OVERVIEW OF SAFETY PRACTICES IN FOODS FOR *SALMONELLA* PREVENTION

by

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Abstract

It will be almost impossible to find a household or an informed consumer, completely oblivious to the health risks posed by foods. According to scientific estimates, 48 million cases of foodborne illness occur each year in the United States, causing 128,000 hospitalizations, 3,000 deaths, which costs $6.4-$77.7 billion in expenses by medical care and lost productivity. These illnesses pose a very big constant, perhaps growing, threat to a vast population. *Salmonella* is the most prevalent foodborne bacteria with more than 1.1 million cases annually in the United States. Increased international trade and distribution, rapid growth in antibiotic resistant bacteria, increase in the number of immunocompromised consumers and changes in agronomic and processing practices poses a very big challenge to monitor, contain and avoid foodborne outbreaks. This can result in contaminated food causing rapid, geographically widespread outbreak.

In the wake of numerous recent foodborne illness outbreaks, this report focuses on current safety practices established by research and available to all the consumers. It studies a significant foodborne bacterium (*Salmonella),* its nature, significance, prevalence, mechanism of action, health risks and preventive safety measures. General food safety practices, to reduce or eliminate the risk, common to all the foodborne bacteria and specially *Salmonella*, include avoiding cross-contamination, thoroughly cooking foods to right lengths of time and temperature, washing fresh produce and fruits prior to consumption and storing foods at the right temperatures. Strict regulations in safe production, safe processing and consumer awareness is highly recommended. People participation is a must.

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Dedication

I sincerely dedicate this report to my beloved Parents (Dr. Surendra Ahirrao & Smita Ahirrao) and lovely sister (Pooja Ahirrao).

Chapter 1 - Foodborne Diseases

According to current scientific estimates, 48 million cases of foodborne illness occur each year in the United States, causing 128,000 hospitalizations, 3000 deaths (CDC, 2011), which costs between $6.5 and $34.9 billion in expenses by medical care and lost productivity respectively (USDA-ERS 2003). By some recent studies, the annual costs of foodborne illnesses have been estimated to be $77.7 billion (Scharff, 2012). The U.S. Department of Agriculture's Economic Research Service estimates that the costs associated with five major pathogens alone (*Escherichia coli* O157:H7, other Shiga toxin-producing *Escherichia coli* (STECs), *Campylobacter*, *Listeria monocytogenes*, and *Salmonella*) amount to at least $6.9 billion annually (USDA-ERS 2003).

Although foodborne illnesses are caused by wide range of foods, meat and poultry products industry, remains the biggest safety concern and focal point in many aspects. The meat and poultry industry is the largest segment of U.S. agriculture. Total meat and poultry production in 2011 reached more than 92.3 billion pounds including the domestic and export market production. The total meat and poultry industry sales were $154.8 billion in year 2009 according to American Meat Institute (AMI). The meat and poultry industry's economic ripple effect generates $864.2 billion annually to the U.S. economy, or roughly 6% of the entire GDP. Frozen chicken products in retail grocery constitute 56% and Food Services constitute 44% of sales. According to the Economic Research Service, USDA estimates, the estimated total per capita consumption of meat and poultry for the year 2013 is going to be 204lb of which, the per capita consumption of chicken products would be 81.8 lb (Appendix B). The proportion distribution of poultry, red meat and fish in the US diet is represented in figure 1(AMI, 2011). The meat and poultry processing industry over the past several years has experienced reduced profits due to several food borne pathogen outbreaks particularly linked to *Salmonella, E. coli, Listeria, Campylobactor, Staphylococcus* and many more.

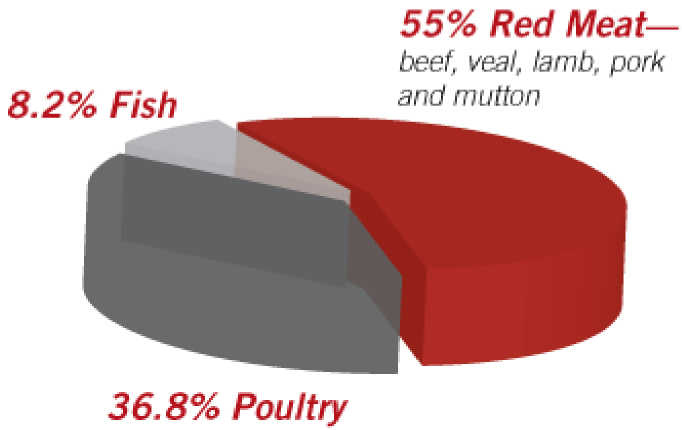

Figure 1: Proportion of meat consumption in the U.S. (AMI, 2011)
(http://www.meatami.com/ht/d/sp/i/47465/pid/47465)

The foodborne illnesses are not easy to detect, confirm and trace back to its origin. It is documented through a reporting system called FoodNet, used by public health agencies that capture foodborne illness in over 13% of the population in United States. It is generally accepted in the scientific community that the true incidences of foodborne diseases are underreported. Of the estimated 13.8 million cases of foodborne illness due to known agents, roughly 30% are due to bacteria. The remaining cases of known etiology are due to parasites in 3% of the cases and viruses in 67% of the cases (Mead et al., 1999). The Foodborne diseases active surveillance network 2010, indicates the rise in *Salmonella* infections since 1996 while there has been a decline in *E. coli* O157H7 infections in the same period (Fig. 2 and 3). The comparison of *Salmonella* infections with infections caused by all other foodborne bacteria is indicated in Appendix A (figure 10).

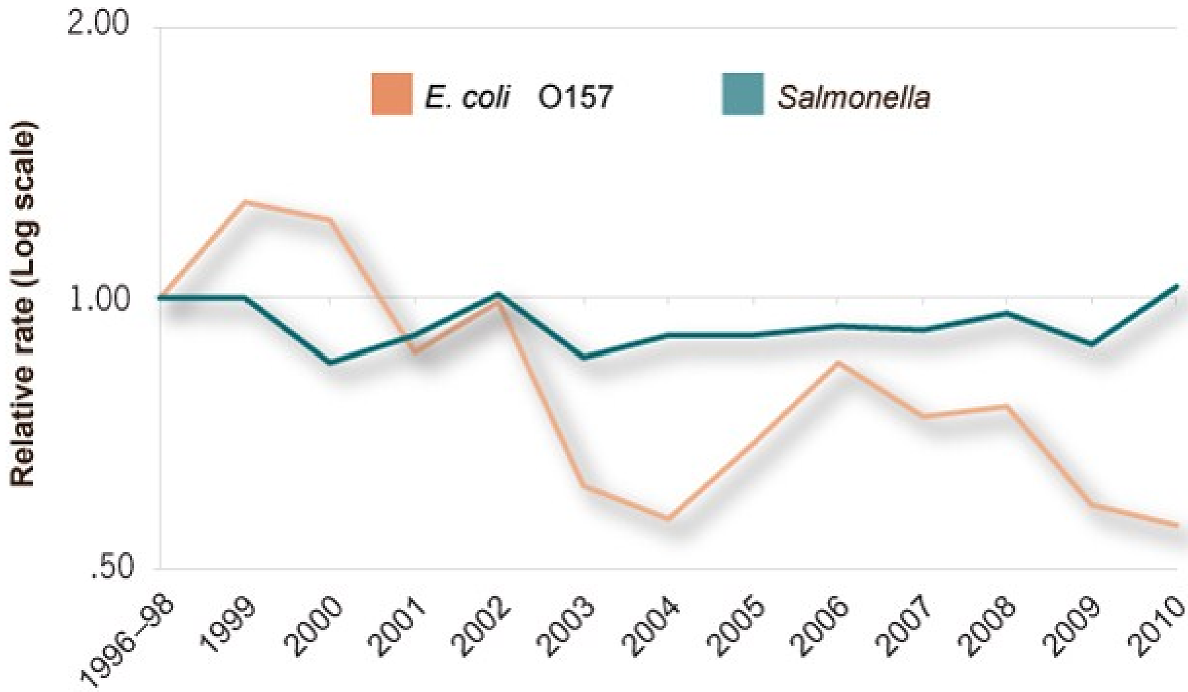

Figure 2: Change in E. coli O157 and *Salmonella* infection, 1996–2010 (Foodborne Diseases Active Surveillance Network, 2010).

(http://www.cdc.gov/vitalsigns/foodsafety/)

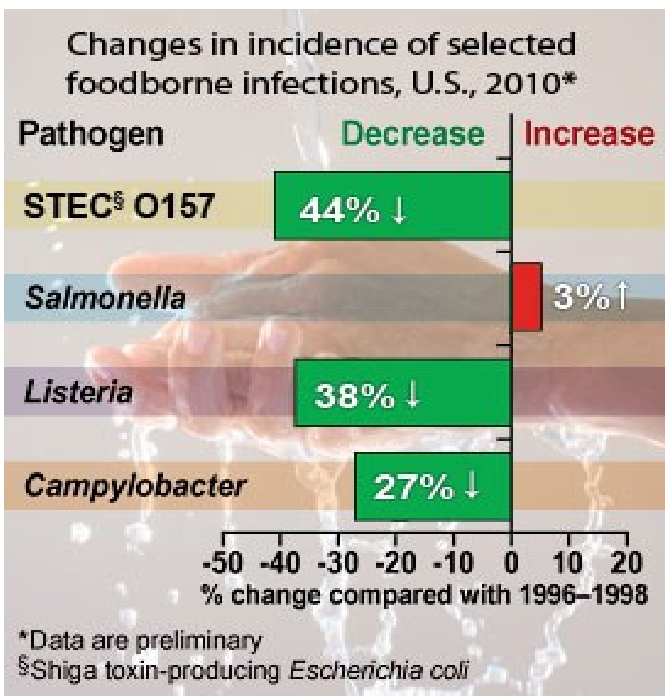

Figure 3: Changes in incidence of selected foodborne infections, U.S., 2010.

(http://www.cdc.gov/features/dsfoodborneillness/)

Bacteria are the causative agents of foodborne illness in 60% of cases requiring hospitalization. *Salmonella*, *Campylobacter,* and *Shigella* are responsible for most cases of foodborne illness among the pathogens documented by FoodNet, 2003. *Salmonella* causes 31% of food related deaths followed by *Listeria* (28%), *Campylobacter* (5%), and *Escherichia coli* O157:H7 (3%) (Mead et al., 1999). These bacteria are more likely to cause foodborne illness in elderly people, immuno-compromised population and kids. International impact of foodborne illness is difficult to estimate. However, about 2.1 million children in developing countries die due to diarrheal illnesses annually. It is suspected that food or water is the medium for many of these illnesses (WHO, 2002).

Most of the foods can be breeding grounds for pathogens as they provide the most essential factors; moisture and vital nutrients. Three types of bacterial foodborne diseases can be recognized: 1) Intoxications, 2) Infections and 3) Toxico-infections. Foodborne bacterial intoxication is caused by the ingestion of food containing pre-formed bacterial toxin, such as the toxins produced by *Staphylococcus aureus* and *Clostridium botulinum*, resulting from bacterial growth in the food. Foodborne infection, on the other hand, is caused by ingestion of food containing viable bacteria such as *Salmonella* or *Listeria*, which then grow and establish themselves in the host, resulting in illness. Foodborne toxico-infections result when bacteria present in food, such as *Clostridium perfringens*, are ingested and subsequently produce a toxin in the host.

Many microorganisms are ubiquitous in nature, occurring in soil and vegetation, in animal wastes and tissues. Some pathogens reside in the intestinal tracts of normal, healthy animals and humans. Human skin surfaces and nasal passages harbor staphylococci. The most common source of contamination for all foods, fresh produce in particular, is water contaminated with fecal matter. It is, thus, obvious how difficult it is to prevent one or more pathogens from contaminating foods. The presence of potentially life threatening pathogens in our environment, the ability of some of them to survive and/or proliferate in low temperatures and in reduced oxygen atmospheres, and, for some pathogens, the low number necessary for causing diseases indicate the seriousness of the potential hazards with which we are faced.

Various studies have established inadequate home food storage and handling practices as major contributors to foodborne illness (Altekruse et al., 1996; Meer et al., 2000). These illnesses can, by and large, be avoided by heating and cooling foods to the appropriate temperatures, storing foods at the appropriate conditions for the recommended time periods, washing hands, keeping kitchen surfaces clean and avoiding cross-contamination. Delicatessens, cafeterias, and restaurants were responsible for 33% of outbreaks (CDC, 2000). Proper handling, cooking, and storage practices in foodservice operations, restaurants and at homes can prevent majority of foodborne illnesses.

It is very evident that, food safety and public health education regarding foodborne illness are not at a desirable level; therefore, they need to be better implemented, continuous and more efficient. CDC, Food Safety and Inspection Services (FSIS) under USDA and all other regulatory authorities should have greater enforcement of proper and safe food handling practices to curtail foodborne illnesses and outbreaks. Regulatory control over food handling in the home is not possible, but increased consumer education could have a beneficial effect.

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Chapter 2 - *Salmonella*

Salmonella is a gram-negative, rod-shaped bacilli with flagella (Figure 4) that can cause diarrheal illness in humans. They are microscopic living creatures that pass from the feces of humans or animals to other humans or other animals. It has diameter of 0.7-1.5µm and length of 2-5µm. *Salmonella* is the most prevalent foodborne bacteria (Bean et al., 1990) along with many others, having over 2,463 serotypes (Popoff et al., 2000). Two types, *Salmonella* Enteritidis and *Salmonella* Typhimurium are most prevalent serotypes in the United States, causing gastroenteritis, and accounting for half of all human infections. *Salmonella* is part of normal gut flora but only pathogenic serotypes, when outnumber benign bacteria, cause an infection. Appendix A (figure 11) shows prevalence of different foodborne *Salmonella* isolates from human sources. Strains that show no symptoms in animals can make humans sick, and vice versa. If present in food, it does not usually affect the taste, smell, or appearance of the food. The bacteria live in the intestinal tracts of infected animals and humans. *Salmonella*, discovered by Dr. Daniel E. Salmon in 1885, have been known to cause illness for over 100 years.

Figure 4: Single *Salmonella* bacterial cell

(http://www.futurity.org/sensors-turn-*salmonella*-into-a-killer/)

There are three main ways *Salmonella* can enter the food supply to cause illness:

1) Animals harbor *Salmonella*, making meats, poultry, eggs, and milk often implicated vehicles.

2) *Salmonella,* which are introduced into the environment, possibly through manure and litter, may persist and contaminate fruits and vegetables on the farm.

3) Cross-contamination in the food service environment or the home, often between raw poultry and ready-to-eat (RTE) products, such as raw vegetables, can also cause salmonellosis.

Salmonella lives in the intestinal track of humans and other animals, including birds. Poultry is the largest source of *Salmonella* for humans (Lynch et al., 2006). *Salmonella* is usually transmitted to humans by eating foods contaminated with animal feces. *Salmonella* present on raw meat and poultry could survive if the product is not cooked to a safe minimum internal temperature, as measured with a food thermometer. It grows at temperatures between 41^{0}F and 113^{0}F and can be readily destroyed by cooking to 165^{0}F. *Salmonella* cannot grow at refrigerator or freezer temperatures. They do survive refrigeration and freezing, however, and will begin to grow again once warmed to room temperature. *Salmonella* can also cause foodborne illness through cross-contamination, e.g., when juices from raw meat or poultry come in contact with ready-to-eat foods. Unwashed hands of an infected food handler may also contaminate food. *Salmonella* can also be found in the feces of some pets, especially those with diarrhea. People can become infected if they do not wash their hands after contact with these feces. Some *Salmonella* are host-adapted like *S. pullorum* in poultry, *S. dublin* in cattle; however, most are not. Although any *Salmonella* is a potential pathogen for humans, most foodborne salmonellosis is caused by non-host-adapted serotypes. The strain, *S. enterica* subsp. *enterica* serotype Typhimurium DT 104, are resistant to several antibiotics, and the increase in its prevalence poses challenges in treatment of the infection (Glynn et al., 1998).

Some infected individuals may excrete *Salmonella* for weeks, months, and, occasionally, years with little or no evidence of clinical disease. Improper hygiene practices by these individuals may lead to either contamination of foods or direct person-to-person contamination. Contamination of the products can occur pre-processing (due to lack of hygiene and proper processing conditions) and post-processing (due to mishandling and lack of proper storage).

Taxonomy of *Salmonella*: It is still evolving but more widely accepted taxonomy of different serotypes of *Salmonella* is as follows:

Kingdom**: Bacteria**

Phylum**: Proteobacteria**

Class**: Gammaproteobacteria**

Order**: Enterobacteriales**

Family**: Enterobacteriaceae**

Genus**: *Salmonella***

Species**: Typhi, Typhimurium, Eteritidis etc.**

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Chapter 3 - Salmonellosis

Salmonellosis is an infection caused by the bacteria *Salmonella*. According to the Centers for Disease Control and Prevention (CDC), roughly 1 to 4 million cases of foodborne salmonellosis occur annually in the United States and an estimated 1.1 million cases of salmonellosis occurred in 2010 in United States, leading to approximately 19,336 hospitalizations and 378 deaths costing the economy $2.4 billion in medical expenses and lost productivity (Scharff, 2012). The majority of human infection with *Salmonella* occurs through ingestion of contaminated foods and poultry in particular is a more frequent source of *Salmonella* (Mead et al., 1999). The Surveillance Report from the Food Diseases Active Surveillance (FoodNet) for 2004, identified *Salmonella* as the most common bacterial infection. It reported the following statistics for foodborne diseases; 42% *Salmonella*, 37% *Campylobacter*, 15% *Shigella*, 2.6% *E. coli* O157:H7, and 3.4% others such as *Yersinia*, *Listeria*, and *Vibrio*.

Most people experience diarrhea, abdominal cramps, and fever within 8 to 72 hours (Figure 6) after the contaminated food was eaten. Additional symptoms may be chills, headache, nausea, and vomiting. Symptoms usually disappear within 4 to 7 days. Many people with salmonellosis recover without treatment and may never see a doctor. However, *Salmonella* infections can be life-threatening especially for infants, young children, pregnant women and their unborn babies, older adults and immunocompromised people who are also at a higher risk for foodborne illness (Lund and O'Brien, 2009).

According to a study conducted in 2001, *Salmonella* was isolated in 19–54% of cattle carcasses, 1.9% of beef samples at retail and 4.2% of retail chicken samples (Beach et al., 2002; Zhao et al., 2001). Hence, it is evident that foods of animal origin can be *Salmonella* carriers. Eggs and egg products, have also been observed to be a significant source of human salmonellosis in the United States. In 1990, the U.S. Dept. of Agriculture required that eggs produced by flocks previously implicated in human disease be tested for *Salmonella.* Although there have been many outbreaks associated with eggs and egg products, the mandatory pasteurization of egg products has been responsible for greatly reducing eggs as a major cause of salmonellosis, and consumer awareness of the need to refrigerate eggs also contributed in the decreased incidence of disease (FDA-CFSAN, 2003). *Salmonella* Enteritidis is localized inside eggs, making thorough cooking absolutely necessary. The CDC estimates that 7 out of 10 cases of *Salmonella* Enteritidis resulted from consumption of raw or undercooked grade A whole-shell eggs (FDA-CFSAN, 2003). This serotype was the second most commonly reported human serotype to the CDC in 2001. The potential for temperature abuse or long holding times, combined with the possibility of inadequate cooking, resulted in the recommendation that institutions use pasteurized egg products or pasteurized in-shell eggs instead of raw-shell eggs (CDC, 2003a). Salmonellosis outbreaks caused by raw, flash fried chicken nuggets or strips have been reported in Australia, Canada and United States.

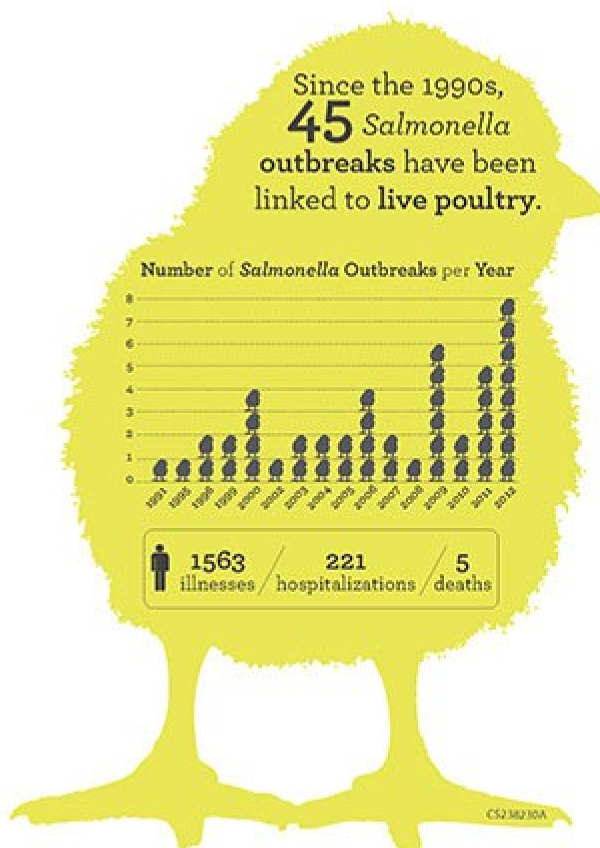

Figure 5: CDC-Number of *Salmonella* outbreaks associated with live poultry.
([http://www.cdc.gov/*salmonella*/pdf/*salmonella*-poultry-poster.pdf](http://www.cdc.gov/salmonella/pdf/salmonella-poultry-poster.pdf))

Several recent outbreaks of salmonellosis linked to partially cooked or raw pre-browned chicken entrees have revealed that consumer confusion related to on-package handling and cooking instructions was a major contributing factor (Minnesota Department of Health, 2006).

From 1998 through 2006, four separate outbreaks of Salmonellosis due to raw, frozen, microwavable, breaded, pre-browned and stuffed chicken products were identified in Minnesota with similar issues of labeling and microwave cooking. In response, state and federal regulators have urged consumers not to microwave partially cooked chicken products even if labeled microwaveable (Minnesota Department of Health, 2006; FSIS, 2006; Minnesota Department of Health 2005).

Following (Table 1) is the detailed list of *Salmonella* outbreaks associated with various food products and categories, in the recent years. It is a comprehensive list prepared by studying all the recent outbreaks acknowledged by CDC. The products involved in the *Salmonella* outbreaks indicate wide variety of products but predominantly it is associated with poultry products.

Table 1: List of Salmonellosis Outbreaks in last few years (CDC, 2013a).

Date	Location (#of states in USA)	No. of Cases	Etiology	Product(s) involved
2013	20, Puerto Rico	338	*S.* Heidelberg	Rotisserie chicken
2013	9	16 (1 death)	*S.* Mbandaka, *S.* Montevideo	Tahini sesame paste
2013	37	316	*S.* Typhimurium	Live poultry
2013	26	125	*S.* Infantis, *S.*Lille, *S.* Newport, *S.* Mbandaka	Live poultry
2013	18	84	*S.* Saintpaul	Cucumber
2013	13	134	*S.* Heidelberg	Frozen chicken
2013	6	22	*S.* Typhimurium	Ground beef
2013	43, Puerto Rico	473	*Salmonella*	Small turtle

2012	24	261(3deaths)	*S.* Typhimurium, *S.* Newport	Cantaloupe
2012	9	46	*S.* Enteritidis	Ground beef
2012	11	46	*S.* Hadar	Live poultry
2012	23	93(1death)	*S.* Montevideo	Live poultry
2012	27	195(2deaths)	*S.* Infantis, *S.*Lille, *S.* Newport	Live poultry
2012	20	49	*S.* Infantis	Dry dog food
2012	28	425	*S.* Bareilly, *S.* Nchanga	Raw scraped ground tuna
2012	20	42	*S.* Bredeney	Peanut butter
2012	12	26(1death)	*S.* Typhimurium	Pet hedgehogs
2012	15	127	*S.* Braenderup	Mangoes
2012	7	20	*S.* Typhimurium	Ground beef
2012	6	190	*S.* Heidelberg	Kosher broiled chicken liver
2011	5	43	*S.* Enteritidis	Turkish pine nuts
2011	34	136	*S.* Heidelberg	Ground turkey
2011	25	106	*S.* Agona	Papaya
2011	42	241	*S.* Typhimurium	African dwarf frogs
2011	5	25	*S.* Enteritidis	Alfalfa sprouts, Spicy sprouts
2011	20	68	*S.* Altona	Chicks and ducklings
2011	15	28	*S.* Johanesburg	Chicks and ducklings
2011	10	20	*S.* Panama	Cantaloupe

2011	26	140	*Salmonella* I 4,[5],12:1	Alfalfa spouts
2010	11	1939	*S.* Enteritidis	Shell eggs
2010	18	44	*S.* Chester	Frozen chicken& rice entree
2010	2	9	*S.* Typhoid	Frozen mamy fruit pulp
2010	15	75	*S.* Hartford	Mexican fast food (chain restaurant)
2010	15	80	*S.* Baildon	Mexican fast food (chain restaurant)
2010	44	272	*S.* Montevideo	Black and red pepper
2009	-	-	*S.* Montevideo	Pistachio nuts
2008	43	1442	*S.* Saintpaul	Raw produce
2008	15	28	*S.* Agona	Rice & wheat puff cereal
2008	Minnesota 11 other states	14 18	*Salmonella* 14,12:i	Stuffed Chicken Breast
2008	Minnesota	4	*S.* Enteritidis	Stuffed Chicken Breast
2006	Minnesota	3	*S.* Typhimurium	Stuffed Chicken Breast
2005-2006	Minnesota 9 other states	27 14	*S.* Enteritidis	Stuffed Chicken Breast
2005	Minnesota	4	*S.* Heidelberg	Stuffed Chicken Breast
2003	British Columbia	23	*S.* Heidelberg	Chicken Nuggets and Strips
1998-1999	Minnesota	33	*S.* Typhimurium	Stuffed Chicken Breast
1998	Australia	9	*S.* Typhimurium	Chicken Nuggets

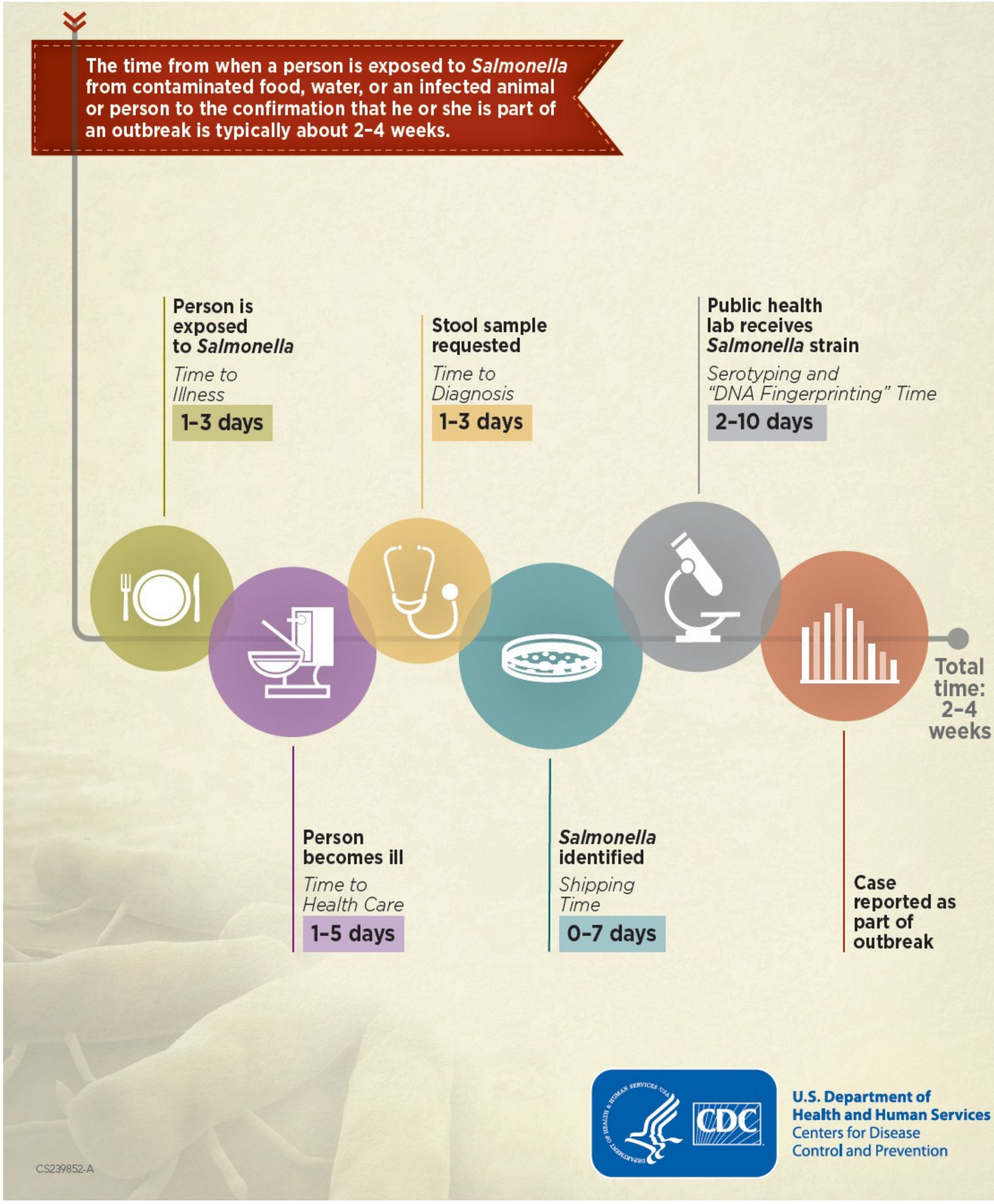

Figure 6: Timeline for reporting cases of *Salmonella* infections (CDC).

(http://www.cdc.gov/*salmonella*/resources/timeline-for-reporting-of-cases.pdf)

Salmonella can also survive and strive in raw milk, which on consumption may cause human salmonellosis. In one study, *Salmonella* was isolated in 6.1% of bulk raw milk samples (Jayarao et al., 2001). According to CDC, between 1972–2000, 16 outbreaks of salmonellosis resulted from raw milk consumption (CDC, 2003b). Milk-borne salmonellosis was particularly prevalent in Scotland prior to 1983, because the sale and consumption of raw milk was common (Sharp, 1986). Milk outbreaks all over the world are primarily associated with raw, unpasteurized milk. The sale of raw milk, with some restrictions, is legal in 27 states of the US (CDC, 2003b). Pasteurization of milk destroys *Salmonella* and currently is the only effective means of control for milk. However, inadequate pasteurization or contact with raw milk after pasteurization can result in contaminated milk.

Animal products are not the only sources of human salmonellosis. Produce can serve as a potential vehicle for *Salmonella* (Brackett R.E., 1999), becoming contaminated either on the farm or through cross-contamination with contaminated products. There have been numerous outbreaks associated with consumption of produce contaminated with *Salmonella* in last few decades. The most important factors contributing to this increase can be attributed to changes in agronomic and processing practices, an increase in per capita consumption of raw or minimally processed fruits and vegetables, increased international trade and distribution, and an increase in the number of immuno-compromised consumers (Beuchat L. R., 2002). Raw sprouts, particularly alfalfa and mung bean, have been involved in 15 salmonellosis outbreaks since 1995 (Thomas et al., 2003). Many outbreaks of salmonellosis have been traced back to alfalfa sprouts, other sprouts, various fruits and fresh produce in past few decades (Appendix C) and in recent past (2009-2013) as listed in Table1. Warm and moist conditions for sprouting allow growth of the pathogen. According to the study by Shi et al., in 2007 many serovars of *Salmonella* can colonize and survive on tomatoes, but that growth is serovar dependent. Like tomatoes, mangoes can internalize *Salmonella* to the fruit portion via the stem scar (Bordini et al., 2007). On-farm contamination of cantaloupes resulted in 24 cases of salmonellosis in 1997 (Mohle-Boetani et al., 1999). Contamination of cantaloupes on one farm caused multistate outbreaks of salmonellosis each spring between 2000 and 2002 (CDC, 2002). Since produce may be eaten raw, different control measures are necessary to prevent illness when the pathogen is introduced on the farm.

3.1 *Salmonella* mechanism of action in Human body

Human body has 10 times more bacteria than human cells; most of these bacteria are innocuous and are in fact part of normal human gut flora. We colonize trillions of these bacteria on mucosal and epithelial surfaces (Costello et al., 2009). All these microbes exist in a balanced symbiotic relationship with the host, without causing any pathogenicity unless the host or the colonized mucosa is invaded by large number of pathogens (Lee and Mazmanian, 2010). These intestinal microbes provide many benefits for humans, including proper development of the immune system, digestion of food, absorption and production of few vital nutrients, and protection against invading pathogenic organisms (Backhed et al., 2005).

Salmonella is ingested through mouth from contaminated food and water (as indicated in figure 7). Most of the bacteria including *Salmonella* are destroyed by stomach acidity but few who survive pass further to gastrointestinal tract (GI tract). It has to compete with existing gut flora (mentioned above) for its survival. The most predominant and prevalent serotypes of *Salmonella* causing gastroenteritis are *S*. Enteritidis and *S.* Typhimurium. They cross M cells and attach to microvilli of epithelial cells after finding proper site. It uses a type III secretion system to enter intestinal epithelium by altering cellular cytoskeletal structure and inducing membrane ruffling (Barbara G et al., 2012). It injects endotoxins and effector proteins, compromising integrity of host cell. It includes Sip proteins(SipA), SopE, SopB, and SptP. Sip proteins encoded by *Salmonella* are required for the action of SopE and for the invasion of epithelial cells (Wood et al., 1996). SipA stabilizes actin filaments, inducing membrane ruffling and perhaps focusing membrane changes where bacteria are localized to allow their entry. *Salmonella* enters though a vacuole where the bacteria is safe and can now start to multiply.

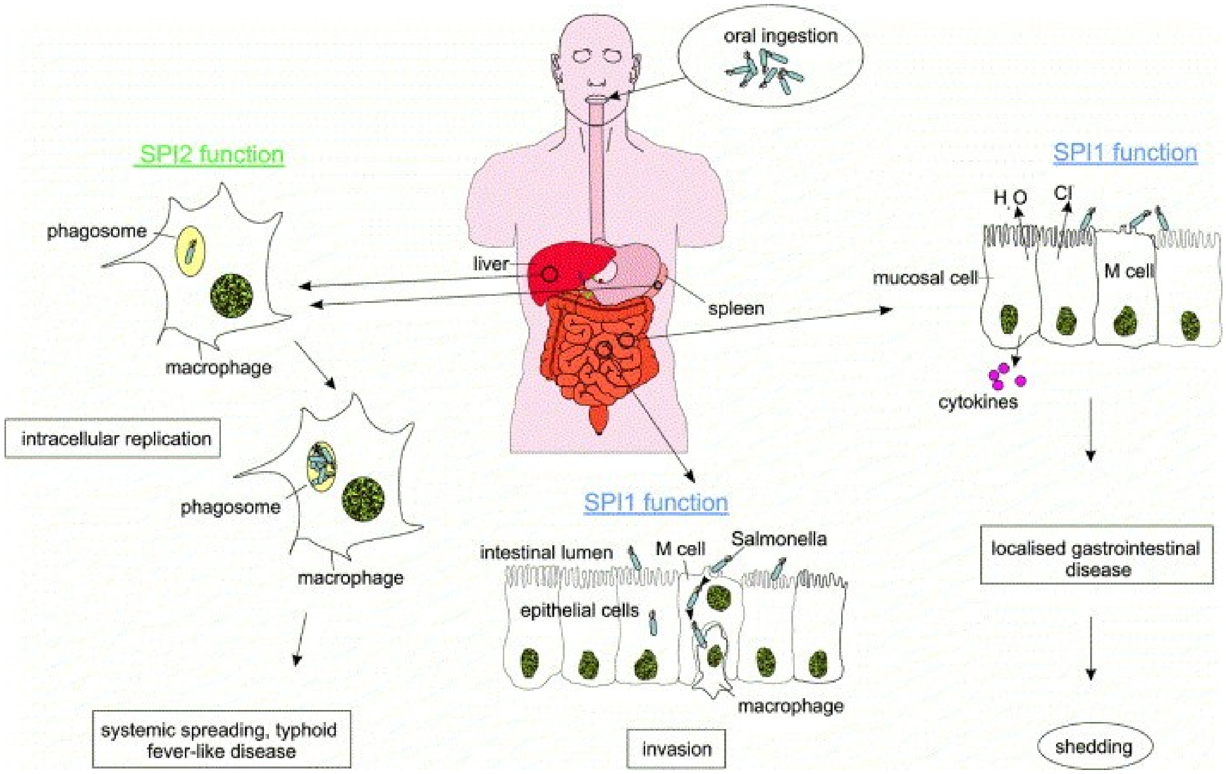

Figure 7: Mechanism of action of *Salmonella* cells in Human body (http://zelenaplus.com/wp-content/uploads/2012/09/gambar-penyakit-salmonellosis.jpg)

Salmonella can cause macrophage apoptosis through effectors injected using a type III secretory system that is encoded by Spi2 (*Salmonella* pathogenicity island 2). This allows the bacteria then to get into the lymphatic system and spread across the body. An inflammatory response is triggered due to secretion of cytokines causing localized gastroenteritis and eventual shedding through excretion. *Salmonella* can also enter intestinal cells directly by the apical pole of the cell or be captured by dendritic cells that emit pseudopods between epithelial cells. The latter process promotes systemic dissemination. In the vast majority of cases, *Salmonella* causes an acute but self-limiting diarrhea, but in systemic spread it cannot be contained within the gastrointestinal tract and invades the body to cause septicemia; consequently, many organs become seeded with *salmonellae*, sometimes leading to osteomyelitis, pneumonia or meningitis. *Salmonella* has been studied extensively but much is still to be discovered about its ever changing virulence.

3.2 Steps in Investigating Foodborne Outbreaks

As enlisted in Table1, large multi-state or nationwide foodborne outbreaks have become more common and are frequently recognized. Advances in surveillance systems in US have enabled CDC and various other state public health authorities to identify outbreaks quickly and more accurately, that would not have been identified previously. The global food supply chain poses a very big challenge to monitor and contain the outbreaks, as it is difficult to maintain the food safety standards for foods from countries all over the world. This can result in contaminated food causing rapid geographically widespread outbreak (CDC, 2013b).

The investigation of outbreaks is very important to identify, contain, monitor, and save people affected by it, to prevent additional illnesses, and to learn how to prevent similar outbreaks from happening in the future. A foodborne outbreak investigation goes through several steps as shown in figure 8. They are described here in order, but in reality investigations are dynamic and several steps may happen at the same time.

1) Detecting a possible outbreak
2) Defining and finding cases
3) Generating hypotheses about likely sources
4) Testing the hypotheses
5) Finding the point of contamination and source of the food
6) Controlling an outbreak
7) Deciding an outbreak is over

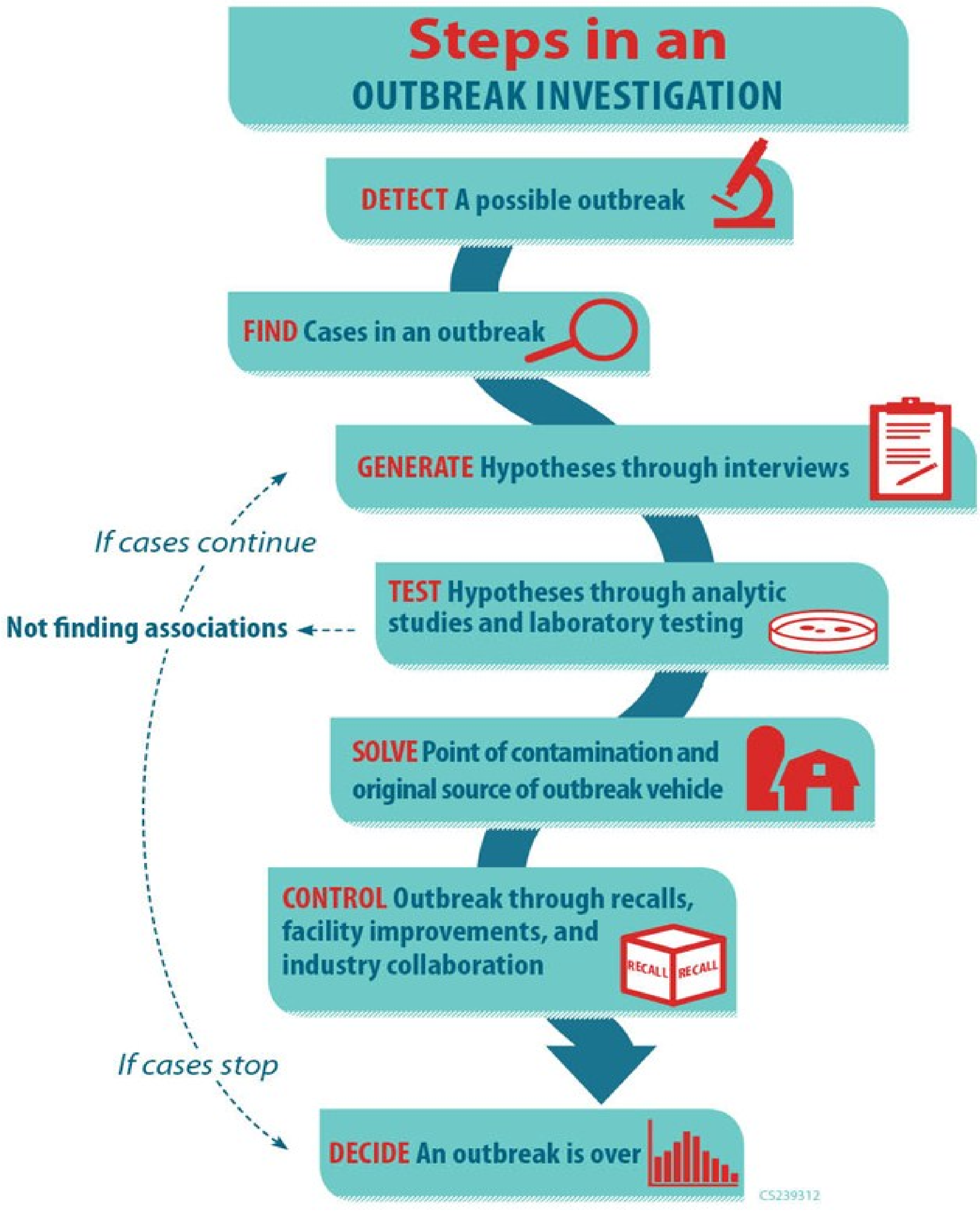

Figure 8: Steps in Foodborne Outbreak investigations. (CDC 2013b) (http://www.cdc.gov/foodsafety/outbreaks/investigating-outbreaks/investigations/figure_outbreak_steps.html)

Foodborne illnesses are caused by pathogens and toxins (chemicals). Pathogens are germs, such as bacteria, viruses, and parasites that can cause illness. More than 250 pathogens and toxins are known to cause foodborne illness. The size and scope of a foodborne outbreak can vary based on which pathogen or toxin is involved, how much food is contaminated, where in the food production chain contamination occurs, where the food is served, and how many people eat it. According to CDC, they are categorized in to following three categories:

- **Small, local outbreak**
- **Statewide or regional outbreak**
- **Nationwide outbreak**

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Chapter 4 - Safety practices for *Salmonella* prevention

Various safety measures and combinations can be employed to ensure safe, assured, reliable supply of food depending on the type of food, type of foodborne pathogen and mode of contamination of the food. Reduction of the incidence of *Salmonella* contamination requires a number of safety approaches, right from farm to fork. The multitude of approaches include heat processing, drying, reducing water activity, irradiation, increasing acidity, vaccination of livestock, improving hygiene, reducing cross contamination and having strictly enforced regulation and surveillance.

Since *Salmonella* is heat sensitive; the most common method of eliminating *Salmonella* from food products is heat processing from industrial scale production to restaurants and even the household kitchen. Heating as a safety measure can be employed in many forms including boiling, canning, pasteurizing, conventional oven heating, microwave heating etc. Ordinary pasteurization or cooking conditions are generally sufficient to kill *Salmonella* in high-moisture foods. The heat resistance of *Salmonella* is markedly increases as water activity (a_w) decreases.

Table 2: USDA recommended internal temperature to which various meat products should be cooked and/or reheated for inactivation of harmful bacteria

Food Type	Recommended Internal Temperature
Fresh beef (well done) Fresh pork (well done)	**170 ^{0}F**
Poultry (chicken, turkey) Leftover meats Stuffing Ground meats (chicken, turkey)	**165 ^{0}F**
Ground meats (beef, pork, veal, ham) Pork, roast beef (medium) Ham (fresh) Eggs	**160 ^{0}F**
Roast beef (rare) Fish	**145 ^{0}F**

Table 2 lists recommendation of the USDA for the internal temperature attained during several types of thermal lethality cooking methods including microwave cooking for wide range of meat and poultry products. It is also indicated graphically in Appendix A (figure 13). Internal temperature should be measured by a food thermometer placed at the center of the product after cooking. In the absence of regulatory guidelines, a 5-6 log reduction of the pathogen of concern, (generally *Salmonella*) has generally been acceptable for most of the products.

Large number of foodborne illness outbreaks, particularly *Salmonella* outbreaks, has been associated to lack of proper cooking and lack of adequate cooking instructions in the case of Ready-to-eat (RTE) or Non Ready-to eat (NRTE) foods. USDA-FSIS has called on industry to develop stronger safe handling labels on such products and validate whether such labels have the desired effect of compelling consumers to produce a verifiably safe product through the use of a meat thermometer (Post, 2006).

Microwave cooking and reheating has grown exponentially in last few decades. It has grown from only 25% households using microwave in 1986 and to more than 90% today, which is estimated to be more than 150 million microwaves in United States. It is critically important to understand the nature of microwave heating and how to ensure safe food cooking using microwaves, as both the popularity and usage of microwave ovens has increased, due to its efficiency and convenience. Several recent studies have indicated the pathogen survival during microwave reheating and cooking as a growing concern for consumers, the regulators and the food industry. Some people do not read the directions provided on the box of a microwave entrée (Smith et al., 2008). Majority of people cook all microwave foods on the highest setting for the shortest amount of time, even if a hold time is recommended for uniformity of temperature. Many of them did not even take the time to read that section of the box (Schiffman, 1995). Various studies have established the non-uniform nature of microwave cooking; forming Cold spots. Cold spots can provide shelter to foodborne pathogens in which they can survive and grow if not stored properly after heating (Fields et al., 1986).

The major factors affecting pathogen survival include hot and cold spots, non-uniform heating, the dielectric properties of a food, wattage and power output of the microwave being used, age of the micowave and the size, shape and orientation of the food in the microwave (Carter, 1994; Flores, 1994). There are no standards for consumers to follow, in order to correct this difference in microwave ovens across the United States and only one set of heating directions is provided with most products; therefore many microwave foods are not completely cooked, leaving them vulnerable to surviving pathogens (Fakhouri and Ramaswamy, 1993; Schiffman, 1997). Some companies have now started to validate microwave cooking procedures for their products and putting the instructions on the label. But the standards are nowhere close to what it should be. In most of the cases it is only one set of instruction for a particular watt setting whereas in United Kingdom the microwave cooking instructions are written in different wattage and time combinations.

For example in one study, effect of microwave heating on *Salmonella* Enteritidis inoculated on fresh chicken was investigated using a microwave oven (800 W) to determine the inactivation, in relation to the time of heating at two power settings: high (level 10) and medium (power level 6). The relationship between heating time and temperature was also been studied. The destruction was 6.4 log cycles at time 95 sec for the high power level, and 5 log cycles at time 140 sec for medium power setting. After 110 sec for higher power level, no survival of *Salmonella* Enteritidis was detected in samples (100g), but at 140 sec for medium power level, these food pathogens were still present (Pucciarelli and Benassi., 2005). According to a 2009 American Meat Institute (AMI) report; on microwave cooking of pre-browned, breaded, uncooked, frozen chicken entrees like chicken tenders, chicken kiev and chicken cordon bleu inoculated with 6-7 log of *Salmonella* spp. inoculum, suggests wide difference in *Salmonella* inactivation and temperature distribution. The mentioned chicken products were cooked at 2 different wattages 600W and 1000W, heat distribution and corresponding pathogen reduction was recorded. Results indicate that 600W microwave with prescribed cooking times consistently recorded temperatures below 165^0F with irregular heating pattern regardless of additional treatments like using a lid, turntable and flipping the product half-way through cooking time; whereas, 1000W microwave cooking showed consistently over 165^0F temperature throughout with uniform heating pattern. The corresponding *Salmonella* reduction/inactivation was in agreement with the temperature profiling study and showed 1-6log reduction in the case of 600W microwave cooking and complete (6-7 log) reduction in 1000W microwave cooking (Phebus R. et al., 2009).

On the other hand, conventional ovens cook uniformly but are too time consuming for an average consumer, to use it all the time. Not enough research has been done to examine whether safe food handling labels perceived as effective translate into safe food handling behavior, including the use of proper thawing and cooking techniques, the use of measures to minimize cross-contamination, and the use of meat thermometers to confirm appropriate cooking, to ultimately minimize the incidence of foodborne illness from these products. Research is necessary to determine how to design microwave foods and microwave processes so that the food can be free of pathogens. It is important to note that no matter how many warnings are given in the case of microwave foods, people will still find it difficult to read and will continue to have the "it could never happen to me" mentality. This, on the whole, calls for innovative packaging for consumer awareness, nationwide elaborate public health and food safety awareness initiatives. Safety needs to be designed into microwave foods, microwave ovens and microwave cookbooks.

Current US standards for milk pasteurization result in more than 12 log reduction of viable *Salmonella* found in milk (Read et al.,1968). Minimum heat processes for pasteurization or cooking of most high-moisture products will eliminate *Salmonella* from these products. Occurrence of *Salmonella* in such processed products generally results from post-processing contamination. Vaccination of egg laying chickens has shown significant reduction in the percent of eggs positive for *Salmonella* Enteritidis (Woodward et al., 2002). Some research has examined the effect of probiotics on the intestinal micro-flora of chickens to improve the gut-flora and colonize the chicken with known microorganisms to "competitively exclude" *Salmonella*. Successful reduction in the percent of the flock positive for *Salmonella* was achieved when the feed was supplemented with yeast (Line et al., 1998) or when chickens were both sprayed with a patented mucosal starter culture and fed the culture through water (Bailey et al., 2000).

In July 1996, USDA's Food Safety and Inspection Service (FSIS) published pathogen reduction performance standards for *Salmonella*. The performance standard (percent positive) was established by collecting the average baseline in the industry. Companies must use HACCP and other measures to ensure that the percent of their product that is positive for *Salmonella* falls below this baseline. The performance standard has been expanded to include steers, cows, broilers, hogs, and several related products. Between 1997 and 2003, FSIS reported a 66% decrease in the presence of *Salmonella* in raw meat and poultry (USDA, 2003). Irradiation was approved in 1999 as a means to control the microorganism as part of a HACCP system (USDA, 1999).

In some cases, dry products may be heat processed for the purpose of elimination of *Salmonella.* Ayres and Slosberg (1949) and Banwart and Ayres (1956) demonstrated the effectiveness of dry-heat treatment on reducing *Salmonella* in pan-dried egg white. This work eventually led to the requirement for dry-heat pasteurization of this product (U.S. Congress, 1970). Similar treatments have been applied to gelatin, rendered animal by-products, nonfat dry milk, and chocolate.

One of the major manufacturing factors responsible for elimination of *Salmonella* from food products are acidification and reduction of Water Activity (a_w). Goepfert and Chung (1970) found out that the combination of acidity and sodium chloride (NaCl) was the principal reason for eliminating *Salmonella.* Smittle (1977) studied mayonnaise and salad dressing and established that the main reason for the *salmonella* inactivation in these products is acidity and reduction of water activity affected by moisture, NaCl, and sugar concentration. These same factors are responsible for control of *Salmonella* in a variety of fermented dairy, meat, and vegetable products. *Salmonella* may survive for extended periods in dehydrated foods. The rate of death of *Salmonella* in food preserved by reduced a_w is increased at higher a_w levels, temperatures, and oxygen levels (Genigeorgis and Riemann, 1979). In low-moisture products such as peanut butter and chocolate, *Salmonella* may remain for years, with little loss of viability. Moist, perishable products are generally distributed under refrigerated or frozen conditions. Though freezing and frozen storage can have some lethal effects on *Salmonella,* conversely it can remain viable for long periods of time in frozen foods and that survival is enhanced as the storage temperature decreases (Georgala and Hurst, 1963).

There has been increasing number of *Salmonella* outbreaks (indicated in table1) associated with fresh produce, such as alfalfa sprouts, spinach, lettuce, cantaloupe, mango and many other fruits and vegetables, in the recent past. Typically, it is introduced to these fresh produce at the farm through external factors. Contamination in these products, which are typically not heated or cooked before consumption, present challenges to the food industry (CDC, 2002; Thomas et al., 2003). Chemical disinfection of the seed coat is not mandatory, but is recommended for sprouts by the Food and Drug Administration (FDA). A survey of sprout producers in California found that most alfalfa sprout growers followed FDA recommendations. Mung bean producers were less apt to follow the guidance (Thomas et al., 2003). An outbreak involving 87 cases of *Salmonella* Mbandaka was linked back to growers who did not disinfect seeds (Gill et al., 2003). The recommended level of chlorine treatment to alfalfa sprout seeds, 20,000 ppm, was not sufficient to eliminate *Salmonella*, as Gandhi et al. (2001) observed. Therefore, compliance on the part of the grower, while worthwhile, does not guarantee a *Salmonella*- free product since chemical sanitizers may not be wholly sufficient to eliminate the presence of *Salmonella* in fruits and vegetables with natural openings and crevices (Beuchat and Ryu, 1997).

In summary, general food safety practices, to reduce or eliminate the risk, common to all the foodborne bacteria and specially *Salmonella* include avoiding cross-contamination, thoroughly cooking foods to right lengths of time and temperature, washing fresh produce and fruits prior to consumption and storing foods at the right temperatures. Strict regulations in safe production, safe processing and consumer awareness is highly recommended. People participation is must. The graphic in figure 9 aptly demonstrates the multi-stage preventive measures to be taken.

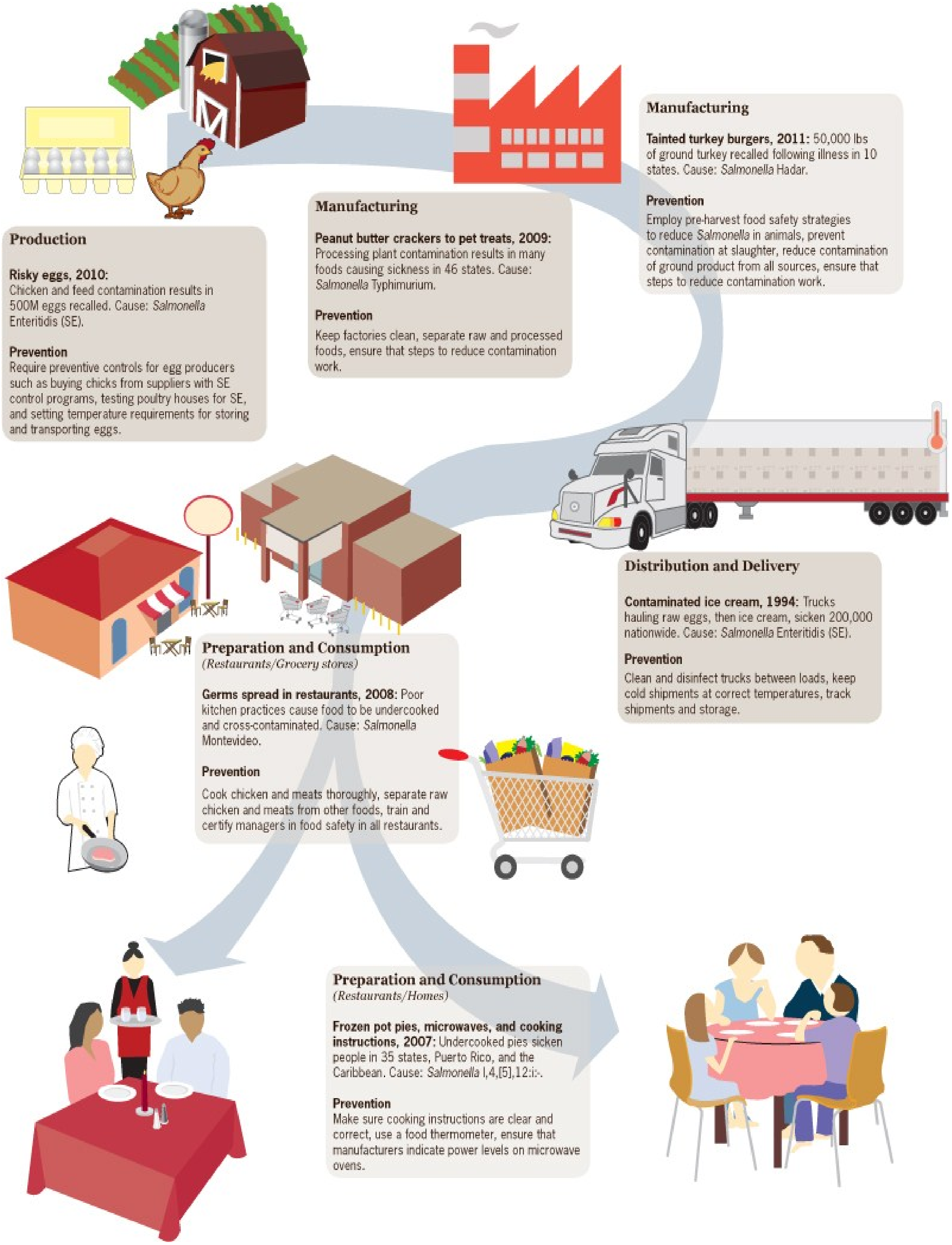

Figure 9: Lessons learned from *Salmonella* outbreaks(CDC 2010).

(http://www.cdc.gov/vitalsigns/foodsafety/infographic.html)

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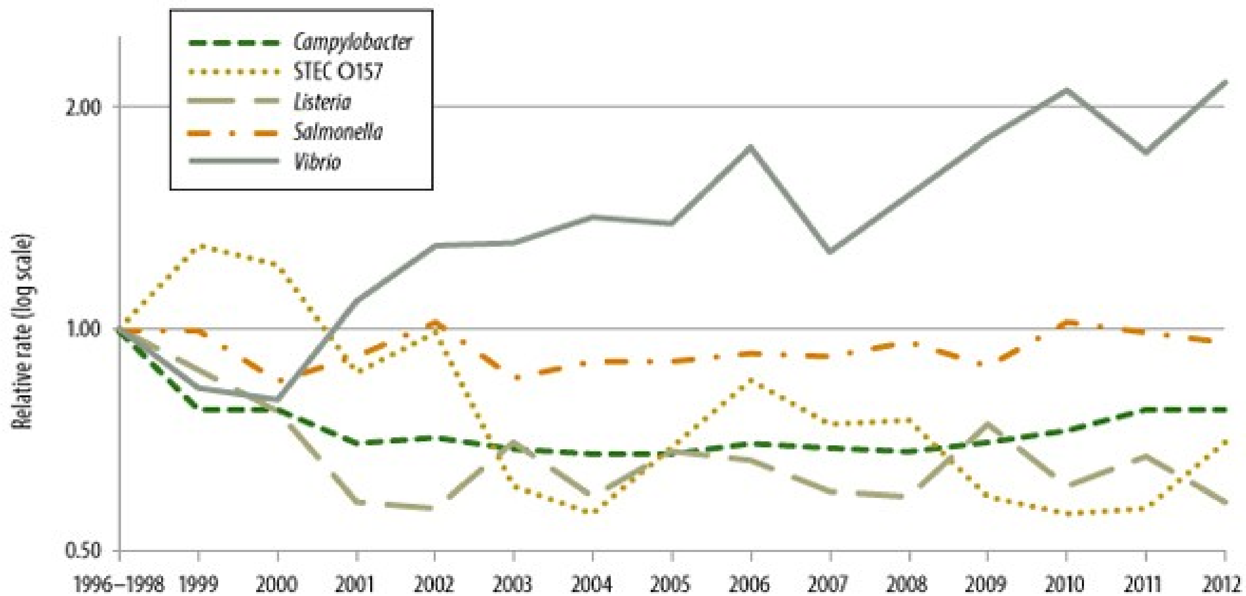
Appendix A - Additional factsheets about *Salmonella*

Relative rates of laboratory-confirmed infections with *Campylobacter*, STEC* O157, *Listeria*, *Salmonella*, and *Vibrio* compared with 1996–1998 rates, by year — Foodborne Diseases Active Surveillance Network, United States, 1996–2012†



* Shiga toxin-producing *Escherichia coli*.

† The position of each line indicates the relative change in the incidence of that pathogen compared with 1996–1998. The actual incidences of these infections cannot be determined from this graph. Data for 2012 are preliminary.

Figure 10: Long term trends by Foodborne Diseases Active Surveillance Network, CDC 2012.

(http://www.cdc.gov/foodnet/data/trends/trends-2012.html)

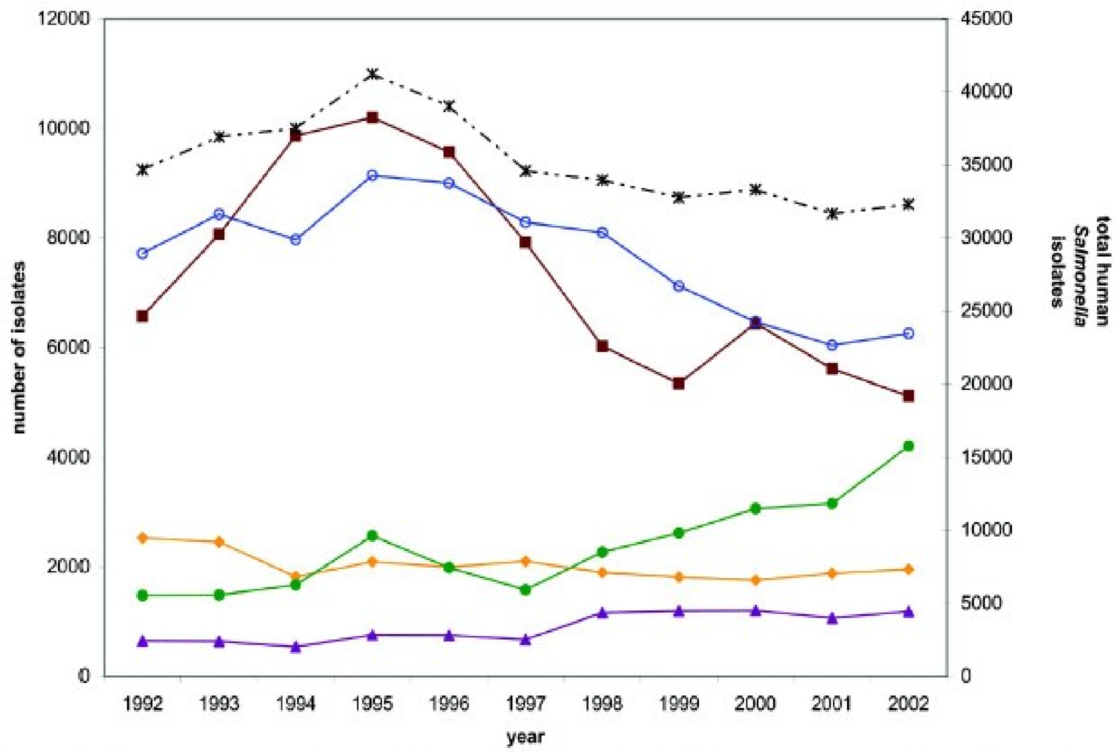


Figure 1. Most Common *Salmonella* Isolates from Human Sources (data from CDC PHLIS Surveillance Data: *Salmonella* Annual Summaries); left axis: (✦) Heidelberg, (■) Enteritidis, (▲) Javiana, (●) Newport, (○) Typhimurium; right axis: (-✳—) total number of all *Salmonella* isolates.

Figure 11: Most common *Salmonella* Isolates from human sources (data from CDC PHLIS surveillance data: *Salmonella* annual summaries) IFT, 2004. (http://www.ift.org/Knowledge-Center/Read-IFT-Publications/Science-Reports/Scientific-Status-Summaries/Bacteria-Associated-with-Foodborne-Diseases.aspx)

FOOD SAFETY

PROGRESS REPORT

FOR 2012

Disease Agents	Percentage change in 2012 compared with 2006–2008	2012 rate per 100,000 Population	2020 target rate per 100,000 Population	CDC estimates that...
Campylobacter	14% increase	14.30	8.5	For every *Campylobacter* case reported, there are 30 cases not diagnosed
Escherichia coli O157	No change	1.12	0.6	For every *E. coli* O157 case reported, there are 26 cases not diagnosed
Listeria	No change	0.25	0.2	For every *Listeria* case reported, there are 2 cases not diagnosed
Salmonella	No change	16.42	11.4	For every *Salmonella* case reported, there are 29 cases not diagnosed
Vibrio	43% increase	0.41	0.2	For every *Vibrio parahaemolyticus* case reported, there are 142 cases not diagnosed
Yersinia	No change	0.33	0.3	For every *Yersinia* case reported, there are 123 cases not diagnosed

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention

For more information, see http://www.cdc.gov/foodnet/

Preliminary FoodNet 2012 Data

April 2013

Figure 12: FoodNet's progress report on six key pathogens, 2012.

(http://www.cdc.gov/features/dsfoodnet2012/food-safety-progress-report-2012-508c.pdf)

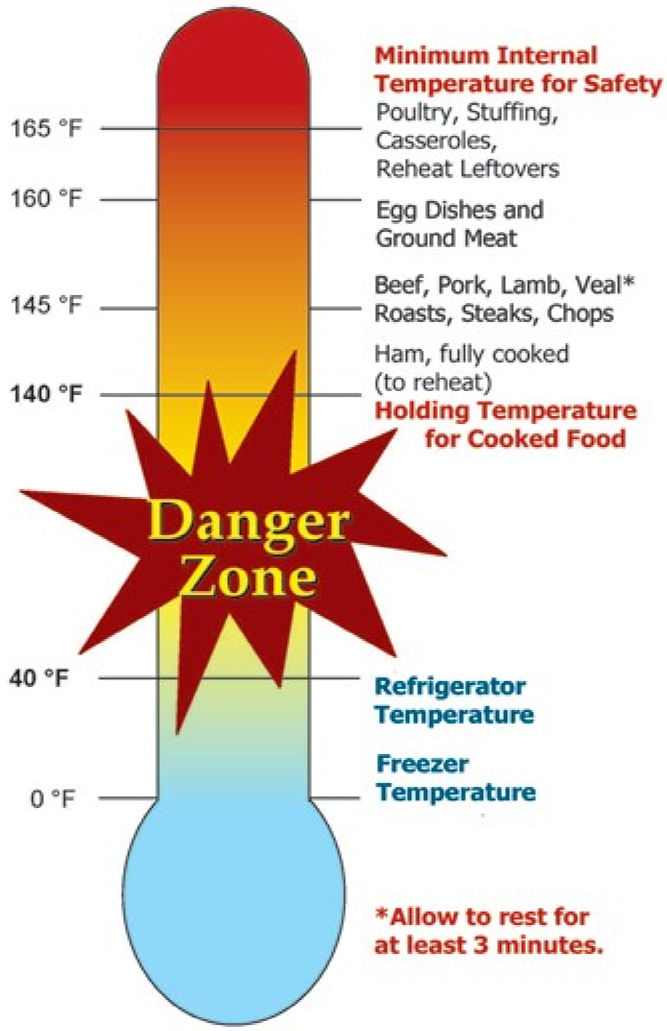


Figure 13: Minimum internal temperature for most of foodborne bacteria safe foods (http://www.fsis.usda.gov/wps/wcm/connect/fsis-content/internet/main/topics/food-safety-education/get-answers/food-safety-fact-sheets/safe-food-handling/danger-zone-40-f-140-f/ct_index).

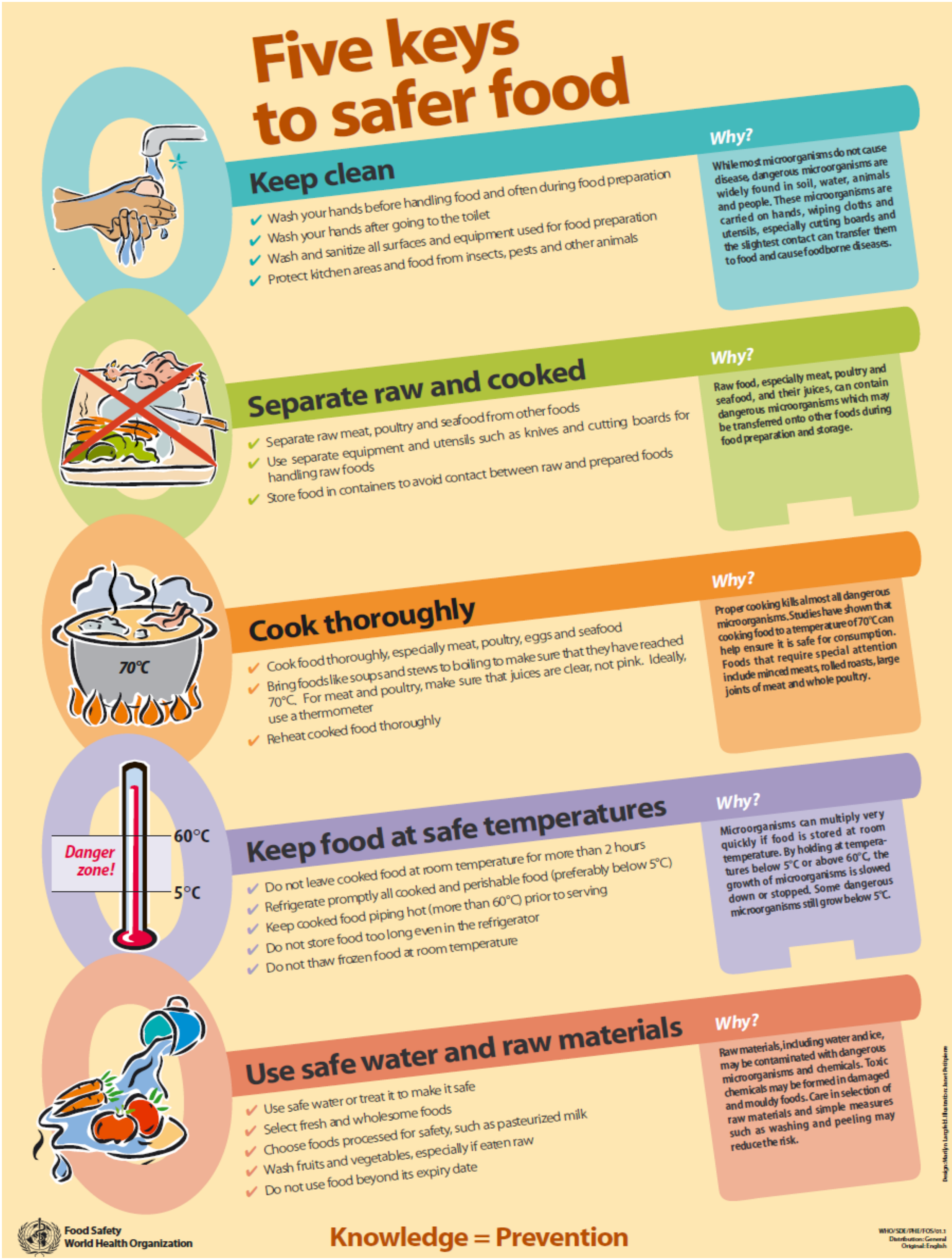


Figure 14: WHO five keys to safer food.

(http://www.who.int/foodsafety/publications/consumer/manual_keys.pdf)

Appendix B - Latest estimates of Annual consumption of various food types in the US (Economic Research Service, USDA 2013)

U.S. red meat and poultry forecasts

	2010					2011					2012					2013					2014		
	I	II	III	IV	Annual	I	II	III	IV	Annual	I	II	III	IV	Annual	I	II	III	IV	Annual	I	II	Annual
Production, million lb																							
Beef	6,248	6,546	6,768	6,741	26,305	6,410	6,559	6,736	6,490	26,195	6,283	6,473	6,586	6,572	25,913	6,172	6,517	**6,640**	**6,270**	**25,599**	**5,870**	**6,135**	**24,150**
Pork	5,607	5,302	5,401	6,126	22,437	5,719	5,370	5,484	6,186	22,758	5,858	5,519	5,631	6,244	23,253	5,777	5,519	**5,700**	**6,400**	**23,396**	**5,930**	**5,700**	**24,135**
Lamb and mutton	43	40	39	42	164	36	40	36	37	149	39	39	39	39	156	38	40	**41**	**38**	**157**	**38**	**39**	**153**
Broilers	8,733	9,198	9,496	9,484	36,910	9,290	9,509	9,542	8,860	37,201	9,089	9,381	9,372	9,197	37,039	9,143	9,466	**9,650**	**9,550**	**37,809**	**9,425**	**9,775**	**38,750**
Turkeys	1,340	1,383	1,415	1,506	5,644	1,402	1,471	1,423	1,495	5,791	1,446	1,505	1,480	1,537	5,967	1,459	1,486	**1,465**	**1,515**	**5,925**	**1,445**	**1,520**	**6,055**
Total red meat & poultry	22,122	22,626	23,291	24,058	92,097	23,011	23,113	23,396	23,225	92,745	22,866	23,085	23,274	23,738	92,962	22,742	23,190	**23,653**	**23,924**	**93,509**	**22,861**	**23,336**	**93,888**
Table eggs, mil. doz.	1,610	1,626	1,645	1,666	6,547	1,624	1,634	1,646	1,686	6,590	1,658	1,653	1,677	1,734	6,722	1,680	1,696	**1,720**	**1,760**	**6,856**	**1,705**	**1,715**	**6,920**
Per capita disappearance, retail lb 2/																							
Beef	14.6	15.1	15.3	14.6	59.6	14.1	14.6	14.7	14.0	57.3	14.0	14.7	14.5	14.2	57.4	13.7	14.5	**14.6**	**13.9**	**56.7**	**13.1**	**13.8**	**54.0**
Pork	11.8	11.4	11.7	12.8	47.8	11.4	11.1	11.0	12.2	45.7	11.1	10.9	11.2	12.7	45.9	11.5	11.3	**11.3**	**12.8**	**46.9**	**11.7**	**11.5**	**47.9**
Lamb and mutton	0.2	0.2	0.2	0.2	0.9	0.2	0.2	0.2	0.2	0.8	0.2	0.2	0.2	0.2	0.8	0.2	0.2	**0.2**	**0.2**	**0.9**	**0.2**	**0.2**	**0.9**
Broilers	20.1	20.5	21.4	20.4	82.4	21.5	21.5	20.8	19.1	82.9	20.1	20.4	20.3	19.7	80.4	20.1	20.3	**20.8**	**20.6**	**81.8**	**20.3**	**21.1**	**83.3**
Turkeys	3.5	3.6	4.1	5.2	16.4	3.5	3.5	4.0	5.0	16.1	3.5	3.6	4.1	4.9	16.0	3.7	3.6	**4.1**	**4.8**	**16.1**	**3.6**	**3.7**	**16.6**
Total red meat & poultry	50.7	51.2	53.3	53.7	208.9	51.3	51.3	51.0	51.0	204.6	49.3	50.3	50.6	52.0	202.2	49.5	50.3	**51.4**	**52.7**	**204.0**	**49.3**	**50.8**	**204.3**
Eggs, number	61.5	61.4	62.2	62.8	247.9	61.1	61.3	62.2	63.1	247.6	62.3	61.2	62.2	64.0	249.7	62.4	61.6	**62.5**	**64.3**	**250.7**	**62.4**	**62.9**	**253.5**
Market prices																							
Choice steers, 5-area Direct, $/cwt	89.44	96.33	95.47	100.28	95.38	110.07	112.79	114.05	121.99	114.73	125.29	120.91	119.69	125.54	122.86	125.52	124.95	**121-124**	**122-128**	**123-126**	**122-132**	**124-134**	**126-136**
Feeder steers, Ok City, $/cwt	98.73	112.65	112.29	113.55	109.31	127.20	131.09	134.74	141.93	133.74	152.81	150.05	139.31	143.40	146.39	141.36	133.10	**151-154**	**151-157**	**142-145**	**154-164**	**170-180**	**160-170**
Cutter Cows, National L.E., $/cwt	51.79	58.79	58.90	54.93	56.10	68.66	74.88	66.11	63.54	68.30	76.57	83.51	76.94	73.81	77.71	77.87	77.46	**78-81**	**78-80**	**77-80**	**79-83**	**83-87**	**81-85**
Choice slaughter lambs, San Angelo, $/cwt	103.87	106.17	115.57	141.62	116.81	174.66	157.99	161.13	148.61	160.60	145.33	127.08	89.28	89.85	112.89	107.53	91.72	**91-94**	**93-99**	**96-99**	**94-104**	**96-106**	**93-103**
Barrows & gilts, N. base, l.e. $/cwt	50.41	59.60	60.13	50.11	55.06	59.94	68.80	71.06	64.66	66.11	61.68	61.79	61.43	58.63	60.88	59.03	65.46	**67-68**	**59-61**	**62-64**	**57-61**	**60-64**	**58-62**
Broilers, 12 City, cents/lb	82.20	85.00	84.50	80.00	82.90	77.90	82.60	78.80	76.80	79.00	87.40	85.1	82	92.1	86.6	103.5	108.6	**93-94**	**89-93**	**98-100**	**88-96**	**90-98**	**95-102**
Turkeys, Eastern, cents/lb	75.60	84.40	97.90	103.70	90.40	90.20	99.90	106.40	111.60	102.00	100.70	106.9	108.5	106.1	105.6	96	97.7	**99-102**	**100-106**	**98-100**	**90-98**	**93-101**	**95-102**
Eggs, New York, cents/doz.	126.00	82.80	93.10	123.20	106.30	105.80	106.60	117.70	131.20	115.30	108.70	99.7	131.9	129.4	117.4	126.9	109.9	**117-120**	**120-126**	**119-121**	**110-120**	**101-109**	**107-116**
U.S. trade, million lb																							
Beef & veal exports	478	585	590	646	2,299	633	702	766	683	2,785	558	625	651	621	2,455	557	631	**650**	**570**	**2,408**	**525**	**500**	**2,300**
Beef & veal imports	573	690	598	436	2,297	461	593	548	454	2,057	582	669	516	452	2,219	590	628	**550**	**530**	**2,298**	**645**	**700**	**2,640**
Lamb and mutton imports	47	46	31	42	166	49	48	31	34	162	37	38	38	40	153	49	44	**38**	**42**	**173**	**44**	**42**	**164**
Pork exports	1,046	1,081	951	1,146	4,224	1,248	1,200	1,261	1,481	5,189	1,444	1,302	1,252	1,386	5,384	1,218	1,226	**1,260**	**1,400**	**5,104**	**1,270**	**1,295**	**5,310**
Pork imports	199	204	237	219	859	201	195	194	213	803	207	191	198	205	801	207	210	**210**	**215**	**842**	**210**	**210**	**845**
Broiler exports	1,469	1,699	1,643	1,954	6,765	1,527	1,588	1,978	1,879	6,971	1,737	1,791	1,867	1,886	7,281	1,777	1,859	**1,912**	**1,973**	**7,521**	**1,798**	**1,899**	**7,622**
Turkey exports	114	136	158	174	582	159	171	173	199	703	181	185	216	218	800	178	182	**180**	**195**	**735**	**190**	**195**	**780**
Live swine imports (thousand head)	1,446	1,408	1,479	1,416	5,749	1,452	1,429	1,407	1,508	5,795	1,441	1,444	1,387	1,380	5,652	1,326	1,301	**1,300**	**1,350**	**5,277**	**1,315**	**1,290**	**5,235**

1/ Forecasts are in bold.

2/ Per capita meat and egg disappearance data are calculated using the Resident Population Plus Armed Forces Overseas series from the Census Bureau of the Department of Commerce.

Source: World Agricultural Supply and Demand Estimates and Supporting Materials.

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9/17/2013

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Livestock, Dairy, & Poultry Outlook/LDP-M-231/Sept 18, 2013

Economic Research Service, USDA

Dairy Forecasts

	2012			2013					2014		
	III	IV	Annual	I	II	III	IV	Annual	I	II	Annual
Milk cows (thous.) 1/	9,211	9,203	9,233	9,225	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Milk per cow (pounds)	5,284	5,335	21,696	5,475	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Milk production (bil. pounds)	48.7	49.1	200.3	50.5	52.0	49.6	49.8	201.8	51.1	52.5	204.5
Farm use	0.2	0.2	1.0	0.2	0.2	0.2	0.2	1.0	2.0	2.0	1.0
Milk marketings	48.4	48.9	199.4	50.3	51.7	49.3	49.6	200.8	50.9	52.3	203.6
Milkfat (bil. pounds milk equiv.)											
Milk marketings	48.4	48.9	199.4	50.3	51.7	49.3	49.6	200.8	50.9	52.3	203.6
Beginning commercial stocks	14.7	13.2	10.9	12.2	15.1	16.9	14.0	12.2	12.3	14.9	12.3
Imports	1.0	1.3	4.1	1.1	0.9	1.0	1.2	4.1	1.0	1.0	4.1
Total supply	64.1	63.4	214.3	63.5	67.7	67.2	64.7	217.2	64.2	68.1	220.0
Commercial exports	2.0	1.9	8.8	2.4	3.0	3.2	2.6	11.0	2.6	2.7	10.4
Ending commercial stocks	13.2	12.2	12.2	15.1	16.9	14.0	12.3	12.3	14.9	16.0	11.5
Net removals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Commercial use	48.9	49.4	193.3	46.1	47.9	50.0	49.9	193.8	46.7	49.4	198.0
Skim solids (bil. pounds milk equiv.)											
Milk marketings	48.4	48.9	199.4	50.3	51.7	49.3	49.6	200.8	50.9	52.3	203.6
Beginning commercial stocks	12.6	11.8	11.8	12.4	13.7	14.2	12.1	12.4	12.2	12.5	12.2
Imports	1.4	1.5	5.7	1.5	1.2	1.2	1.3	5.2	1.5	1.2	5.4
Total supply	62.5	62.1	216.9	64.1	66.7	64.7	62.9	218.4	64.5	66.0	221.1
Commercial exports	8.3	7.6	33.3	8.3	10.6	10.0	9.2	38.1	9.2	9.6	37.3
Ending commercial stocks	11.8	12.4	12.4	13.7	14.2	12.1	12.2	12.2	12.5	13.0	11.8
Net removals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Commercial use	42.4	42.1	171.2	42.1	41.9	42.6	41.5	168.1	42.8	43.4	172.1
Milk prices (dol./cwt) 2/											
All milk	18.27	21.50	18.53	19.50	19.57	19.35 -19.55	20.45 -20.95	19.70 -19.90	19.45 -20.25	19.15 -20.15	19.35 -20.35
Class III	17.80	20.17	17.44	17.44	18.04	17.75 -17.95	18.40 -18.90	17.90 -18.10	17.00 -17.80	17.20 -18.20	17.05 -18.05
Class IV	15.87	18.34	16.01	17.71	18.62	18.95 -19.25	19.25 -19.85	18.60 -18.90	18.30 -19.20	18.30 -19.40	18.45 -19.55
Product prices (dol./pound) 3/											
Cheddar cheese	1.773	1.952	1.708	1.686	1.780	1.755 -1.775	1.810 -1.860	1.755 -1.775	1.670 -1.750	1.680 -1.780	1.670 -1.770
Dry whey	0.541	0.643	0.594	0.632	0.575	0.565 -0.585	0.580 -0.610	0.585 -0.605	0.575 -0.605	0.585 -0.615	0.585 -0.615
Butter	1.684	1.785	1.594	1.555	1.622	1.425 -1.465	1.425 -1.505	1.500 -1.540	1.395 -1.505	1.485 -1.615	1.470 -1.600
Nonfat dry milk	1.269	1.505	1.328	1.546	1.619	1.750 -1.770	1.785 -1.825	1.675 -1.695	1.685 -1.745	1.645 -1.715	1.675 -1.745

1/ Starting in May, contains no data updates or analysis on milk cows or milk output per cow.
2/ Simple averages of monthly prices. May not match reported annual averages.
3/ Simple averages of monthly prices calculated by the Agricultural Marketing Service for use in class price formulas. 'Based on weekly "Dairy Product Prices", National Agricultural Statistics Service. Details may be found at http://www.ams.usda.gov/dyfmos/mib/fedordprc_dscrp.htm

Source: World Agricultural Supply and Demand Estimates and supporting materials.
For further information, contact: Roger Hoskin 202 694 5148, rhoskin@ers.usda.gov
Published in Livestock, Dairy, and Poultry Outlook, http://www.ers.usda.gov/publications/ldpm-livestock,-dairy,-and-poultry-outlook.aspx.

Updated 9/13/13

Appendix C - Table of Human outbreaks of Salmonellosis due to contaminated produce (CDC).

TABLE 1. EXAMPLES OF HUMAN OUTBREAKS OF SALMONELLOSIS DUE TO CONTAMINATED PRODUCE

Produce	Salmonella *serotype*	*Year*	*No. of illnesses*	*Contamination source*[a]	*Additional reference*
Watermelon	*Salmonella* sp.	1950	6		Blostein 1993
Watermelon	Miami	1954	17		Gayler *et al.* 1955
Watermelon	Oranienburg	1979	18		CDC, 1979
Watermelon	Javiana	1991	26	Rind contamination	FDA, 2001
Watermelon	Javiana	1993	27	Rind contamination	
Watermelon	Newport	2006	20		
Cantaloupe	Poona	1991	>400		CDC 1991; FDA, 2001
Cantaloupe	Chester	1989–1990	<245	Rind contamination	FDA 2001
Cantaloupe	Saphra	1997	24		Mohle-Boetani *et al.* 1999
Cantaloupe	Poona	2000	43	Rind contamination	FDA, 2001
Cantaloupe	Poona	2001	50	Rind contamination	CDC, 2002
Cantaloupe	Poona	2001	27	Rind contamination	CDC, 2002
Cantaloupe	Muenchen	2003	58	Rind contamination	
Cantaloupe	Litchfield	2008	51	Rind contamination	
Honeydew	Newport	2003	68		
Honeydew	Litchfield	2007	30	Ill food handler	
Honeydew, musk, Watermelon	Enteritidis	1999	82		
Honeydew, musk, Watermelon	Poona	2001	23		
Cantaloupe/honeydew	Muenchen	2003	58		
Mung sprouts	Enteriditis	2000	45	Environment at sprouter	Mohle-Boetani *et al.* 2009
Mung sprouts	Enteriditis	2001	35	Environment at sprouter	Mohle-Boetani *et al.* 2009
Mung sprouts	Enteriditis	2001	26	Environment at sprouter	Mohle-Boetani *et al.* 2009
Alfalfa	Anatum	1990	15		
Alfalfa	Stanley	1995	>272	Contaminated seeds	Mahon *et al.*, 1997
Alfalfa	Newport	1995–1996	>133	Contaminated seeds	Van Beneden *et al.*, 1999
Alfalfa	Stanely	1995	128		Jaquette *et al.*, 1996
Alfalfa	Stanely	1996	30		Jaquette *et al.*, 1996
Alfalfa	Montevideo/Melegridis	1996	>500	Contaminated seeds	Taormina *et al.* 1999
Alfalfa	Senftenberg	1997–1998	52	Contaminated seeds	Taormina *et al.* 1999
Alfalfa	Infantis/Anatum	1997	109	Contaminated seeds	Taormina *et al.* 1999
Alfalfa	Havana	1998	18	Contaminated seeds	Backer *et al.*, 2000
Alfalfa	Havana/Cubana/Tennessee	1998	34	Contaminated seeds	Taormina *et al.* 1999
Alfalfa	Mbandaka	1999	68	Contaminated seeds	Harris *et al.*, 2003
Alfalfa	Muenchen	1999	99		Proctor *et al.*, 2001
Alfalfa	Kottbus	2001	31	Contaminated seeds	Winthrop *et al.*, 2003
Alfalfa	Saintpaul	2003	16		
Alfalfa	Chester	2003	26	Contaminated seeds	
Alfalfa	*Salmonella* spp.	2004	12		
Alfalfa/clover	Saintpaul	1999	36		
Alfalfa/clover	Typhimurium	1999	112		Brooks *et al.*, 2001
Tomatoes	Javiana	1990	174	Water bath	Sivapalasingam *et al.*, 2004
Tomatoes	Montevideo	1993	84	Water bath	CDC, 1993

Tomatoes	Baildon	1998–1999	85	Contaminated field by domesticated animals	Cummings *et al.*, 2001
Tomatoes	Thompson	2000	42	Unknown	Gupta and Crowe, 2001
Tomatoes	Newport	2002	510	Contaminated pond water used for irrigation	Greene *et al.*, 2008
Tomatoes	Braenderup	2004	561	Food preparation environment?	Gupta *et al.*, 2007
Tomatoes	Braenderup	2005	84		Gupta *et al.*, 2007
Tomatoes	Newport	2005	72	Contaminated pond water used for irrigation (related to 2002 outbreak)	Greene *et al.*, 2005
Tomatoes	Typhimurium	2006	183	Food preparation environment?	FDA, 2006
Tomatoes	Berta	2006	16		
Red Chili peppers	Montevideo	2000	27		
Serrano peppers	Saintpaul	2008	1442	Contaminated irrigation water	FDA, 2008a
Mangoes	Oranienburg	1998	9		
Mangoes	Newport	1999	79	Contaminated processing water	Sivapalasingam *et al.*, 2003
Mangoes	Saintpaul	2001	26		Beatty *et al.*, 2004
Mangoes	Saintpaul	2003	17		
Carrots	Braenderup	1990	111		CDC, 1990
Carrots	Typhimurium	2005	8		
Lettuce	Enteritidis	1992	12		
Lettuce	Heidelberg	1993	18		
Lettuce	Braenderup	1994	19		
Lettuce	Thompson	1994	16		
Lettuce	Enteriditis	2003	14		
Lettuce	Newport	2004	97		
Cilantro	Thompson	1999	76	Contamination at grower?	Campbell *et al.*, 2001
Basil	Senftenberg	2007	74 total (11 in US)	Contamination at grower?	Pezzoli *et al.*, 2008
Mushroom	*typhimurium* var. Copenhagen	2002	10		
Mushroom	Heidelberg	2003	65		
Potato	Enteritidis	1991			
Potato	Enteritidis	1998	21		
Potato	*Salmonella* spp.	2004	16		
Potato	*Salmonella* spp.	2004	26		
Strawberries	*Salmonella* Group B	2003	13	Food preparation environment	

[a]Data source http://www.cdc.gov/foodborneoutbreaks/outbreak_data.htm. If no source is given, no source was determined for that outbreak.