Science of the Total Environment 562 (2016) 751–759

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Agrifood systems and the microbial safety of fresh produce: Trade-offs in the wake of increased sustainability

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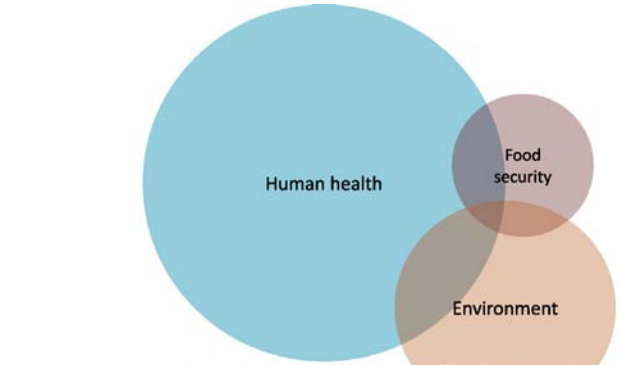
HIGHLIGHTS

- Measures taken to improve safety were assessed for their impact on sustainability.
- Fresh produce safety improvements may come at the expense of sustainability.
- Environment, food security and human health constituted the three domains of sustainability.
- Measures to improve safety should be adapted to each agrifood system.

GRAPHICAL ABSTRACT



Citations in the Web of Sciences related to the three domains of sustainability in the case of fresh produce. Areas are proportional to the numbers of citations.

ARTICLE INFO

Article history:
Received 18 February 2016
Received in revised form 29 March 2016
Accepted 30 March 2016
Available online xxxx

Editor: Jay Gan

Keywords:
Foodborne pathogens
Waste water
Wildlife

ABSTRACT

Fresh produce has been a growing cause of food borne outbreaks world-wide prompting the need for safer production practices. Yet fresh produce agrifood systems are diverse and under constraints for more sustainability. We analyze how measures taken to guarantee safety interact with other objectives for sustainability, in light of the diversity of fresh produce agrifood systems. The review is based on the publications at the interface between fresh produce safety and sustainability, with sustainability defined by low environmental impacts, food and nutrition security and healthy life. The paths for more sustainable fresh produce are diverse. They include an increased use of ecosystem services to e.g. favor predators of pests, or to reduce impact of floods, to reduce soil erosion, or to purify run-off waters. In contrast, they also include production systems isolated from the environment. From a socio-economical view, sustainability may imply maintaining small tenures with a higher risk of pathogen contamination. We analyzed the consequences for produce safety by focusing on risks of contamination by water, soil, environment and live stocks. Climate change

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http://dx.doi.org/10.1016/j.scitotenv.2016.03.241

Livestock
Organic farming
Climate change

may increase the constraints and recent knowledge on interactions between produce and human pathogens may bring new solutions. Existing technologies may suffice to resolve some conflicts between ensuring safety of fresh produce and moving towards more sustainability. However, socio-economic constraints of some agri-food systems may prevent their implementation. In addition, current strategies to preserve produce safety are not adapted to systems relying on ecological principles and knowledge is lacking to develop the new risk management approaches that would be needed.

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The growing world population, +1.18% from 2010 to 2015, (United_Nations, 2015), and the persistence of nearly 800 million chronically undernourished people (FAO et al., 2012, 2015) create a strong pressure to increase food production and food availability in many parts of the world. In developed countries, pressures come from the difficulties for farmers to make profits rather than from the concern over food security (Lal, 2008). Concomitantly, agriculture has been singled out as responsible for environmental damage through direct and indirect pollution, and through transformation of landscapes with their effects on biodiversity. As early as the 1980s (WCED, 1986), there were already several studies that investigated paths toward sustainable agriculture that respected the environment and secured food resources and farmers' incomes. However, agriculture must also produce foods of sufficient quality, in particular foods meeting the acceptable level of microbial safety expected by the public and by governments. Most foodborne illness comes from animal production, but as of the 1990s in the US (Lynch et al., 2009), and more recently in the EU (EFSA-Panel-on-Biological-Hazards, 2013), the contribution of fresh produce to foodborne illness has rapidly increased. To integrate microbial food safety into the road map for more sustainable agriculture, we analyzed how measures taken to guarantee produce safety interact with other objectives and constraints in light of the diversity of fresh produce agrifood systems.

The present review does not address chemical hazards, which relate to risk factors different from those of microbial hazards.

1. The three domains of sustainable fresh produce

In 2010 the Food and Agriculture Organization defined "sustainable diets" as "those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations" (FAO, 2010). Hence, we identified three domains relevant to sustainable fresh produce: healthy for consumer (health), environmentally friendly production (environment), and production to meet the world demand (world) also referred to as food security. Health for consumers includes microbial safety, which is therefore part of sustainability and its health domain. However, in the present review for the sake of simplicity, we frequently use "sustainability" for "aspects of sustainability other than microbial safety". We established a list of keywords to retrieve publications in these domains from WOS (all databases since 1975, including conferences). The exact queries are detailed in Supplementary Data. For fresh produce, the three domains "health", "environment", or "world" yielded respectively 133422, 44331, 14250 citations. Publications concerning microbial safety represented 38% of the "health" domain. The overlap between each pair of the three domains represented 9752 citations for environment X health, 3532 for environment X world, 5631 for health X world and 1007 for environment X health X world. This suggests that the three domains are relatively disjoint. To verify the interactions between the three domains, we assessed the rate of cross citations, i.e. "do articles of domain A cite articles in domain B"? Only 5.8% of the articles of the "health" domain cited at least one article of the two other domains "environment" or "world". "Environment" and "world" made less usage of the other domains with respectively 4.9% and 1.9% of articles citing at least one article from the two other domains. This confirms that the three domains are rather independent from one another, indicating a relatively low number of integrative studies with a global view of fresh produce sustainability. From the data base established for this analysis, we subsequently assessed the trends of research orientation in the interaction of sustainable production of fresh produce with microbial safety.

2. Risk factors for contamination of fresh produce

A large proportion of fresh produce is consumed raw, without microbiocidal treatment, and its microbial safety is a direct consequence of food chain conditions and practices. Epidemiological investigations of outbreaks, associated with testing of fresh produce for pathogens or indicators, have revealed some major risk factors linked to primary production and post-harvest conditions and practices. These include presence of livestock in the nearby environment of fresh produce production, contact with wild-life, contamination of soil with fecal material, fecal contamination of water used for irrigation or other agricultural purposes, lack of hygiene of handlers and of equipment, and inadequate washing procedures (Fig. 1) (EFSA-Panel-on-Biological-Hazards, 2013; Park et al., 2012). The impact of these risk factors on consumers' health