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***Salmonella* and Antimicrobial Resistance in Fresh Produce**

Agnes Kilonzo-Nthenge and Winnie Mukuna

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Abstract

Contamination of fresh produce with *Salmonella* may occur during any point from fork to table. It may occur during produce production, harvest, processing, and transportation. Fresh produce has been recognized as a common source for *Salmonella* since the bacteria has the ability to attach and internalize in produce. *Salmonella* has been isolated from produce including mangoes, cantaloupe, cucumbers, alfalfa sprouts, and lettuce. Bacteria from fresh produce include a number of opportunistic human pathogens which may be resistant to several antibiotics. Antimicrobial resistant bacteria may have the potential to make their way over to fresh produce through contaminated irrigation water and manure applied to agricultural fields. *Salmonella* resistant to antibiotics including vancomycin, erythromycin, ampicillin and penicillin has been isolated from vegetables. With the increasing foodborne illness associated with fresh produce, there is a lot of emphasis on good agricultural practices (GAPs) to validate that farms are producing fresh produce in the safest means possible. With proper education and training on GAPs, produce growers will be able limit the occurrence of *Salmonella* and other foodborne pathogens in fresh produce.

Keywords: *Salmonella*, fresh produce, antimicrobial resistance, good agricultural practices

1. Introduction

The demand for fresh produce in the United States is intensifying, in part, due to their nutritional value and consumer health awareness [1]. Studies have shown that consuming more fruits and vegetables can lead to a more productive and healthier lifestyle [2]. Despite the health benefits attained from fresh produce, microbial safety of fresh produce continues to be a major challenge as these foods are consumed raw, and are known for spreading infectious

foodborne diseases [3]. About 48 million people in America get sick, 128,000 are hospitalized, and 3000 die from consuming adulterated fresh fruits and vegetables every year [4]. Fresh produce has been recognized as a common source for *Salmonella* since the bacteria has ability to attach and internalize in produce [5]. Fresh produce can become contaminated anywhere along the farm to plate continuum [6]. According to FDA [7], contamination with pathogenic bacteria may be directly or indirectly through contact with animals or insects, soil, water, dirty equipment, and human handling. Most *Salmonella* infections are caused by poultry products; however, it is estimated that fruit and vegetables are implicated in about 50% of *Salmonella* illnesses [8]. *Salmonella* outbreaks are frequently linked with animal products; however there have been outbreaks related to fresh produce, particularly in the United States [9]. *Salmonella* has been isolated from produce such as mangoes [1], cantaloupe [10], cucumbers [11], alfalfa sprouts and lettuce [12, 13]. The rise of antimicrobial resistance is thought to be as a result of excessive use of antibiotics in agriculture. Most antibiotics are used for treating animal and plant diseases in agriculture [14].

2. *Salmonella* and produce

2.1. *Salmonella* outbreaks

Fresh produce is ever more contributing to the consumer diet, an inclination that has been paralleled by an intensification in foodborne illnesses. Globally, many fresh produce linked outbreaks have occurred over the last few years including *Salmonella* outbreaks. Between 2012 and 2015, there were 596 *Salmonella* outbreaks which resulted in 13,765 illnesses, 2136 hospitalizations, and 18 deaths [11]. Within the same time period, 68 outbreaks were associated with lettuce and these outbreaks caused 1293 illnesses, 136 hospitalizations, and 3 deaths. *Salmonella* Typhimurium and *Escherichia coli* O15:H7 are the most significant foodborne pathogens that cause outbreaks through the consumption of contaminated fresh produce [15]. In October 2015, a multi-state outbreak of *Salmonella* Poona occurred in the United States. The outbreak was associated with 14-day shelf life cucumbers and it resulted to over 150 hospitalizations, 3 deaths and 671 confirmed cases of the outbreak in 34 states [4]. In 2008 and 2011, *Salmonella enterica* serovars outbreaks were linked to imported cantaloupes from Honduras and Guatemala [16]. Another foodborne disease outbreak was caused by *Salmonella* Newport and *Salmonella* Typhimurium. This outbreak was linked to cantaloupes in United States from a cantaloupe production and packaging operation in Indiana [16]. In 2008, a large outbreak of *Salmonella* Saint Paul took place in the United States and was linked to the consumption of jalapeño and serrano peppers [17]. Tomatoes have also been implicated in many *Salmonella* outbreaks [18]. In 2007, fresh herbs retailed in the UK exposed an international outbreak of *Salmonella* infection connected to tainted basil from Israel that involved at least 51 individuals from England, Wales, Scotland, Denmark, the Netherlands and the USA [19]. *Salmonella*, *E. coli* O157:H7, and *Listeria monocytogenes* have been associated with illnesses linked to produce from USA, Finland and Denmark [20]. Several produce-related outbreaks associated with *Salmonella* have also been global, for example *Salmonella* Saintpaul in fresh peppers from North America, *Salmonella* Senftenberg in tomatoes from Europe and North America, *Salmonella* Weltevreden in alfalfa sprouts from Europe, and *Salmonella* Thompson in arugula from Europe [21].

2.2. Emerging antimicrobial resistant *Salmonella* in fresh produce

Antibiotic resistance has been recognized as a global health problem and as the uppermost health challenges facing the twenty-first century [22]. The emergence of antimicrobial resistant (AMR) bacterial in foods [23] including fresh produce has become a challenge and a major public health concern worldwide. Antimicrobial resistance is responsible for 2 million illnesses and 23,000 deaths yearly in the US, with over \$20 billion as direct health-care costs and \$35 billion in lost productivity [4]. Previous studies have identified antibiotic resistant bacteria on vegetable products at harvest or at the retail level [14, 24]. AMR is an emerging problem worldwide and antimicrobial usage in animal production is understood to be a contributing factor [25]. Fecal material from food animals, humans, and animals often contain bacteria that are resistant to some antibiotics [26]. It is reported that extensive use of antimicrobials in agriculture expose antimicrobial-resistant bacteria to humans through contaminated food products [27]. It is also documented that antibiotic resistant bacteria has been identified in animal waste, wastewater, river sediments, and farmland soil [28]. Antimicrobial resistant bacteria may be disseminated to the environment through farm waste, and may reach humans through the consumption of contaminated foods of animal origin, water, and vegetables [29]. Leafy greens are contaminated with antibiotic-resistant bacteria from animal and human sources during production and harvesting [30]. Consumption of fresh produce, particularly raw fresh produce, represents a route of direct human exposure to resistant microorganisms.

Salmonella is an important cause of foodborne infections and some species are becoming increasingly resistant, creating it more challenging to treat patients with severe infections [31]. The occurrence of ARM in *Salmonella* has become a major concern in food safety [31]. The contamination of food by *Salmonella* is an international concern due to contamination and antimicrobial resistance rates in imported food products [32, 33]. According to Wadamori et al. [34], *Salmonella* resistant to antibiotics including vancomycin, erythromycin, ampicillin and penicillin has been isolated from vegetables. Most common multidrug resistance phenotype of *Salmonella* is reported to confer resistance to ampicillin and streptomycin [35]. Antibiotic resistant *Salmonella* has also been detected in fresh vegetable at the retail level [36]. Brazilian ready-to-eat (RTE) salad vegetables have been associated with resistant *Salmonella* enterica isolates [37].

Several studies on antimicrobial resistance in animal-producing environments have been conducted [37]. However limited publications are prevailing on whether vegetables or the environment where they are produced has the potential to act as a reservoir of antimicrobial resistance [38]. According to Sjölund-Karlsson [39], several studies on antimicrobial resistance of *Salmonella* from humans, food animals, and retail meats have been conducted, whereas limited research on *Salmonella* associated with fresh produce is less common. It is essential to understand the nature of fresh produce safety challenges, origins of antimicrobial resistant bacteria, contamination pathways, risk factors to the consumer, and approaches to exclude or reduce the occurrence of *Salmonella* and other contaminants. There is a dire need to conduct more research and determine the origins of antimicrobial resistance in fresh produce.

2.3. Educational programs and good agricultural practices (GAPs)

Leafy green vegetables are the highest priority in terms of fresh produce safety from a global perspective [40]. During the period from 1996 to 2006, many countries implicated leafy greens

as a primary vehicle of concern implicated in *Salmonella* foodborne illnesses [40]. The application of GAPs is broadly accepted as the most significant measure in reducing *Salmonella* and other foodborne pathogens in fresh produce. GAPs are important not only for production but also to minimize food safety risks [41]. GAPs are voluntary guiding principles concentrating on best agricultural practices for fresh produce production that validate the production, packing, handling, and storage of produce. GAPs reduce the potential risks of microbial contamination in fresh fruits and vegetables.

With the increasing foodborne illness associated with fresh produce, there is a lot of emphasis on good agricultural practices to verify that farms are producing fruits and vegetables in the safest means possible. GAPs should be used as a control measure in fighting food safety threats within the fresh produce chain, while good hygienic practices (GHP) should be the second important measure for produce growers to use in concurrence with GAP [42]. A fresh produce grower's current food safety knowledge is often shaped by their knowledge of contamination hazards associated with the production of fresh produce, the sources of microbial threat and the impact caused by the hazard [43]. A study by Kilonzo-Nthenge [36] indicated about 64% of the farmers instituted hygiene practices on their farms. From this study, many produce farmers are faced with many challenges in produce production. These include limited knowledge of GAPs and finding food safety denoted information on produce safety. Growers' limited familiarity with GAPs implies a need for food safety education, which trained Extension educators should deliver [36].

Recent outbreaks and changes in consumer demands have prompted the writing of new regulations that establish standards for produce safety. However, these regulations do not cover all produce farms. There is a need to support every farmer in the produce industry. Large growers can fairly easily absorb the costs and annual audit fees associated with GAPs program; however, limited-resource farms often do not pursue these programs due to the costs, which can be exorbitant. Many growers are also not aware on risk factors on their farms and therefore, risk communication is critically needed to persuade produce growers to take appropriate actions and safe practices to avoid and reduce foodborne pathogens farms. Fresh produce farmers need additional education and training on implementing GAPs to prevent the spread of foodborne pathogens. With proper education and training on GAPs, produce growers will be able to shift their focus from responding to contamination to preventing it.

There is a need for cooperative Extension Programs to develop curriculums that can be given to county Extension agents to present to local producers. In addition tailored food safety plans and GAPs should be developed for small-scale fresh produce growers. The new agriculture marketplace require produce growers who are not only aware but also highly knowledgeable in food safety as it relates to their fresh produce.

2.4. *Salmonella* and the farming environment

Several groups of microorganisms can contaminate fruits and vegetables at any point throughout the food supply chain. Fresh produce is contaminated with pathogenic bacteria directly

or indirectly through contact with animals or insects, soil, water, dirty equipment, and human handling. The application of manure and other animal wastes in organic fresh produce production has the potential to contaminate produce with pathogenic bacteria including *Salmonella*, *Listeria*, and *Escherichia coli* O157:H7. Antibiotic resistant bacteria have been identified in animal waste, wastewater, river sediments, and farmland soil [28]. The challenge arises when these pathogens are antibiotic resistant bacteria. Antimicrobial resistant bacteria may have the potential to make their way over to fresh produce through contaminated irrigation water and manure applied to agricultural fields [44]. Resistant bacteria have the ability to colonize fresh fruits and vegetables in a number of ways including direct use of antibiotics during cultivation, use of contaminated irrigation water; hence a public health issue.

2.5. International food trade and *Salmonella*

The antimicrobial resistance has become a global concern as geographic borders among countries have become less discrete due to increasing global trade. Given that no country is self-sufficient in the supply of food, trade in overall is essential to ensure access to food products. For example, increasing global trade agreements and the demand for fresh produce have led to a significant growth in U.S. produce imports. Increasing global connectivity trade can facilitate the introduction of both antimicrobial resistant and pathogenic bacteria to a country through food imports. A rapidly growing universal trade in agricultural food products has significantly enabled the introduction of new *Salmonella* serovars within the geographical boundaries of importing countries. Imports allow a continuing and abundant supply of fresh produce in the U.S., however antimicrobial resistant bacteria may diffuse to the country as a result of contaminated produce from other countries. In a previous report, *Salmonella* (3.48 and 0.58%) was positive for imported and U.S. grown produce, respectively [45]. Evidence shows that fresh produce trade has the potential to disseminate antibiotic resistant bacteria between countries; a noble example is the 2005 nationwide outbreak of multidrug resistant *Salmonella* Typhimurium DT104B in Finland which was due to contaminated lettuce imported from Spain [46]. *Salmonella* has been isolated from various types of fresh produce including cantaloupe, cilantro, cucumber, leafy green, pepper, and tomatoes from Honduras [47].

Antimicrobial resistant bacteria may have the potential to make their way over to fresh produce through contaminated irrigation water and manure applied to agricultural fields. The utmost threat to the consumer is when vegetables and fruits are consumed without being washed. Practicing good agricultural practices (GAPs) on farms and good handling practices on farms and homes is often recommended to elude *Salmonella* in fresh produce.

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