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Sources and contamination routes of microbial pathogens to fresh produce during field cultivation: A review

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ABSTRACT

Foodborne illness resulting from the consumption of contaminated fresh produce is a common phenomenon and has severe effects on human health together with severe economic and social impacts. The implications of foodborne diseases associated with fresh produce have urged research into the numerous ways and mechanisms through which pathogens may gain access to produce, thereby compromising microbiological safety. This review provides a background on the various sources and pathways through which pathogenic bacteria contaminate fresh produce; the survival and proliferation of pathogens on fresh produce while growing and potential methods to reduce microbial contamination before harvest. Some of the established bacterial contamination sources include contaminated manure, irrigation water, soil, livestock/ wildlife, and numerous factors influence the incidence, fate, transport, survival and proliferation of pathogens in the wide variety of sources where they are found. Once pathogenic bacteria have been introduced into the growing environment, they can colonize and persist on fresh produce using a variety of mechanisms. Overall, microbiological hazards are significant; therefore, ways to reduce sources of contamination and a deeper understanding of pathogen survival and growth on fresh produce in the field are required to reduce risk to human health and the associated economic consequences.

Contents

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1. Introduction

Foodborne diseases are rife in many regions of the world, with at least 1 in 10 people falling ill yearly from consumption of contaminated food and 420, 000 deaths occurring as a result, according to the World Health Organisation (WHO) (2015). Foodborne diseases have exerted pressure on medical services, contributed to economic and political distress, exacerbated malnutrition and led to human suffering. There are several agents such as chemicals, pathogens, and parasites, which may adulterate food at different points in the food production and preparation process (Allos et al., 2004). Many of these agents have been extensively characterized and investigated by numerous studies (Farber and Peterkin, 1991; Zhao et al., 2001; Le Loir et al., 2003; Ehling-Schulz et al., 2004; Adzitey et al., 2013; Botana, 2014). Strategies and protocols to prevent occurrence (and outbreak) of foodborne diseases have been devised and implemented by many researchers, regulatory bodies, and governments. However, despite the considerable progress achieved scientifically, foodborne diseases continue to occur, representing a significant cause of morbidity and mortality globally (Mead et al., 1999; Murray et al., 2013). Although foodborne diseases are more common in developing countries particularly in Africa and South East Asia with specific groups of people such as children, the immunocompromised, pregnant and aged being particularly at risk, foodborne diseases are not limited to these regions or groups of people (WHO, 2007). For instance, according to the Centres for Disease Control and Prevention (CDC), between 2001 and 2009, there were 38.4 million episodes of domestically acquired foodborne gastroenteritis caused by unspecified agents in the United States alone (CDC, 2009). Approximately 17.8 million acute gastroenteritis occurred, and there were at least 473,832 hospitalizations in the US each year and 215 779 hospitalizations caused by the 24 known gastroenteritis pathogens. An estimated 5072 persons died of acute gastroenteritis each year, of which 1498 deaths were caused by the 24 known foodborne pathogens (Scallan et al., 2011). Health Canada (2011) estimates that 11–13 million cases of foodborne illnesses occur in Canada every year.

Although the conventional notion is that foodborne diseases typically originate from meat and poultry products, vegetables and fruits have been implicated in various foodborne outbreaks (Westrell et al., 2009; Lynch et al., 2009; [European Food Safety Authority (EFSA), 2013]. A significant increase in foodborne disease outbreaks or cases associated with consumption of fresh produce has been reported. This increase has been largely due to a general increase in produce consumption, globalization of the produce industry and more effective surveillance (Tauxe et al., 1997; Lederberg et al., 2003; Havelaar et al., 2010). Increased consumption of fresh produce is likely due to global government efforts to promote healthy eating, the associated health-promoting benefits of consuming fresh produce and ease of access to fresh local produce (Pollack, 2001; Regmi, 2001; Berger et al., 2010; Painter, 2013). Since fresh produce is mostly eaten raw or after minimal processing, pathogen contamination constitutes a potential health risk (Callejón et al., 2015; Li et al., 2017). There are numerous factors capable of compromising the microbiological integrity of produce along the farm to fork continuum, all of which have potentially fatal outcomes. However, pre-harvest hazards to produce have been recognized as important because usually, once pathogen contamination is established in the field, it can be challenging to decontaminate produce. There are numerous circumstances that can undermine the safety of produce on farms. Many of these arise because agriculture has grown more intensive over the years, and produce fields are often located near animal production zones thus entwining the ecological connections between wild animals, livestock and produce (Strawn et al., 2013a,b). This, in many cases, predisposes fruits and vegetables to pre-harvest hazards. Some important pre-harvest hazard sources to produce include the use of contaminated soil, irrigation water and manure for produce cultivation. Wild animals and insects have also been implicated as vehicles of pathogens to produce.

To ensure produce safety on a sustainable scale, it is imperative to correctly understand the routes of entry, fate, transport, establishment, and survival of pathogens in the agricultural environment such as soil, irrigation water and manure. The knowledge gap in this regard is being filled rapidly, as many studies have attempted to explain the behavior of foodborne pathogens in agricultural media and describe the associations among pathogens, produce and the agrarian environment. In this review, the extent of the produce contamination problem is discussed as well as the sources and routes of contamination of soil, irrigation water, fruits, and vegetables. Also, the various mechanisms and strategies through which bacterial pathogens become established on fruits and vegetables are briefly examined.

2. Overview of outbreaks associated with fresh produce

The nutritional and health benefits of consuming fruits and vegetables have been recognized and widely publicized. This has elicited changes in human dietary habits, with many consumers incorporating more fruits and vegetables into their meals. Consequently, the global production of fruits and vegetables has surged exponentially in recent decades. The increased demand for produce has led to modifications such as increased use of soil amendments, utilization of alternative water sources and increased imports and exports in agriculture-spanning across agronomic practices, processing, preservation, packaging, distribution, and marketing (Beuchat, 2002). Some of these modifications, however, have great potential to compromise the safety of fruits and vegetables. The biological hazards that are most relevant to fresh produce safety are either zoonotic or human in origin and can be classified into spore-forming bacteria, non-spore forming bacteria, viruses, parasites and prions (James, 2006). Most studies/surveillance efforts have identified bacterial contaminants in produce-borne illness outbreaks. There is, therefore, a disproportionately higher abundance of information regarding bacterial contamination in the literature. This