Technological Evolution and Food Safety Practices

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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STS Research Paper

Introduction

Every year, foodborne illnesses cause over 420,000 deaths, in which 30% of them occur among children under 5 years old, according to the World Health Organization (WHO) (WHO, n.d.). Based on a report from the Center of Disease Control and Prevention (CDC), there are roughly 47.8 million cases of foodborne illnesses and 127,839 people are hospitalized in America on average every year (CDC, 2018). Foodborne illnesses are diseases that are caused by consuming contaminated food or beverages (WHO, n.d.). Foodborne illnesses usually encompass a wide range of symptoms, from diarrhea to cancer. While most symptoms present as gastrointestinal issues, foodborne illnesses symptoms can also be neurological, gynecological, and immunological. While many of foodborne illness cases are usually mild, severe consequences such as kidney failure, brain and nerve damage, as well as death do happen amongst people (Assistant Secretary for Public Affairs, 2021). Foodborne diseases severely affect not only in the physical well-being, but also in the financial. The cost of produce-related foodborne illnesses totaled up to nearly $39 billion per year (Schnirring, 2010).

With such overwhelming financial and physical well-being concerns when it comes to foodborne illnesses, one cannot help but wonder whether technological tools can play a role in bettering food safety practices. Hence, this research explores the relationship between technological evolution and food safety practices: how the need for better food safety practices affect the motivation for technological advancement, how food safety practices vary among different social groups, and ultimately, how food safety practices affect the health aspect of humans as a whole. To better answer whether or not there is a relationship between food safety practices and technological evolutions, I investigated the causes of foodborne illnesses, settings in which they occur, relevant social groups affected, what tools are developed for this purpose, and whether or not technological tools are sought out by those social groups.

Methods

Most of this research was conducted via reviewing relevant articles, research papers, and any relevant government journals. The first step for my research was to investigate the common causes for foodborne illnesses, whether that is due to improper food storage, lack of accessibility to avoid non-contaminated food, and more. Once I determined the common causes, the second area of research was figuring out under what circumstances and settings do foodborne illnesses occur. Understanding the common causes and origination settings of foodborne illnesses shed light on which social groups are more affected, and if there is a common trend between the quality of food safety and social groups. Therefore, after analyzing the circumstances in which foodborne illnesses originate, the third area of research was identifying the social groups that are most affected. Once I identified the relevant social groups, the next step would be to explore what safety precautions and technological solutions the social groups usually seek out and if there is a common trend among their practices. How often do restaurants and the mass food production industry face foodborne illnesses breakouts? What action do they take to prevent outbreaks from happening, and what technology do they seek out to resolve these issues? How does that differ from when schools or universities face foodborne illnesses breakouts? The answers to these questions guided the research towards the overarching question of whether or not there is a relationship between technological evolution and food safety, and if there is, what would that relationship look like.

Results

Common Causes for Foodborne Illnesses

Understanding the origins of foodborne illnesses will provide insights on how one would allocate resources and utilize tools for prevention. Most foodborne outbreaks as well as cases of individual illnesses are caused by pathogens in food (Food and Drug Administration, n.d.). These pathogens can either be bacteria, viruses, parasites, or more, and humans would develop illness symptoms if they consume food that contains harmful pathogens. Elaine Scallan and collaborators have found that approximately 59% of foodborne illnesses are caused by viruses, 39% are caused by bacteria, and 2% by parasites (Scallan et. al, 2011). The pathogen that caused the most number of illnesses is norovirus, which affected about 58% of the illness cases. For hospitalization cases, bacterias caused over 64% of cases, viruses caused 27% cases, and parasites caused 9%. For death cases, bacterias caused 64% cases, parasites caused 25%, and viruses caused 12%. Salmonella is the leading cause of both hospitalization and death cases. It is evident that food contaminated with bacteria and parasites have much more severe consequences. The question arises: how do these pathogens even form in the first place, given that the food itself may not contain harmful pathogens in the first place?

According to The BC Cook Articulation Committee, most viruses in food are transmitted from the person who handles the food through improper handling or poor sanitation (Committee, 2015). Parasites that live in animals or humans can cause illness when the food infected is not cooked at a high enough temperature, or is not frozen at a temperature that is cold enough to kill the parasites. Improper cooling, advanced preparation, and contaminated raw food or ingredients are amongst the top ten causes of foodborne illnesses from harmful pathogens. Most of these top ten causes involved human factors, whether that is from cross-contamination or from advanced preparation, and improper temperature while handling food. While most of these causes appear to be preventable, they still affect millions of people every year. Hence, the next research subtopic will explore the circumstances and settings in which the mishandling of food is at higher risks, in turn increasing the possibility of foodborne illnesses occurring.

Circumstances and Settings Where Foodborne Illnesses Occur

According to the CDC, the majority of foodborne illness outbreaks occur in retail establishments, which are places that prepare and serve food to consumers (CDC, 2019). Out of those retail establishments, over 80% were restaurants, which usually served complex food items that require a process to reduce or eliminate foodborne illnesses pathogens, as well as other preparation processes, such as cooling or reheating (Committee, 2015). Because of the mass production of food, restaurants are prone to more incidents of improper storage or mishandling of food. The most common contributing factor to foodborne illness outbreaks in restaurants come from bare-hand contact with a food worker who was suspected to be ill or infectious, which occurred about 27.9% of the time. The most common proliferation contributing factors come from insufficient time or temperature during the cooking or heating process, which occurred about 10.8% of the time.

Schools' dining halls are similar to retail establishments since they are also in charge of preparing food in bulk and serving them to students, which makes them just as susceptible to foodborne illness outbreaks as restaurants are. Salmonella was the most commonly identified pathogen, accounting for 36% of outbreak reports with a known etiology (Daniels, n.d.). The most commonly reported food preparation practices that contributed to these school-related outbreaks were improper food storage and holding temperatures and food contaminated by a food handler, similar to the restaurant industry. Additionally, young students are more likely to be more severely affected by harmful pathogens, which increase the stakes and incentives for better food safety practices in a school setting.

Establishments that are required to produce food in high volumes are more susceptible to foodborne illness outbreaks due to the fact that there are higher risks of human errors and improper food handling. To further investigate who populations affected by foodborne illnesses from these establishments are and their impacts on the mission for better food safety practices, the next subsection will identify the social groups commonly involved in the restaurants and schools' dining halls settings.

STS Framework and Relevant Social Groups

I use social construction of technology (SCOT) to be the STS framework for this research. SCOT is a theory that claims the advancement of technology is due to various social groups and their interpretation and acceptance of new technologies (Bijker et. al, 2012). One of the core concepts of SCOT is relevant social groups, which are groups of stakeholders who have similar purposes or meaning of the technology. In this research, the primary social groups that will be focused the most on are the restaurants and schools, which are the two groups that mainly prepare and serve food in bulk.

Technological Tools Developed to Better Detect Foodborne Hazards

As noted above, Salmonella is one of the most common pathogens that cause foodborne-infection. Therefore, there are a variety of methods to improve Salmonella detections, and better ensure the safety of consumers. Traditional methods for Salmonella detection are laborious and time-consuming, but they still serve as the basis for testing in laboratories (Hu, 2021). The traditional method is as follows: placing samples directly into different types of selective agar such as Salmonella agar, or xylose-lysine-deoxycholate (XLD) agar. In doing so, Salmonella in the sample would be detected if colonies appear on the agar plates as red-pink, 1-3mm in diameter, and surrounded by red zones in the agar. However, certain types of samples, such as food or blood, sometimes contain a very small amount of Salmonella, which can lead to incorrect interpretation of the results. The samples would have to be enriched, or grow more, then to be tested again in another agar to better identify if Salmonella is present. This method of detection can be costly and time consuming, therefore more rapid and reliable identification of Salmonella is extremely important for public health and food safety (Malorny, 2008). Polymerase chain reaction (PCR) method, a more rapid approach to detecting Salmonella, has been standardized in the last 5 years by the International Organization for Standardization (ISO) and is now used for food testing. The PCR method has many advantages, one of which is the potential to "amplify small numbers of organisms, non-culture bacteria, and dead bacteria" (Hu, 2021). This means that the PCR method is able to detect the target pathogen more accurately, which increases the chance of detecting Salmonella, even when there are only small amounts of the pathogen present.

Food traceability is another example of a system in the food industry that plays a crucial role in ensuring food safety. Food traceability can be defined as "the ability to follow the movement of a feed or food through specified stage(s) of production, processing and distribution" (Manning, 2021). This system is important to food safety because it is essential to control any possible risks or contamination that may affect the food chain. While there is a high availability of such many revolutionary technologies for food traceability, there are various barriers inherent in food systems which impede successful implementation of food traceability in individual companies or in sub-sections of supply chains (Manning, 2021). Therefore, many new rapid analytical methods and sensing techniques were developed. Most of those analysis techniques are based on vibrational spectroscopy, such as infrared (IR) or Raman spectroscopy. Due to many advantages, such as the simultaneous, rapid and non-destructive analysis and the prediction of major chemical components in many food ingredients and foods, animal and plant materials, these techniques have been some of the most utilized methods of analysis (Manning, 2021).

Technological Solutions That Restaurants Seek Out

Throughout time, there has been a variety of new technological tools being utilized by restaurants to further improve and ensure the safety of food products. One notable example would be the radio frequency identification technology (RFID) at Chipotle. RFID is a technology whereby digital data encoded in RFID tags or smart labels are captured by a reader via radio waves (American Barcode and RFID, 2022). RFID consists of the following three components: an RFID tag or smart label, an RFID reader, and an antenna. RFID tags contain an integrated circuit and an antenna, which are used to transmit data to the RFID reader. The reader then converts the radio waves to a more usable form of data, which is then transferred through a communications interface to a host computer system, where the data can be stored in a database and analyzed at a later time. In a way, RFID technology is similar to barcode technology, such that data from a tag or label are captured by a device that stores the data in a database. RFID is more advanced than any usual barcoding technology because RFID tag data can be read outside the line-of-sight. At Chipotle, RFID is used to improve food traceability by tracing food from suppliers to restaurants using serialization (Littman, 2022). With RFID, Chipotle's suppliers save time on inventory management, reduce human error, and improve expiration date visibility and accountability. This system also assists employees in better tracking inventory and reducing their work time on doing inventory checks.

Another example of a technological tool being used to better food safety is a food safety informatics tool called Touchblock™. This is a food monitoring technology, which was designed to transmit real-time and temperature data every 6 minutes (Tucker et. al, 2011). This technology was used in a study by Tucker and collaborators where automated and remote, wireless monitoring and transmitting technology were installed in industrial grade, walk-in refrigerators, freezers, and dry storage. Data was collected every 6 minutes throughout the 24 hour period, and a 2 hour data interval was reported every 12 hours. The result of this study shows that reporting food safety data periodically can serve as a "real-time food safety monitoring surveillance system for foodservice establishments and public health inspectors" (Tucker et. al, 2011). Touchblock™ helps quantify temperatures outside the accepted range, which helps address efficient and proper response in "real time" to prevent microbial growth, spoilage of products resulting in loss of product inventory, and potential foodborne illnesses. This study elaborated on how this new technology on reporting real-time data can significantly enhance the ability of industry and food protection regulators. The current method monitoring is rather manual, where foodservice operations are required to keep a "paper" log of daily time and temperatures. This method of paper log recordkeeping is done manually by hand, using handheld thermometer probes or reading the temperature gauge on freezers or refrigerators. Many users of the current manual, paper log approach have voiced their support for the food safety informatics system since it would provide more integrity, accuracy, and reliability.

Analysis

Through the findings in the Results section, we can see that foodborne illnesses are mostly prevalent in settings such as restaurants and schools dining halls, where a large amount of food must be prepared in bulk. Due to the nature of bulk preparation and its complexity, it is more prone to human errors, such as mishandling of food and cross contamination. Additionally, many of the current food traceability systems as well as temperature monitoring systems are manual-based, where the necessary information is hand-recorded by humans, which also increases the risk of human errors as well as possibility of fraudulent recordkeeping. Therefore, it is evident that there is a high need for more accurate and more automated solutions to the current food safety approaches.

For instance, the RFID example that the fast-food chain Chipotle utilized is one of the many examples where technology is used to better food safety practices in restaurant settings. Additionally, it is also an example of how technology is implemented to automate a current manual approach in hopes of reducing human error as well as increasing efficiency. The food traceability system is the target system that Chipotle is attempting to improve using the RFID technology. Since food traceability has a primary goal of keeping track of the movement of the food chain to prevent any possible contamination. Chipotle's previous approach to food traceability was through human labor, as employees would manually record data such as expiration dates while tracking inventory (Littman, 2022). Due to the need to better prevent foodborne illnesses since Chipotle faced a huge outbreak in 2018, they have sought out the RFID system, which improved their current manual food traceability system to be more automated and efficient.

Similarly, the Touchblock™ tool is another example of technological tools being created for the very purpose of improving food safety. By automating the process of recording temperature, this tool minimizes the manual labor that employees would have as well as minimizing any possible human errors along the process. It also provides a better way to keep the information up-to-date in real time and increases the integrity of required recordkeeping, as employees could make up numbers while they record the data. This tool demonstrates that technology can serve as a proactive tool to prevent foodborne outbreaks, rather than a reactive tool to address outbreaks that already happen.

The above examples are only a few of many technological tools that were developed for the sole purpose of improving food safety. These tools are only made possible as technology evolves throughout time, since the approaches they replaced are manual. This shows that there is a clear relationship between technological evolution and food safety, since the need for food safety pushes for better technological tools, and the technological advancements provide means to better food safety.

Conclusion

Foodborne illnesses have long been affecting us globally, with over millions of people affected every year. Many of the foodborne illnesses stem from malicious pathogens in the food such as bacterias and viruses, which are usually caused by improper food storage and cross-contamination during the preparation process. Hence, retail establishments such as restaurants or schools dining halls are most susceptible to foodborne illnesses breakouts since food must be prepared in bulk at these settings. My research has found that multiple technological tools and techniques have been developed to further improve food safety at these settings, ranging from improving temperature monitoring systems and inventory tracking systems. Many of the current approaches in managing food safety are manual, which is why relevant social groups like restaurants seek out technological tools to automate the process, in hopes of improving accuracy and efficiency. With the new technologies aiding with food safety procedures, establishments such as restaurants and schools can better prevent foodborne diseases outbreak and ensure that consumers can safely consume their products. My research findings have shown that there is a direct relationship between technological evolution and food safety, as food safety can be improved using new technologies, which are inspired and pushed by the need for better, more robust safety approaches. While our current technology would not be able to fully stop all foodborne illnesses from happening, they certainly play a huge role in decreasing the chance of outbreaks, and increasing the ability to better protect consumers from foodborne illnesses.

Work Cited

American Barcode and RFID. (2022, April 15). *What is RFID - How Does RFID Work?*. AB&R. Retrieved May 1, 2023, from https://www.abr.com/what-is-rfid-how-does-rfid-work/

Assistant Secretary for Public Affairs (ASPA). (2021, May 27). *Food Poisoning*. FoodSafety.gov. Retrieved February 2023, from https://www.foodsafety.gov/food-poisoning#:~:text=Serious%20long%2Dterm%20effects%20associated,Brain%20and%20nerve%20damage

Bijker, W. E., Bijker, W. E., Hughes, T. P., Pinch, T. J., & Douglas, D. G. (2012). *The Social Construction of Technological Systems: New Directions in The Sociology and History of Technology*. MIT Press.

Centers for Disease Control and Prevention. (2018, November 5). *Burden of foodborne illness: Findings*. Centers for Disease Control and Prevention. Retrieved February 2023, from https://www.cdc.gov/foodborneburden/2011-foodborne-estimates.html

Centers for Disease Control and Prevention. (2019, February 21). *Foodborne illness outbreaks at retail establishments - National Environmental Assessment Reporting System, 16 state and Local Health Departments, 2014–2016*. Centers for Disease Control and Prevention. Retrieved February 2023, from https://www.cdc.gov/mmwr/volumes/68/ss/ss6801a1.htm

Committee, T. B. C. C. A. (2015, May 15). *Causes of foodborne illnesses*. Food Safety Sanitation and Personal Hygiene. Retrieved February 2023, from https://opentextbc.ca/foodsafety/chapter/causes-of-foodborne-illnesses/

Daniels, N. A., Mackinnon, L., Rowe, S. M., Bean, N. H., Griffin, P. M., & Mead, P. S. (n.d.). *Foodborne disease outbreaks in United States schools*. The Pediatric infectious disease journal. Retrieved February 2023, from https://pubmed.ncbi.nlm.nih.gov/12237592/

Food and Drug Administration. (n.d.). *Most common foodborne illnesses - Food and Drug Administration*. Retrieved February 2023, from https://www.fda.gov/files/food/published/Most-Common-Foodborne-Illnesses-%28PDF%29.pdf

A Foodborne Illness Outbreak Could Cost a Restaurant Millions, Study Suggests. Johns Hopkins Bloomberg School of Public Health. (2018, April 16). Retrieved February 2023, from https://publichealth.jhu.edu/2018/a-foodborne-illness-outbreak-could-cost-a-restaurant-millions-study-suggests

Hu, Lan. (2021). *Food Safety: Rapid Detection and effective prevention of foodborne hazards*. APPLE ACADEMIC PRESS.

Littman, J. (2022, March 31). *Chipotle tests RFID technology to improve food traceability.* Restaurant Dive. Retrieved March 2023, from https://www.restaurantdive.com/news/chipotle-tests-rfid-technology-to-improve-food-traceability/621340/

Manning, L. (2021). *Developing Smart Agri-Food Supply Chains: Using technology to improve safety and quality*. Burleigh Dodds Science Publishing.

Malorny, B., Löfström, C., Wagner, M., Krämer, N., & Hoorfar, J. (2008, March). *Enumeration of salmonella bacteria in food and feed samples by real-time PCR for quantitative* *microbial risk assessment*. Applied and environmental microbiology. Retrieved February 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2258648/.

Scallan, E., Hoekstra, R. M., Angulo, F. J., Tauxe, R. V., Widdowson, M.-A., Roy, S. L., Jones, J. L., & Griffin, P. M. (2011, January). *Foodborne illness acquired in the United States--major pathogens*. Emerging infectious diseases. Retrieved February 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3375761/

Schnirring, L. (2010, March 3). *Study says foodborne illness costs US $152 billion a year*. CIDRAP. Retrieved February 2023, from https://www.cidrap.umn.edu/foodborne-disease/study-says-foodborne-illness-costs-us-152-billion-year#:~:text=Using%20data%20from%20the%20Centers,nearly%20%2439%20billion%20each%20year.

Tucker, C. A., Larkin, S. N., & Akers, T. A. (2011). *Food Safety Informatics: A Public Health Imperative*. Online journal of public health informatics. Retrieved March 2023, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3615782/.

World Health Organization. (n.d.). *Estimating the burden of foodborne diseases*. World Health Organization. Retrieved February, 2023, from https://www.who.int/activities/estimating-the-burden-of-foodborne-diseases