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Review

Microgreens—A review of food safety considerations along the farm to fork continuum

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ABSTRACT

The food safety implications of microgreens, an emerging salad crop, have been studied only minimally. The farm to fork continuum of microgreens and sprouts has some overlap in terms of production, physical characteristics, and consumption. This review describes the food safety risk of microgreens as compared to sprouts, potential control points for microgreen production, what is known to date about pathogen transfer in the microgreen production environment, and where microgreens differ from sprouts and their mature vegetable counterparts. The synthesis of published research to date may help to inform Good Agricultural Practices (GAPs) and Good Handling Practices (GHPs) for the emerging microgreen industry.

1. Prevalence of produce-associated foodborne illness

One in ten people worldwide contract illnesses from food contaminated with infectious agents, and 420,000 of those cases result in death (Alegbeleye et al., 2018; Hoffmann et al., 2017). The World Health Organization reported in 2015 that Africa, Southeast Asia, and the Eastern Mediterranean bear the greatest burden, while the Americas and Europe bear the least (World Health Organization, 2015). Nevertheless, the most recent report of confirmed cases of food-borne illness from the Centers for Disease Control and Prevention (CDC) in the United States concluded that in 2015 alone there were 902 food-borne disease outbreaks resulting in 15,202 illnesses, 950 hospitalizations, 15 deaths, and 20 food product recalls (Center for Emerging Diseases, 2015). The true figures could be higher as these events are from confirmed outbreaks. Scallan et al. (2011) reported that an estimated 47.8 million cases of domestically acquired food-borne illness may occur annually in the United States.

A 2013 CDC report on the attribution of illnesses to food commodities showed that 46% of the foods involved in outbreaks are produce, causing 23% of the fatalities (Painter et al., 2013). Further, the CDC's Food-borne Disease Outbreak Surveillance System reported that out of 120 multi-state outbreaks between 2010 and 2014, 17 were from fruits, 15 were from vegetable row crops, 10 were from sprouts, and 9 were from seeded vegetables (e.g. cucumbers, mini peppers) (Crowe et al., 2015). A myriad of pathogens can contaminate produce, including spore-forming bacteria, non-spore forming bacteria, viruses, parasites, and prions. The multi-state outbreak report by Crowe et al. (2015) demonstrates that the most common produce-associated bacterial pathogens are *Salmonella enterica*, *Listeria monocytogenes*, and shiga toxin-producing *Escherichia coli*. Human norovirus, the leading cause of food-associated acute gastroenteritis, is responsible for 5% of all food-borne illnesses of known etiology in the United States (Scallan et al., 2011) and 65% of those in Canada (Thomas et al., 2013). A search on September 7, 2018 for 'norovirus' and 'food' in the CDC's National Outbreak Reporting System (NORS) Database revealed that norovirus is the major cause of outbreaks associated with leafy greens. After multiple ingredient foods and foods considered 'unclassifiable,' 'vegetable row crops,' 'other,' 'mollusks,' and 'fruits' are the most common food categories implicated in norovirus outbreaks.

A 2013 report by the European Food Safety Authority (EFSA) attributed an increase in cases of foodborne illness (from 18% to 26%), hospitalizations (from 8% to 35%) and deaths (5% to 46%) between 2007 and 2011 to one large verocytotoxigenic *Escherichia coli* (VTEC) outbreak in Germany in 2011. Fenugreek sprouts were identified as the infected food and over 3800 people were affected (European Food Safety Authority, 2013). The EFSA later reported that active surveillance of eight European Union (EU) member states revealed one sample of 344 collected was positive in 2016 compared to zero positive samples out of 444 collected from six member states in 2013 (European Food Safety Authority, 2017). Produce-associated outbreaks in the United States have also increased in the last two decades, from 8% of food-borne illness outbreaks between 1998 and 2001 to 16% between 2010

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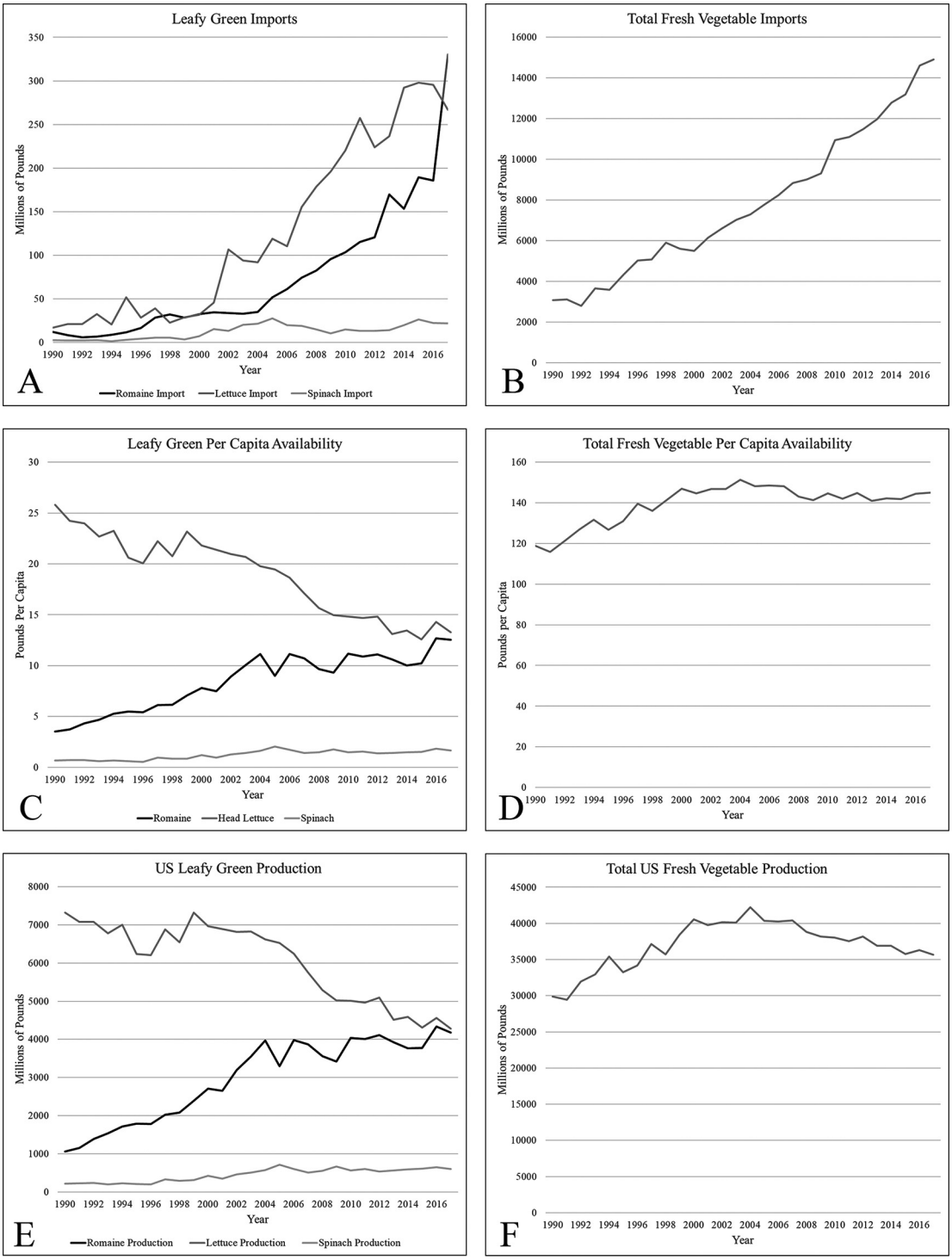

Fig. 1. Leafy green consumption and availability.
Lettuce, leafy green, and total fresh vegetable imports (A and B), per capita availability (C and D), and production (E and F) in the United States from 1990 to 2016. Source: ERS/USDA, Accessed June 4, 2018.

and 2013 (Bennett et al., 2018).

Alegbeleye et al. (2018) postulated that increases in produce-related outbreaks are at least partially due to improved surveillance and reporting. However, they suggest a true increase in produce-associated illness may simply be a result of increased consumption of fruits and vegetables. Data collected by the United States Department of Agriculture's Economic Research Service (ERS/USDA) from 1990 to 2016 show that while head lettuce availability per capita and domestic production has gone down, there has been an increase in availability and production of romaine lettuce and a slight increase in spinach availability. There has also been an increase in imported fresh vegetables that is suggested to correspond with an increase in imported Romaine and head lettuce (Fig. 1).

An increase in importing supports the assertion by Alegbeleye et al. (2018) that agriculture has become more globalized. Globalization adds challenges in regulating food safety since practices differ between countries, such as water quality management and waste water treatment. According to a report by the International Food Policy Research