Prevalence of Salmonella spp. in Vegetables: A Review Paper

By

Mashiyat Nudar
16326008
Sudipta Mahboob
16226001

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Declaration

It is hereby declared that

1. The thesis submitted is my/our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

Student's Full Name & Signature:

Mashiyat Nudar	**Sudipta Mahboob**
16326008	16226001

Approval

The thesis titled "Prevalence of Salmonella spp. in Vegetables: A Review Paper" submitted by

1. Mashiyat Nudar (16326008)
2. Sudipta Mahboob (16226001)

of Spring, 2022 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of B.Sc. (Microbiology) on 05.03.2022.

Examining Committee:

Supervisor:
(Member)

____

Dr. Fahim Kabir Monjurul Haque
Assistant Professor
Department of Mathematics and Natural Sciences

Program Coordinator:
(Member)

____

Dr. Mahbubul H. Siddiqee
Assistant Professor
Department of Mathematics and Natural Sciences

Departmental Head:
(Chair)

____

A F M Yusuf Haider
Professor & Chairperson
Department of Mathematics and Natural Sciences

Abstract

A number of studies have found a link between salmonellosis outbreaks and the eating of raw vegetables. This study is a literature evaluation on the prevalence of *Salmonella spp.* in fresh vegetables that was conducted using accessible resources without regard to geography. The prevalence of *Salmonella spp.* in vegetables, the *Salmonella spp.* serotype, the nation, the year, the total collected samples, and the number of positive samples were retrieved from relevant studies on the prevalence of *Salmonella spp.* in vegetables published between 2016 and 2021. SPSS version 25 was used to analyze all of the data. In twelve countries, raw, fresh, RTE vegetable samples were tested. *Salmonella spp*. was found in lettuce, cucumbers, and tomatoes, among other places. In the primary inquiry, the average prevalence of lettuce, cucumber, and tomatoes was 28.69 percent, 8.54 percent, and 7.88 percent, respectively. These findings suggest that *Salmonella spp.* can be found in raw or minimally processed vegetables, resulting in direct infection of consumers or cross-contamination of other items. Consumers may be exposed to a serious health risk as a result of these infected vegetables.

Keywords: *Salmonella spp.* ; prevalence; vegetables

Dedication

My Parents and Faculties

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Chapter 1

Introduction

The nutritional value of fruits and vegetables is remarkable for humans because they contain a wide range of minerals, micronutrients, vitamins, and fiber. They are also beneficial to health and well-being because they contain low amounts of fat and calories, making them a low-fat, high-fiber food. They ensure that the body receives the necessary amounts of vitamins, fats, minerals, and oil for normal growth and development of the human body(Gundappa& Gaddad, 2016).Consumption of *Salmonella spp.* contaminated vegetables is a public health risk that requires special attention, particularly in countries where such outbreaks are common.(Adzitey,2018). Salmonellosis is a food borne illness caused by non-typhoidal *Salmonella spp. enterica serovars*, most often *Enteritidis* and *Typhimurium*. Within 12 to 72 hours, most people infected with *Salmonella spp.* suffer diarrhea, fever, and abdominal pains. When infected with *Salmonella spp.* ,vulnerable groups such as children, the elderly, and immune-compromised adults may have acute dehydration, which might be life-threatening. In developed countries, *S. enterica serovar Enteritidis* and *S. enterica serovar Typhimurium* are the most prevalent food borne pathogens among the 2,659 serovars of *Salmonella spp.*(Saw et al., 2020).

Salmonella spp. is responsible for 94 million instances of gastroenteritis and 155,000 deaths worldwide each year(Yang et al., 2020). Many recent cases of food borne disease have been linked to 53 different types of fresh vegetables, particularly those that are ready-to-eat or little processed. A major worry is *Salmonella spp.* because of the number of infections and severity of sickness(Kuan et al., 2017).

Continuous changes in dietary patterns and agronomic techniques, as well as an increase in the consumption of raw vegetables and fresh produce importation, are thought to contribute to an increase in the number of outbreaks linked to vegetables and animal feed of vegetable origin(Samar et al., 2019).Consumption of *Salmonella spp.* contaminated vegetables is a public health risk that requires special attention, particularly in countries where such outbreaks are common(Samar et al., 2019).A wide range of produce items have been linked to human illness outbreaks around the world, with some commodities being more frequently linked to outbreaks than others. For example, leafy greens like lettuce and spinach, as well as fresh herbs like parsley and basil, are well-known potential sources of bacterial infections.

According to reports, accounting for at least half of these outbreaks in the United States (53 percent) and the European Union (50 percent)(Gundappa& Gaddad, 2016).

Salmonella spp. infection is still a major public health concern around the world, putting a financial strain on both developed and developing countries due to the expenses of disease surveillance, prevention, and treatment (Eng et al. 2015) on raw foods including vegetables and fruits. *Salmonella spp.* was revealed to be the most frequently detected causal agent of food borne outbreaks (representing 22.5 percent of total outbreaks), highlighting its public health impact(EFSA,2015)(Silva et al. 2017).

The goal of this literature review is to look at recent global data on the prevalence of *Salmonella spp.* in vegetables.

Chapter 2

Methods

2.1 Search Strategy

Using the same keywords, a comprehensive scientific search on the presence of *Salmonella spp.* in vegetables was conducted in valid electronic global databases: Pub Med, Google Scholar, Science Direct, and Statista. From 2015 to 2022, the search was conducted using a systematic approach. *Salmonella spp.*, vegetable, prevalence, outbreak, consumption, production ,lettuce, spinach, leafy vegetable, sprout, salad ,cauliflower, egg plant onion, carrot, cilantro, tomato, cucumber, broccoli, cabbage, cantaloupe, parsley, arugula, pepper, Lady's finger, coriander, mint, rice paddy herb basil, radish, potato and bean were among the keywords used to search the databases. Articles with any of these keywords in their abstracts or titles were included in the study. A total of 190 articles were chosen in the end.

2.2 Study Selection

190 publications were chosen after screening these relevant abstracts. The study excluded articles that did not use English in the main text, review articles, and book chapters, as well as publications related to case control study surveillance, genotyping, antibiotic resistance food handlers and their hygienic practices, and artificially contaminated samples. Following that, all of the eligible primary studies were screened in full text from the databases. They were eventually excluded if the complete text of the articles was not available. After analyzing all of the data from the recovered articles, 37 primary studies published between 2016 and 2021 were determined to be relevant. We grouped the datasets based on nation, year, total collected samples, number of positive samples, prevalence, and serotypes from each study.

2.3 Data Extraction

Fresh or raw vegetables, as well as newly grown vegetables, were studied in each relevant primary study's population. Vegetables (fresh cut, organic, leafy, root crops) and ready-to-eat (RTE), beans and sprouts, and salad (mixed, gravy) were all deemed fresh produce in this study. Retail stores, hypermarkets, farms, and supermarkets all provided samples. Studies that used any treatment on fresh produce, such as heat, pressure, irradiation, or bactericidal, as well as those that discovered effects of cross contamination, were excluded from the test.

2.4 Statistical Analysis

The IBM® SPSS Statistics version 25 software was used to display all of the data in graphs and charts.

Chapter 3

Global Production and Consumption of Vegetables

From 1986 to 1995, roughly 0.95 percent of vegetables per capita were consumed. Consumption of fresh fruits and vegetables per capita was 0.38 percent and 0.38 percent, respectively. China is the country with the largest consumption. Fruits account for 6.4 percent of the total (Mritunjay & Kumar, 2015)The smallest amount of Fresh fruits and vegetables made up 0.19 percent of the total. There was a decrease in the production of vegetables in Sub-Saharan Africa, and there was a reduction in the production of fruits and vegetables. African and Near-Eastern Asian countries' consumption rates (Mritunjay & Kumar, 2015). It has been discovered that the output of fresh produce is on the decline. Fruits and vegetables, for example, have seen a huge increase in popularity. From 1980 to 2004, there was a 94 percent increase (Mritunjay & Kumar, 2015). Global population expansion has been blamed for the increase.

In recent years, new patterns of vegetable intake have emerged. The largest rate of consumption was found in Asia, followed by Europe, Northern America, Oceania, and Africa (FAO, 2020). Europe's consumption rate was determined to be slightly greater than that of Northern America, which had a dramatic drop in consumption per capita in the years after. Oceania's consumption increased steadily but was slightly lower than Asia, Europe, and North America(FAO,2020).(Figure.1)

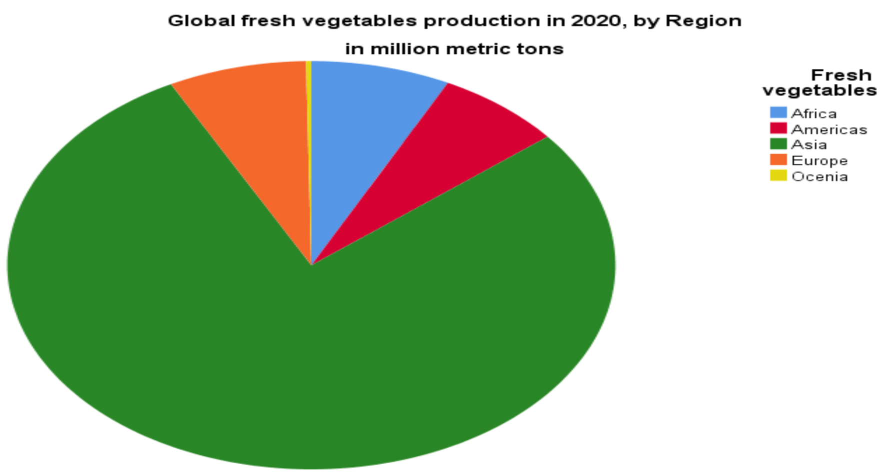


Figure.1: Global production of vegetables by region(Shahbandeh,2020)

Fruit and vegetable production has expanded dramatically during the previous few years. Between 2000 and 2010, the level of vegetable production increased at a faster rate. It gradually increased until 2018, when it began to decline slightly (FAO, 2020). Because of India's growing urban population and long commutes to work, many people prefer to consume sprouts, fruits, and raw veggies over fast food because they are thought to be healthier (Mritunjay & Kumar, 2015). The World Health Organization conducted a survey on street-vendor food, finding that fresh fruits and vegetables account for roughly 86 percent of the entire food market(Mritunjay& Kumar, 2015) . Countries like America are well-known for being big sources of fresh food, and it's important to note that roughly 35% of it is imported. Fresh fruits and vegetables must be free of contamination due to the numerous nutrients they supply in our daily diet (Grace &deila,2017).

Fresh fruits and vegetables play a key role in the worldwide food market, so their safety is also a global concern (Mritunjay & Kumar, 2015) . Because China and India produce more fresh fruits and vegetables, they are more susceptible to contamination. Not only customers and importers, but also producers, are concerned about the safety of fresh goods. Consumption of cabbages, onions, tomatoes, and other vegetables is increasing in Africa because they are widely available in the market, making them more accessible, convenient, and affordable than fruits such as apples, grapes, and others(Emmanuel,2014). The increased demand for fresh fruits and vegetables has put strain on the whole supply chain, from farmers to retailers to consumers (Buck et al., 2003). Farmers in Africa who grow a lot of vegetables and fruits for local consumption confront a number of risks, including poor water quality and insect infection, necessitating microbial contamination research(Amoah, I. D,2014).By 2020, Asia would account for nearly three-quarters of global vegetable production. China was the world's biggest producer of fresh vegetables in that year, with a production volume of more than 594 million metric tons. The United States, which came in third position, produced 33 million metric tons of fresh vegetables in 2020. California was the leading producer of fresh market veggies in the United States in 2020. Onions and tomatoes were the most commonly consumed vegetables in the United States that year, with per capita consumption of onions and tomatoes reaching 21 and 19 pounds, respectively. Tomatoes accounted for roughly 186.82 million metric tons of global vegetable production in 2020, broken down by type(Shahbandeh,2022).(Figure.2)

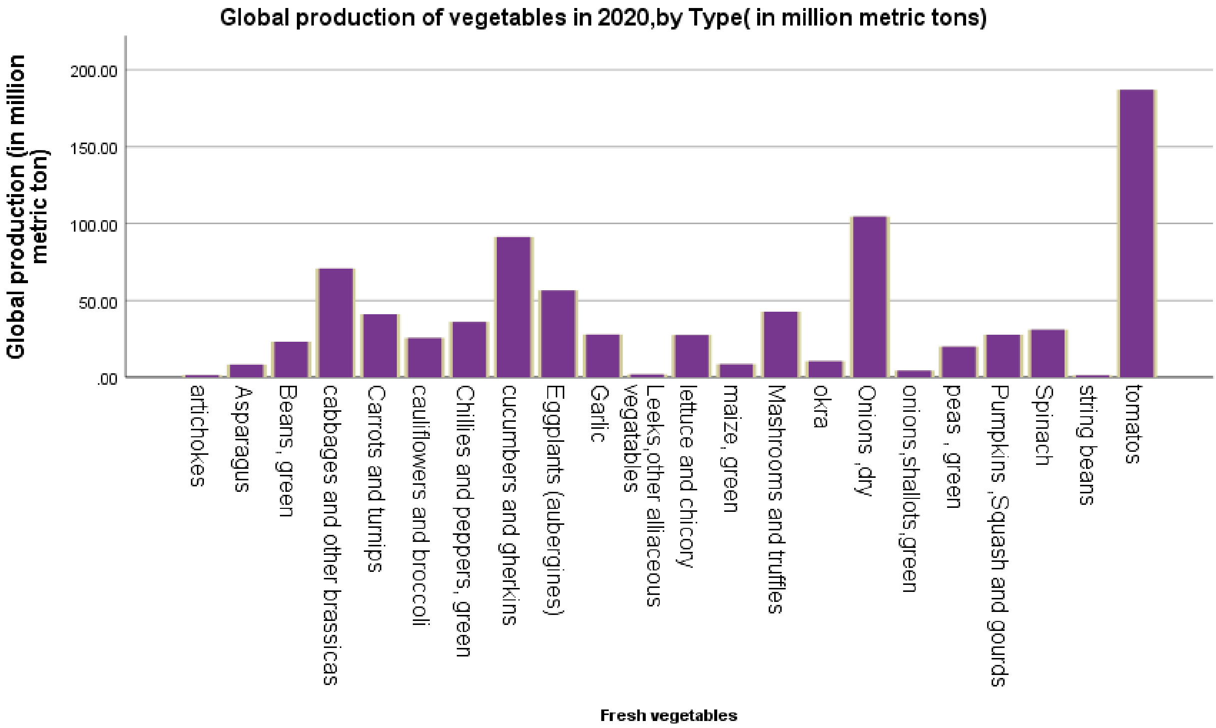


Figure.2:Global production of vegetables by type(Shahbandeh,2022)

Africa produced 85.15 million metric tons of vegetables in 2020, according to global vegetable production by region. Asian countries produced the majority of the world's vegetable production(Shahbandeh,2022). (Figure.1)

China has the highest per capita consumption of veggies, based on a comparison of 158 countries (328 kg). Chad has the lowest vegetable consumption per capita at 7.80 kg. Nicaragua, with 10.4 kg of vegetable intake, and Zimbabwe, with 16.1 kg, are two more countries with poor vegetable consumption("28 Reliable Vegetable Consumption Statistics for 2022.").

Chapter 4

Outbreak

A *Salmonella spp.* epidemic occurred in South Australia in 2016, with 230 cases reported. In addition, an outbreak occurred in New South Wales (Australia) in the same year, with 97 cases documented. In 2016, a multi-state outbreak was reported in the United States, with over 27 persons afflicted. In the same year, a *Salmonella spp.* outbreak was recorded in the United States, affecting 40 states and infecting 907 persons(Popa & Papa, 2021).An outbreak was recorded in Greece in 2016, affecting 56 people. In addition, 40 instances were documented in Greece, Germany, the Czech Republic, and Luxembourg in 2016(Mandilara et al., 2018).Several outbreaks were reported in Australia and Japan in 2017, with a total of 87 kindergartners affected. The CDC in the United States recorded 24 cases of *Salmonella spp.* illness in 16 states in 2017. In 2018, Israel reported a *Salmonella spp.* outbreak with 40 cases. In addition, 49 people have been reported in Australia. In 2017, there were 92,649 cases of salmonellosis reported in Europe, including 156 deaths(Popa & Papa, 2021). Greece, Estonia, Poland, Portugal, Slovakia, Spain, and the United Kingdom all reported a rise in the number of cases(2017).Between February and November 2017, eight EU/EEA countries reported 196 confirmed cases. Furthermore, 16 nations reported 340 historical confirmed cases and 374 historical probable cases prior to February 2017, with the United Kingdom reporting the most(Popa & Papa, 2021).Between August 2018 and February 2019, 30 cases were confirmed in France, one in Belgium, and one in Luxembourg. In Romania, an outbreak occurred in Iasi in 2018, with 134 cases reported(Somorin et al., 2021).A salmonellosis outbreak affecting 80 people was reported in Chile in November 2019. An outbreak occurred in the United States in 2019, infecting over 1,000 persons in 49 states. In the United States in 2020, there will be 473 more sick persons. As of July 28, 2020, there has been 938 cases reported from 48 states.(Popa & Papa, 2021)(Table .1)

In 2021, Austria, Belgium, the Czech Republic, Finland, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden, and the United Kingdom, respectively, reported seven, 46, four, nine, six, 46, two, three, 34, four, 46, and 102 confirmed cases(Jernberg et al., 2021).(Table.2)(Figure.3)(Figure.4)

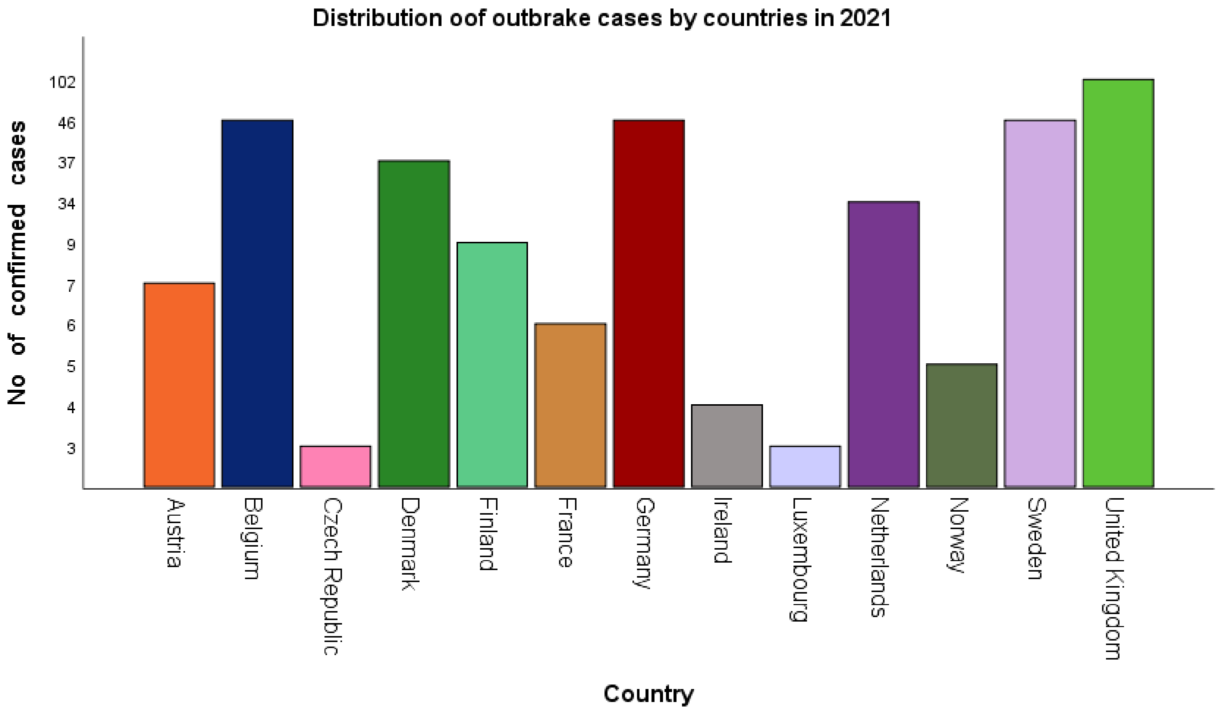
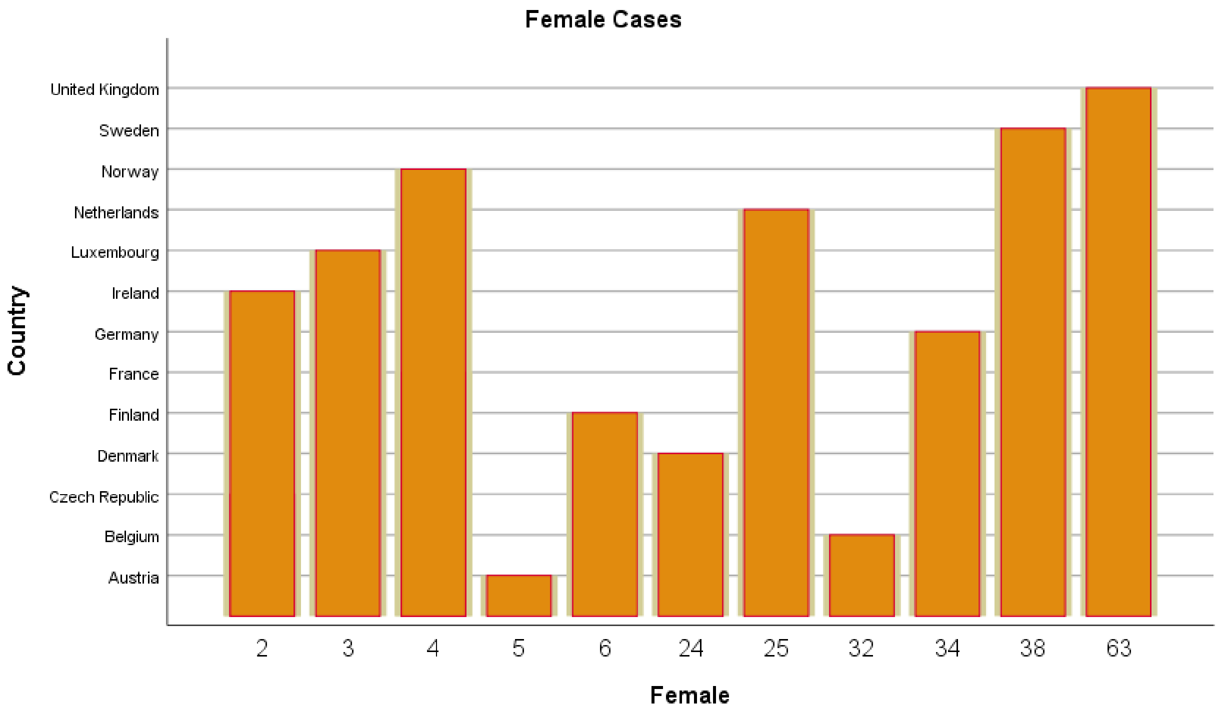


Figure.3: Outbreak cases by country in 12 EU/EEA countries and the UK(Jernberg et al., 2021)



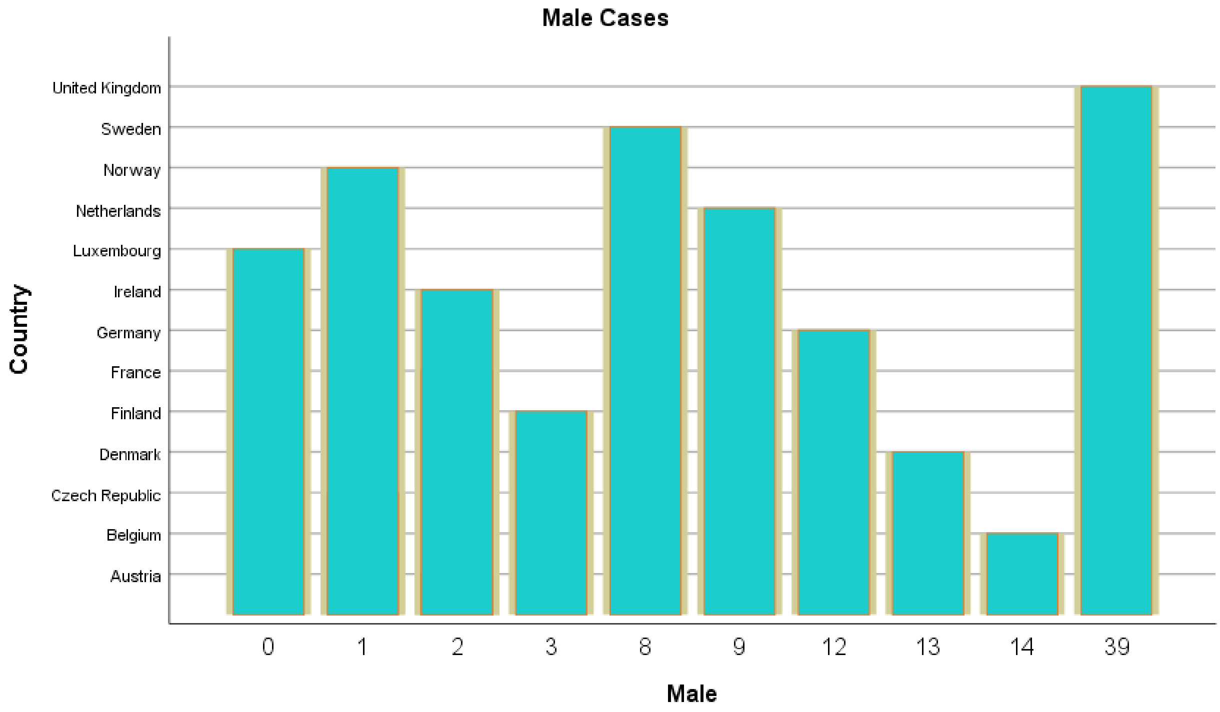


Figure.4: Outbreak cases by gender(Jernberg et al., 2021)

Table 1: Worldwide Salmonella spp. Causing Outbreaks

Year	Country	Regions	No. of cases	Reference
2016	Australia	South Australia	230	(Popa & Papa, 2021)
	Australia	New South Wales	97	
	USA		27	
	USA	40 states	907	
	Greece		56	(Mandilara et al., 2018)
	Pakistan, USA		5,377	(Popa & Papa, 2021)
	Europe	Greece, Germany, Czech Republic, Luxembourg	40	(Mandilara et al., 2018)
2017	Japan		87	(Popa & Papa, 2021)

	USA	16 states	24	
	Pakistan		250	
	Europe	8 countries	196	
2018	Israel		40	
	Romania	Iași	134	(Somorin et al., 2021)
	Australia		49	(Popa & Papa, 2021)
2019	Chile		80	
	USA	49 states	>1,000	
	USA	Several states	>1,000	
	USA	California	7	
	USA	California	7	
2020	USA		18	

Table 2: Salmonella spp. Causing Outbreaks in the year of 2021

Country	No of confirmed cases	Female	Male	Reference
Denmark	37	24	13	(Jernberg et al., 2021)
Austria	7	5	2	
Belgium	46	32	14	
Czech Republic	3	2	1	
Finland	9	6	3	
France	6	4	2	
Germany	46	34	12	
Ireland	4	2	2	
Luxembourg	3	3	0	
Netherlands	34	25	9	
Norway	5	4	1	
Sweden	46	38	8	
United Kingdom	102	63	39	

Total	348	242	106	

Chapter 5

Reported prevalence of Salmonella spp. in collected vegetables

To conduct the literature review, a total of 190 articles were screened to look for prevalence information on *Salmonella spp.* on vegetables. The majority of the screened papers discussed case control study surveillance, risk factors, genotyping, antibiotic resistance, food handlers' hygienic practices, and methods for disinfection over artificially contaminated samples (food categories other than fruits and vegetables), treatment methods such as heat, pressure, irradiation, and bactericidal on fresh produce, and the effects of cross contamination. Due to the exclusion criteria, only 37 primary papers were included for the literature review.

Malaysia, India, Ethiopia, Ghana, Thailand, Vietnam, China, Canada, Nepal, Burkina Faso, the West Indies, and Jordan were among the 12 countries in which primary studies were conducted(Table.3). Among the studies, the samples of Cauliflower(9), Tomato(10) and Egg plant(5)(Samar et al., 2019), 40 cabbages,20 lettuces such as iceberg lettuce ,leafy lettuce, butter head lettuce and romaine lettuce, 40 tomatoes, 40 carrots and 40 cucumbers(Saw, S. H., et al.2020), Tomato (76),Carrot(35),Cucumber(41),Onion (45),Potato (30),Lady's finger (10),Sponge gourd (15),Chili (24) ,Ivy gourd (13) ,Capsicum(10),French Beans (22) ,Drumstick (14),Pumpkin (23),Zucchini (34),Cauliflower(34),Spinach(9),Coriander leaves (15),Dill (4) ,Parsley (3) ,Fenugreek Leaves (14),Gongura (12) (Gundappa& Gaddad, 2016), 405 samples of Amaranth green (26), Amaranth red (25), Bean sprouts (25), Coriander(25) , Water spinach (26) ,Winged bean (25) ,Laksa leaves (26) ,Iceberg lettuce (25) ,Mint (25),Spring Onion (25) ,Indian pennywort (25), Wild parsley (25) ,Lettuce salad (25), Chinese f. Cabbage (26),Sweet basil (26) ,Japanese parsley (25) (Abatcha et al., 2018) ,a total of 120 vegetable samples of lettuce(30),cabbage(30), tomato(30), and carrot(30) (Weldezgina & Muleta, 2016) ,12,073 samples of leafy vegetables(leaf lettuce, head lettuce, mixed greens, spinach), 4,837 tomatoes, , 3,381 green onions (Denis et al., 2016), 134 lettuce samples(Somda et al., 2017), 406 raw vegetable samples-coriander (90), lettuce (83), tomato (104), and cucumber (129)(Yang et al., 2020) , a total of 172 food samples, including 100 vegetables and 72 Thai fermented foods(na Phuket et al., 2019) , green leaf lettuce (120)/

lettuce leaves (Chanseyha, Chhay, et al.2018)(Hull-Jackson et al., 2019),vegetables and raw salads (59 samples)(na Phuket et al., 2019), retail fresh vegetables included cripshead lettuce (174), cutting lettuce (163), green leaf lettuce (20), long coriander (30), mint (29), mustard green (31), rice paddy herb (28), sweet basil (28), watercress (20), water dropwort (n20), and water spinach (29)(Nguyen et al., 2021), a total of 216 servings of pre-made salads (72 radish, 72 carrots and 72 cucumbers(Sapkota et al., 2019) , Romaine lettuce(22), Cucumber(26)(Ni et al., 2018) , a total number of 405 raw leafy vegetables such as bean sprout,, amaranth red, Chinese flowering cabbage, lettuce salad, amaranth green, winged bean, laksa leaves , Indian pennywort , iceberg lettuce, mint , Japanese parsley, wild parsley , water spinach and sweet basil were collected. Nevertheless, some papers did not have sufficient data of total number of samples , number of positive samples and prevalence(Ni et al., 2018) . Lettuce was the common types of vegetable , which was found in maximum papers.(Table.3)

Through 2016 to 2021, data on the prevalence of *Salmonella spp.* in vegetables was gathered from online published studies.(Table.3) Pub Med and Google Scholar were the electronic databases used in this study. From 2016 to 2021, researchers researched fresh vegetables in twelve countries (Malaysia, India, Ethiopia, Ghana, Thailand, Vietnam, China, Canada, Nepal, Burkina Faso, West Indies, and Jordan) (Table.3). *Salmonella spp.* had been discovered in vegetables such as Cauliflower (1.9%)(Samar et al., 2019) , Tomato (2.63%), Carrot (20.00%), Cucumber (17.07%), Onion (6.67%), Potato (3.33%), Lady's finger (10.00%) ,Sponge gourd (6.67%), Chili (29.16%) ,Ivy gourd (30.77%) , Capsicum (30.00%),French Beans (13.63%), Drumstick (21.42%), Pumpkin (8.70%), Zucchini (5.89%),Cauliflower (14.70%),Spinach (33.33%),Dill (75.00%),Parsley (33.33%),Fenugreek Leaves (21.42%), Gongura (8.33%) (Gundappa & Gaddad, 2016) , Amaranth green (27.0%), Amaranth red (28.0%), Bean sprouts (28.0%), Coriander (52.0%), Water spinach (31.0%), Winged bean (20.0%), Laksa leaves (15.4%), Iceberg lettuce (8.0%), Mint (12.0%), Spring Onion (4.0%), Indian pennywort (24.0%), Wild parsley (24.0%), Lettuce salad (32.0%), Chinese f. Cabbage (11.5%), Sweet basil (8.0%), Japanese parsley (16.0%)(Ni et al., 2018) ,Lettuce (13.3%),Carrot 16.7%), Tomato (20%), Cabbage (30%) (Weldezgina & Muleta, 2016) ,Leafy Vegetables (0.02%), Green Onion (0.03%)(Denis et al., 2016) , Lettuce (100%)(Somda et al., 2017) , (7.8%) coriander, (6.0%) lettuce,(1.0%) tomato ,(0.8%) cucumber (Yang et al., 2020),Edible vegetables (36.59%)(Gundappa et al., 2021) ,64% in fresh vegetables(na Phuket et al., 2019) , Green leaf lettuce (23.33%)(Chanseyha, Chhay, et al.2018), Ready to eat vegetables (1.5%) (Hull-Jackson et al., 2019),Fresh vegetables (12.9%)(Nguyen et al., 2021),Raw vegetables (2.6% to 6.6 %)(Kuan et al., 2017),Raw vegetables salads (35.2%)(Sapkota et al., 2019). , Romaine lettuce (4.5%) ,Cucumber (3.8%)(Ni et al., 2018), Leafy vegetables (21.5%)(Abatcha et al., 2018) .(Table.3)

The prevalence of *Salmonella spp.* on vegetables (Table.3) was calculated using data from 20 studies that included a variety of vegetables, the most common of which was lettuce, calculated using data of 6 studies, which had an average incidence of 28.69 %. The lettuce had the highest prevalence of 100.0 %. Cucumbers (Table.3), the second most commonly found vegetable, with an average prevalence of 8.54 % based on four publications, with the maximum frequency of 17.07 %. The average prevalence of tomatoes (Table.3), the second most commonly found vegetable, was determined to be 7.88 % in three primary investigations, with the maximum prevalence reported to be 20%. The incidence of *Salmonella spp.* in vegetables is shown in (Table.3) Burkina Faso has the highest prevalence of 100 percent (Siourimè et al., 2017) at supermarkets, farms, and retail marketplaces.

Salmonella spp. occurrence on vegetables was linked to several forms of preparations, such as sliced, pulped, soil removal, and washing. Fresh unprocessed green vegetables, when cleansed and disinfected, sliced, and washed, had a considerable impact on RTE prevalence. Fresh salads and cold-RTE obtained from retail marketplaces(Yang et al., 2016)had a strong unfavorable influence on mixed vegetables.

The prevalence of *Salmonella spp.* was not significantly affected by the sample location, which included retail stores, fresh items, wholesale, and street markets, distribution centers, farms, and processing factories. On the other hand, no apparent trend linked with changes owing to sample location or country was detected for green vegetables. Furthermore, mixed vegetables had a negative significant influence on retail stores((Yang et al., 2016)these findings are consistent with information revealed by processing method.

Table.3: Prevalence of Salmonella spp. in Vegetables

Year	Analyzed vegetables	Country	Number of samples	Number of positive samples	Prevalence (%)	Reference
2016	Tomato	India	76	5	2.63%	(Gundappa & Gaddad, 2016)
	Carrot		35	7	20.00%	(Saw, S. H., et al. 2020)
	Cucumber		41	7	17.07%	
	Onion		45	3	6.67%	
	Potato		30	1	3.33%	
	Lady's finger		10	1	10.00%	
	Sponge gourd		15	1	6.67%	
	Chili		24	7	29.16%	
	Ivy gourd		13	4	30.77%	
	Capsicum		10	3	30.00%	
	French Beans		22	3	13.63%	
	Drumstick		14	3	21.42%	

	Cauliflower		34	5	14.70%	
	Spinach		9	3	33.33%	
	Dill		4	3	75.00%	
	Parsley		3	1	33.33%	
	Fenugreek Leaves		14	3	21.42%	
	Gongura		12	1	8.33%	
	Cabbage	Ethiopia	30	9	30%	(Weldezgina & Muleta, 2016)
	Tomato		30	6	20%	
	Carrot		30	5	16.7%	
	Leafy vegetables(leaf lettuce, head lettuce, mixed greens, spinach)	Canada	12,073	2	0.02%	(Denis et al., 2016)
	Green onions		3,381	1	0.03%	
2017	Lettuce	Burkina Faso	134	94	100 %	(Somda et al., 2017).
	Green leaf lettuce	Thailand	120	------	23.33%	(Chanseyha, Chhay, et al.2018)
	Loose leaf lettuce, cabbage, and tomato	Malaysia	----	----	2.6% to 6.6 %	(Kuan et al., 2017)
	Romaine lettuce	Shanghai, China	22	1	4.5%	(Ni et al., 2018)

	Cucumber		26	1	3.8%	
2018	Amaranth green	Malaysia	26	7	27.0%	(Abatcha et al., 2018).
	Amaranth red		25	6	28.0%	
	Bean sprouts		25	7	28.0%	
	Coriander		25	13	52.0%	
	Water spinach		26	8	31.0%	
	Winged bean		25	5	20.0%	
	Laksa leaves		26	4	15.4%	
	Iceberg lettuce		25	2	8.0%	
	Mint		25	3	12.0%	
	Spring Onion		25	1	4.0%	
	Indian pennywort		25	6	24.0%	
	Wild parsley		25	6	24.0%	
	Lettuce salad		25	8	32.0%	
	Chinese f. Cabbage		26	4	11.5%	
	Sweet basil		26	2	8.0%	
	Japanese parsley		25	5	16.0%	

	Cabbage	Ghana	-----	18	-----	(Adzitey, 2018)
	Lettuce		------	18	------	
	Laksa leaves	Malaysia	----	2	----	(Abatcha et al., 2018).
	Wild parsley		-----	1	-----	
	Sweet basil		-----	1	-----	
	Winged bean		-----	1	----	
	Raw leafy vegetables(lettuce salad, amaranth green, winged bean, laksa leaves, Indian pennywort, iceberg lettuce, mint, Japanese parsley, wild parsley, water spinach, and sweet basil		405	87	21.5%	
2019	Cauliflower	Jordan	9	1	1.9%	(Samar et al., 2019)
	Fresh vegetables	Thailand	100	------	64%	(na Phuket et al., 2019)
	Vegetables and raw salads	Barbados, West Indies	59	-----	1.5%	(Hull-Jackson et al., 2019)
	Cripshead lettuce, cutting lettuce, green leaf lettuce, long coriander, mint, mustard green, rice paddy herb, sweet basil, watercress, water dropwort, water spinach	Vietnam	572	74	12.9%	(Nguyen et al., 2021)

	Ready-to-eat salad samples (radish, carrots and cucumbers)	Nepal	216	66	35.2%	(Sapkota et al., 2019)
2020	Cucumber	Malaysia	40	5	12.5%	(Saw, S. H., et al., 2020)
	Cabbage		40	1	2.5%	
	Coriander	China	90	7	7.8%	(Yang et al., 2020)
	Lettuce		83	5	6.0%	
	Tomato		104	1	1.0%	
	Cucumber		129	1	0.8%	
2021	Edible vegetables	India	550	71	36.59%	(Gundappa & Gaddad, 2016)

Chapter 6

Diversity of *Salmonella spp.* serotypes in various vegetables

Several serotypes were reported in studies from 2016-2021 from the selected countries such as, Malaysia, India, Ethiopia, Ghana, Thailand, Vietnam, China, Canada, Nepal, Burkina Faso, West Indies, and Jordan, having the most available data(Table.4). The serotypes *Typhimurium* (Saw, S. H., et al.2020), *Aberdeen, Albany , Augustenborg , Bareilly ,Braenderup , Brancaster , Cerrot ,Corvallis ,Djugu, Dumfries, Enteritidis , Hvittingfoss, Kastrup, Kentucky, Mbandaka, Minnesota, Newport, Paratyphi B, Planckendael, Obugu, Ohio, Redhill, Richmond, Salamae, Stanley, Typhimurium , Weltevredent*(Abatcha et al., 2018), *Paratyphi A, Paratyphi B, Paratyphi C, Typhi* (Ni et al., 2018) (Yang et al., 2020) *,Stanley, Lagos , Rissen, Thompson, Braenderup, Bareilly, Montevideo, Newport, Hadar ,* *Albany, Enteritidis, London, Meleagridis, Aberdeen, ParatyphiB, Hvittingfoss, Stanley, Brenderup, Rissen, Dabou, Derby. Enteritidis* (Hull-Jackson et al., 2019), *Weltevreden, Derby ,Lexington ,Worthington*((Nguyen et al., 2021), *Enteritidis, Typhimurium* (Kuan et al.,2017) *Paratyphi* (Abatcha et al., 2018), *Enteritidis* were identified in vegetables.(Table.4)

Table.4: Salmonella spp. Serovars Reported From Vegetables

Year	Country	Analyzed Vegetables	Serotype	Reference
2019	Jordan	Cauliflower	*Salmonella spp.*	(Samar et al., 2019)
2020	Malaysia	Cabbage Cucumber	*Salmonella spp.* *S. enterica* serovar *Typhimurium*	[Saw, S. H., et al.2020]
2016	India	Tomato Carrot Cucumber Onion Potato Lady's finger Sponge gourd Chili Ivy gourd Capsicum French Beans Pumpkin Zucchini Cauliflower Spinach Dill Parsley Fenugreek Leaves Gongura	*Salmonella spp.*	(Gundappa & Gaddad, 2016)
2018	Malaysia	Amaranth green Amaranth red Bean sprouts Coriander Water spinach Winged bean Laksa leaves Iceberg lettuce	*S. Aberdeen* *S. Albany* *S. Augustenborg* *S. Bareilly* *S. Braenderup* *S. Brancaster* *S. Cerrot* *S. Corvallis*	(Abatcha et al., 2018).

		Mint Spring Onion Indian pennywort Wild parsley Lettuce salad Chinese f. Cabbage Sweet basil Japanese parsley	*S. Djugu* *S. Dumfries* *S. Enteritidis* *S. Hvittingfoss* *S. Kastrup* *S. Kentucky* *S. Mbandaka* *S. Minnesota* *S. Newport* *S. Paratyphi B* *S. Planckendael* *S. Obugu* *S. Ohio* *S. Redhill* *S. Richmond* *S. Salamaeserovar* *S. Stanley* *S. Typhimurium* *S. Weltevredent*	
2016	Ethiopia	Lettuce Carrot Tomato Cabbage	*Salmonella spp.*	(Weldezgina & Muleta, 2016)
2018	Ghana	Cabbage Lettuce	*Salmonella spp. enterica*	(Adzitey, 2018)
2016	Canada	Leafy Vegetables Green Onion	*Salmonella spp.*	(Denis et al., 2016)
2017	Burkina Faso	Lettuce	*S.Paratyphi A* *S.Paratyphi B* *S.Paratyphi C* *S.Typhi* *Salmonella spp.*	(Siourimè & SomdaNamwin, et.al.2017)
2020	China	Coriander Lettuce Tomato Cucumber	*S.Stanley* *S.Lagos* *S.Rissen* *S.Thompson* *S.Braenderup* *S.Bareilly* *S. Montevideo* *S.Newport* *S.Hadar* *S.Albany* *S.Enteritidis,* *S.London* *S.Meleagridis* *S. Aberdeen.*	(Yang et al., 2020)

2019	Thailand	Fresh vegetables	*S. Paratyphi B,* *S. Hvittingfoss* *S. Stanley* *S. Brenderup* *S. Rissen* *S. Dabou* *S. Derby.*	(na Phuket et al., 2019)
2019	Barbados, West Indies	Green leaf lettuce	*Salmonella spp.*	(Hull-Jackson et al., 2019)
2019	Vietnam	Fresh vegetables	*Salmonella spp.* *S. Weltevreden* *S. Derby* *S. Lexington* *S. Worthington*	(Nguyen et al., 2021)
2017	Malaysia	Organic vegetables	*S. Enteritidis* *Salmonella spp. Typhimurium*	[Kuan,Chee-Hao, et al.2017]
2018	Malaysia	Laksa leaves Wild parsley Sweet basil Winged bean	*S.Paratyphi*	(Abatcha et al., 2018).
2017	Malaysia	Raw vegetables	*S. Enteritidis*	[Kuan, Chee-Hao, et al.2017]
2019	Nepal	Raw vegetable salad	*Salmonella spp.*	(Sapkota et al., 2019)
2017	Shanghai, China	Romaine lettuce Cucumber	*Salmonella spp.*	(Ni et al., 2018)
2018	Malaysia	Leafy Vegetables	*Salmonella spp.*	(Abatcha et al., 2018).
2021	India	Edible vegetables	*Salmonella spp.*	(Gundappa & Gaddad, 2016)

Salmonellosis is one of the most common bacterial infections spread through food((Somda et al., 2017) .Vegetables consumption has increased in recent years, and a great range of minimally processed fresh-cut vegetables are accessible in supermarkets, food service establishments, and can even be cooked at home(Gundappa & Gaddad, 2016) .Unfortunately, an increase in raw vegetable consumption has led in an increase in the frequency of sickness outbreaks(Gundappa & Gaddad, 2016). The most common cause of produce-associated salmonellosis outbreaks has been identified as uncooked leafy vegetables(Yang et al., 2020) .The highest incidence of *Salmonella spp.* was found in raw and fresh vegetables, mixed veggies, and RTE salads, indicating cross-contamination during processing, particularly on post-harvest washing, cut, personnel, and insufficient storage conditions. Vegetables other than fruits (27 percent) and no specified vegetables (45,723 reported cases) were the food categories with the most complaints of food borne illnesses between 2010 and 2015 (45,723 reported cases) (12.2 percent) (Li et al., 2018). Norovirus (42.4 percent), *Salmonella spp. enterica* (19.9%), *Staphylococcus aureus* (7.9%), and *Escherichia coli* STEC were the most common pathogens found on the post-harvest (7.7 percent) (Li et al., 2018). Water, cross-contamination, storage duration, non-controlled temperatures, and contaminated raw materials were also identified as risk factors for vegetable infection. Aside from that, irrigation water and fertilizers based on animal dung are used(Mercanoglu Taban & Halkman, 2011)(Li et al., 2018). The most important cause for *Salmonella spp.* infection in vegetable growth in soil is irrigation water(Melloul,A. A et al., 2001).There are various factors along the food supply chain that could lead to raw vegetables being contaminated with *Salmonella spp.* or other food borne pathogens, including pre harvesting, harvesting, post harvesting, transportation, and processing(Saw, S. H., et al., 2020).

Fresh food contamination can be caused by a variety of sources, including the environment, animals, and humans(Saw, S. H., et al., 2020).Because food borne pathogens can pass from contaminated soil to vegetables, soil is one of the sources of cross-contamination during pre-harvesting(Saw, S. H., et al., 2020). As a result, vegetables that come into direct touch with the soil while planting are more likely to be contaminated. Furthermore, inexperienced and untrained employees who use improper handling procedures (Saw, S. H., et al., 2020) .During harvesting and post-harvesting may cause cross-contamination of fresh vegetables(Saw, S. H., et al., 2020). Apart from that, microbial contamination is exacerbated by unsanitary workplaces and poor sanitation in the surrounding area. This is especially true for raw vegetable display spaces at retail markets, which are rarely or improperly sanitized and cleaned(Saw, S. H., et al., 2020). According to our literature review, Our data are compatible with meta-analysis findings for food borne pathogens in Africa, where increased prevalence rates of *Salmonella spp.* in raw and RTE meals indicate a breach in important control points during food handling(Paudyal et al., 2017).Furthermore, poor general hygiene, the quality of raw materials, water, cold storage, and human intervention may all influence the pathogen's prevalence in RTE foods. Similarly, chemicals like as calcium salts, organic acids, chlorine, hydrogen peroxide, ozone, and organic antimicrobials can be used to reduce microbial development, spoilage, and color changes in salads. In addition, the population of S. Typhimurium on cutting lettuce decreased by around 1 CFU/g after 14 days of cold storage at 4 °C, compared to a rise of 2 to 3 CFU/g after 3 days of cold storage at 22 °C.

Finally, the population of *S. Typhimurium* was considerably larger when non-cut lettuce was stored at 22 °C (Abd-Elall, A. M. M., and A. I. A. Maysa,2015). *Salmonella spp.* infection is a difficult problem to solve since it necessitates tight control over cultivation, harvest, storage, transportation, and marketing. It can also occur anywhere in the supply chain and is tough to eradicate(Bihn, Elizabeth A., and Stephen Reiners,2018). As a result, implementing GAPs (Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables) from seed to production (World Health Organization, 2008), GMPs for postharvest, and HACCP for transformation, such as fresh-cut operations, is critical to reducing the risk of pathogen transmission in fruits and vegetables. As a result, implementing GAPs (Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables) from seed to production (FDA 2008), GMPs for postharvest, and HACCP for transformation, such as fresh-cut operations, is critical to reducing the risk of pathogen transmission in fruits and vegetables(World Health Organization, 2008).

Chapter 7

Conclusion

Salmonella spp. is one of the most common pathogens found in vegetables, and is linked to several operations such as washing, cutting, or disinfection, as well as sample location. Food producers, distributors, and vendors are responsible for ensuring that their products comply with all applicable food safety regulations, and the food industry has a wealth of resources at its disposal to assist in the production, transportation, storage, and sale of fresh fruits and vegetables of acceptable quality and safety(Denis et al., 2016) . To raise awareness about the safety and quality of vegetables, more prevalence research on *Salmonella spp.* in vegetables are needed (Saw, S. H., et al., 2020).

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