006 – 2008. The majority of food recalls occur in the spring and summer months and least occur in the winter months. There was a total of 2112 food recalls, 671 were recalls due to *Listeria, Salmonella*, and *E. coli*. Out of the three pathogens, the most recalled pathogen between 2016 – 2018 was *Listeria* comprising of 17% of the 2112 food recalls. During the years of 2016 – 2018, the remaining 1441 recalls were due to allergens (such as undeclared egg, milk, wheat, nuts), foreign matter contamination (such as plastic, metal, insects, rubber), other reasons (such as spoilage, poor quality standards) and microbial contamination from other pathogens (such as *Vibrio parahaemolyticus*, Hepatitis A, Paralytic Seafood Poisoning (PSP), *Pseudomonas aeruginosa*, *Cyclospora,* and *Clostridium botulinum*). The data also shows that food recalls during the 2016 – 2018 are starting to decrease (Figure One).

There was a total of 942 food recalls during the years of 2006 – 2008. 287 recalls were recalls due to *Listeria, Salmonella*, and *E. coli*. The most recalled pathogen between 2006-2008 was *Salmonella* comprising of 25% of the 942 food recalls. During the years of 2006 – 2008, the remaining 655 recalls were due various chemical contamination (such as melamine, pesticides), heavy metals (such as lead, mercury, arsenic, aluminum), foreign matter contamination (such as glass, metal, plastic), other reasons (such as no permit, choking hazard, flu-like illness) and microbial contamination from other pathogens (such as *Vibrio parahaemolyticus, Shigella sonnei, Bacillus cereus, Staphylococcus aureus, Burkholderia cepacian*, PSP, Ciguatera toxin, *Clostridium botulinum*).

As hypothesised, *Listeria* recalls have increased within the past ten years and are significantly higher during the years of 2016 – 2018 (Figure Eight). When analysing trends of *Listeria* in various food products, recalls in milk and dairy products, meat products, and produce have increased. The most dramatic increase of *Listeri*a occurred in produce increasing by over 60%. The increase of *L. monocytogenes* food recalls could be due to a variety of different factors. First, after the Maple Leaf Outbreak of *Listeria* in 2008, *Listeria* monitoring has increased; therefore, the increase in *Listeria* recalls could be a result of more vigorous testing (1). Secondly, the amount of food products on the market could have increased. An increase of products will result in more products to test; therefore, more chances to test positive for *Listeri*a. Thirdly, with the increase of mass production of products on the

market there is more competition for food manufacturers. To keep up to industry demand there may be less focus on sanitation procedures within food processors and more focus on producing more products faster. Since *Listeria* is more ubiquitous than *Salmonella*, it can contaminate a wider variety of products (30; 19). Lastly, the increase of recalls could be attributed to a break down in good management practices directly at the farms where produce is grown. *Listeria* could be transferred to produce from contaminated irrigation waters or contaminated soil before the produce has reached the processor as the literature review suggests (34; 11; 25).

When analysing trends in *Listeria* recalls in various food products, examples of produce were frozen vegetables, salad, salad kits, coleslaw, spinach, pea shoots, broccoli slaw, kale, and cut green beans. As for dairy products, *Listeria* recalls occurred in chocolate milk, cheese, soy, butter, comté cheese, ice cream, and raw goat milk. Examples of meat products are meat and egg salad sandwiches, smoked salmon, chicken hummus, chicken egg rolls, pork, chicken, and beef.

When analysing trends of *Salmonella* in various food products, there has been a slight decrease in dairy products and an increase in *Salmonella* recalls in produce and meat products. The most dramatic increase occurred in meat products increasing by approximately 50 percent. During the analysis of food recalls, the most *Salmonella* meat recalls occurred in 2018 with recalls in oysters and frozen chicken products. Another meat product of interest recalled for *Salmonella* was tuna loins. As for produce, products recalled for *Salmonella* were coconut, cantaloupe, chilli peppers, chives, papaya, and microgreens. As for dairy products, products recalled was goat cheese and ice cream. Under 'other' for Salmonella recalls it showed that the pathogen is entering more dry products like flour, cake mixes, fish batter, and gold fish crackers. Other products recalled for the pathogen is green tea, candy, dietary supplements pet food, flax seed powder, and potato chips.

When analysing trends of *E. coli* in various food products, there has been a slight increase in both dairy, meat, and produce recalls. The most dramatic increase occurred in meat products, which contained high recalls of ground beef. When analysing trends of *E. coli* in various products, examples of produce recalls were cauliflower, jalapenos, green leaf lettuce, and sprouts. When it comes to dairy products, the most interesting recall of *E. coli* occurred was soy nut butter.

KNOWLEDGE TRANSLATION

The research has been inspired by BCCDC's interest in comparing modern food recalls to

recalls done by Macquarrie in 2009. Perhaps the analysis of this data can help with future food security or be used for detecting hidden patterns that may alert health agencies to potential future outbreaks. The research also can be used to identify different products that the pathogens are being found in. One of the goals of this study is to raise awareness of *Listeria* in food products especially in produce. As indicated by Bucur et.al (2018) society is demanding more healthier alternatives in food products which results in changes in how food is being packaged and preserved. Perhaps the industry has to look for new methods in controlling *Listeria* in food processing environments such as natural additives, bacteriocins, or other treatments (2).

It is also recommended to explore the efficiency of the Health Canada recall website. The website contains bulky chunks of text and images that makes filtering through recalls time consuming and difficult. Furthermore, many of the recalls have been repeated on the CFIA recall data base. Perhaps uniting MAPAQ and Health Canada into the CFIA database available in both English and French would create a single unified Canadian recall database for the public and public health agencies.

LIMITATIONS

Time is a significant limitation in this study. Gathering and filtering through large amounts of recall data took significant time. CFIA, Health Canada, FDA, and FSIS all organised their recall data differently. When collecting recalls some recall sites were easier to navigate than others. For example, the CFIA website provided a variety of filters, such as type of pathogen, class of recall, reason for recall, and date that made looking for recalls much easier than other agencies. Health Canada's recall data base was the most difficult website to collect information. Filtering through Health Canada's data base was time consuming and yielded identical data listed in the CFIA data base with only a few exceptions.

Another limitation was that the researcher was unable to speak or read French the MAPAQ recalls were not counted in the Canadian recalled data. If more time was available, the researcher could have found a partner to help translate the French recall data and add it to the study. This could have strengthened the validity of the study further.

It is important to note that not all products responsible for outbreaks are recalled. *E. coli* is a pathogen that is under represented in the recall database since it is an indicator of a recent contamination (Health Sciences, 2019). *E. coli* is responsible for many outbreaks in produce but recalls may not be issued for suspected produce contamination. For example, in 2018 there were several public health notices related to E. coli infections linked to romaine lettuce (33). There

were no recalls issued for romaine lettuce in the majority of the public health notices. So accurately determining the top pathogen, *Listeria* or *E. coli*, in produce contamination is limited.

FUTURE RESEARCH

This study brought up three possible future studies. First, starting Jan 15, 2019, fourteen current sets of regulations will be replaced by the Safe Food for Canadians Act and Regulations (7). It would be interesting to conduct this study again five years from now to see if the new Safe Food for Canadians Act and Regulations will help decrease food recalls by improving traceability. A second possible study that could be done would be to analyze the types of associations that exists between the type of pathogen and type of product. It would be interesting to determine if there are new bacteria trends in other products instead of focusing just on dairy, meat, and produce. Lastly, it also would be interesting to correlate food recalls with food outbreaks to see if there is a possible connection. Perhaps previous recalls done before the outbreak could have been used to alert the health agencies to a potential future outbreak.

CONCLUSION

The results of this study conclude that total food recalls, *L. monocytogenes, Salmonella*, and *E. coli* recalls have all increased over the last ten years. The study also showed there is an increase in *Listeria* recalls in produce. *Listeria* increased presence in food recalls indicates that further investigation is needed to determine if there is a break down in sanitary practices amongst food processors or a breakdown of sanitation procedures at the farm level.

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COMPETING INTEREST

"The author declares that there are no competing interests"

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