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Viral outbreaks linked to fresh produce consumption: a systematic review

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fresh produce, hepatitis A, lettuce, norovirus, raspberries, salad, strawberries.

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Abstract

Aims: A systematic review to investigate fresh produce-borne viral outbreaks, to record the outbreak distribution worldwide and to analyse the implication of different types of fresh produce and viral types as well.
Methods and Results: Four databases (PubMed/Medline, Scopus, Eurosurveillance Journal and Spingerlink electronic journal) and a global electronic reporting system (ProMED-mail) were searched up to 2016. One hundred and fifty-two viral outbreaks linked to fresh produce consumption were identified. The majority of the reported outbreaks was reported in Europe, followed by North America, Asia, Australia, Africa and South America. A great number of the outbreaks was recorded in Denmark and Finland. The most common viral pathogens were norovirus (48·7%) and hepatitis A virus (46·1%). The most frequent type of fresh produce involved was frozen raspberries (23·7%). Differences in the reporting of outbreaks were recorded between the scientific literature and ProMED.
Conclusions: The number of reported illnesses linked to fresh produce has increased in several countries. Consumption of contaminated fresh produce represents a risk to public health in both developed and developing countries, but the impact will be disproportionate and likely to compound existing health disparities. For this reason, all countries should systematically collate and report such data through a disease surveillance system, in order to adopt risk management practices for reducing the likelihood of contamination.

Introduction

Sales of fresh produce have significantly increased during the last decade, as consumers have increasingly become concerned with healthy food and nutrition (The Organic Industry 2008). Fruit and vegetables are considered as important components of a healthy and balanced diet and recognized as an important source of nutrients, vitamins and fibre for humans (Mulabagal *et al.* 2010; Odriozola-Serrano *et al.* 2010). Thus, their consumption is encouraged in many countries by governmental health agencies as a source of protection to protect against a range of illnesses such as cancers and cardiovascular diseases (Piyasena *et al.* 2003; Berger *et al.* 2010; Birmpa *et al.* 2013).

Furthermore, from 1980 to 2004, the global production per annum of fruit and vegetables has increased by 94% (Wirsenius *et al.* 2010). Thus, it is of high importance to ensure safe consumption of these products (European Union 2007). Consumption of fresh produce has increased over the past two decades for many reasons; for example, consumers always try to meet the projected standard of healthy living and in response to this demand, a large variety of domestic and imported produce has become available during all seasons (Warriner *et al.* 2009). Globally, fruit and vegetable consumption has increased on average by 4·5% yearly between 1990 and 2004 (European Union 2007). The annual consumption of fruits and vegetables in the United States during 1997–1999 was 25% above the levels of years 1977–1979 (Food and Drug Administration 2001). In Canada, from 1963 to 2010, the annual consumption of fruits and vegetables had

increased by 56% and 26% respectively (Olaimat and Holley 2012).

While fruit and vegetables are clearly considered as part of a healthy diet, foodborne illnesses related to the consumption of fresh produce is widely reported (Lynch *et al.* 2009). Fresh and freshly cut produce is responsible for a growing number of foodborne disease outbreaks each year (Beuchat 2002). Raw fruits and vegetables have been known to serve as vehicles of human diseases for at least a century. Thus, the recognition of raw fruits and vegetables as potential vehicles for the transmission of pathogenic micro-organisms known to cause human diseases is not new. Nevertheless, documented viral outbreaks of foodborne illnesses associated with fruits and vegetables in industrialized countries are relatively rare (Public Health Laboratory Service 2017). For instance, in 1996, only 6 of about 200 reported foodborne disease outbreaks in the United Kingdom were associated with the consumption of fruits and vegetables. In recent years, however, the frequency of outbreaks epidemiologically associated with raw fruits and vegetables has been increased in some industrialized countries (e.g. the United States) as a result of a change in dietary habits and an increased import of food (Altekruse *et al.* 1997). In the United Kingdom, between 1996 and 2006, a total of 88 reported outbreaks was documented with more than 3435 reported cases of illnesses relating to fresh fruits and vegetables (Organization 1998). In 2011, the Advisory Committee on the Microbiological Safety of Food (ACMSF) reported that in the United Kingdom between 2008 and 2010, 531 cases of illness relating to the consumption of fruits and vegetables, including one death were reported (Advisory Committee on the Microbiological Safety of Food 2011). In developing countries, foodborne illnesses caused by contaminated fruits and vegetables are frequent and in some areas they cause a large proportion of illnesses. However, due to the lack of foodborne disease investigation and surveillance in most of these countries, most outbreaks go undetected and the scientific literature reports only a few outbreaks. In 1995–1996, only a 2% of foodborne disease outbreaks was related to fruits and vegetables in Latin America (PAHO/INPPAZ 1996). Outbreaks caused by the hepatitis A virus (HAV), the calicivirus, the norovirus (NoV) and Norwalk-like viruses have been associated with the consumption of fresh produce and specifically with the consumption of frozen raspberries or frozen strawberries, lettuce, melons, salads, diced tomatoes and fresh-cut fruit (Pönkä *et al.* 1999; Beuchat 2002; Maunula *et al.* 2009; Severi *et al.* 2015). HAV and norwalk-like viruses are the most commonly documented viral food contaminants (Food and Drug Administration 2001). Outbreaks caused by the NoV are characterized by a mean incubation period of 24–48 h, although a range from 15 to 60 h has been observed, a mean illness duration of 12–48 h and a high percentage of patients with diarrhea, malaise, fever, nausea and abdominal cramps. On the other hand, outbreaks caused by the HAV are characterized by clinical symptoms such as long incubation periods of 25–30 days and patients usually report fever, malaise, anorexia, nausea, abdominal pain, jaundice and dark urine (Food and Drug Administration 2001).

Until recently, no data were available concerning the prevalence of the NoV on fresh produce. Nevertheless, NoV outbreaks, which have been reported, were linked to leafy greens (Gallimore *et al.* 2005; Makary *et al.* 2009; Ethelberg *et al.* 2010; Wadl *et al.* 2010). Soft red fruits have also been implicated in NoV outbreaks (Le Guyader *et al.* 2004; Maunula *et al.* 2009). A review of food- and water-borne outbreaks provoked by the NoV, from 2000 to 2007, revealed that in the 42·5% of the cases the food handler was responsible for the outbreak, contaminating sandwiches and catered meals, followed by water (27·5%), bivalve shellfish (17·5%) and fresh produce (12·5%) (Gaulin *et al.* 1998).

The lack of appropriate methods to detect the NoV on fresh produce has hampered the testing of this food commodity–pathogen combination. Over the last decade, several methods for the virus, and in particular the NoV, extraction and detection, have been evaluated (Butot *et al.* 2007; Baert *et al.* 2009). A cluster of HAV outbreaks associated with green salad onions was reported in the United States in 2003 (Chancellor *et al.* 2006). The initial outbreaks were centred in a restaurant in Pennsylvania that resulted in 575 cases of HAV and one death (Wheeler *et al.* 2005b). Although the restaurant was initially identified as the source of the outbreak, subsequent investigation linked it to other cases in Tennessee and Georgia. Later, one farm in Mexico was identified as the most likely source of the virus (Wheeler *et al.* 2005a). Interestingly, the persistence of the viruses, such as the poliovirus, has shown to be dependent on the vegetable type. For instance, viruses introduced onto green onions remained stable for over 14 days (Kurdziel *et al.* 2001).

At the preharvest level, contact with polluted irrigation water or organic fertilizers is possible (Wei and Kniel 2010). During harvest, in particular during handpicking of crops, an infected person can transmit the virus. Furthermore, at the postharvest level the produce can be contaminated by contact with polluted process water or during food preparation by infected food handlers (Baert *et al.* 2008).

To the best of our knowledge this study is the first global systematic review of viral outbreaks linked to fresh produce consumption. A comprehensive epidemiological analysis of viral outbreaks due to fresh produce is scarce.

To improve the understanding of viral outbreaks induced by fresh produce, we conducted a systematic review to describe the spatial and temporal distribution and the magnitude of all foodborne outbreaks related to the consumption of fresh produce, in order to highlight the need of monitoring and surveillance.

Materials and methods

Data sources and search strategy

The PRISMA and ORION statements were used in the search and the analysis process (Stone *et al.* 2007; Liberati *et al.* 2009). PubMed/Medline, Scopus, the Eurosurveillance Journal and the Spingerlink electronic journal were the databases used to identify peer—reviewed articles reporting outbreaks associated with fresh produce. The database search was performed between January and September 2017—nevertheless, there had been a continuing reviewing of the database during the whole time the reporting of the systematic review was taking place using the following search terms and their variations in combination: 'outbreaks AND Fresh Produce', 'infectious virus AND Fresh Produce', 'hepatitis A outbreak', 'imported cases AND fresh produce', 'salad AND outbreak', 'berries AND infectious virus', 'strawberries AND infectious virus', 'raspberries AND viral outbreaks'. The titles, key words and abstracts of the articles included in the online databases were searched for these search terms. The grey literature was also searched using the software programme for Monitoring Emerging Diseases (ProMED–mail) using similar search terms.

Selection criteria

All study design types were included. Single case reports were not included, unless the case was the primary infective case of the outbreak. Non-English language studies were included and translated with the aid of Google translator. The systematic review included both experimental and nonexperimental studies from all years till 2016, totally counting 11063 articles/records (including the records published by ProMED-mail). Additional publications, not found in the electronic searches, were also selected from bibliographies of relevant articles. Also, conference abstracts, editorials and letters to the editor published online were included. Expert opinions and qualitative studies were excluded. All articles that met the inclusion criteria were assessed for validity. Validity was determined on a 10–point scale made *a priori* (Table 1). Studies not meeting five or more of the 10 validity criteria were excluded due to inadequacy of information.

Table 1 The selection criteria developed a priori

Validility criteria	
1	Only viral outbreaks
2	Viruses involved in the outbreak
3	Number of the cases of the outbreak
4	Symptoms, such as mixed gastroenteritis symptoms, typical HAV infection symptoms, mixed, etc.
5	Country of the epidemic
6	Country of the fresh produce origin
7	Fresh produce species (frozen/fresh strawberries, frozen/fresh raspberries, salad, tomatoes and tomatoes product such semi-dried tomatoes, etc.)
8	Hospitalization
9	Deaths recorded and number of deaths recorded
10	Method of outbreak investigation (epidemiological, laboratory or both)

Data selection

Fifty-eight scientific articles and 22 reports from ProMED-mail met the inclusion criteria and were all in English, except for two, one in French and one in German. All of them were included in the systematic review.

All studies fulfilled the criteria for the case definition of viral outbreaks linked to fresh produce consumption. Based on each set of criteria, the number of individuals enrolled, was recorded. To analyse the results of the studies, the framework outlined in the PRISMA and ORION statements (Stone *et al.* 2007; Liberati *et al.* 2009) was followed for the review process. Outbreak reports and subsequent investigations, including non-randomized studies, form the main body of the evidence regarding the risk factors and the clinical importance of healthcare-associated infections. Major outcome variables were extracted independently by two investigators into a spreadsheet using IBM SPSS Statistics, v.24 with a standardized approach. Any disagreement was resolved by discussion.

Assessment of risk of bias

This systematic review may be biased because of risk of bias of the included studies. The quality of the included studies was assessed by two reviewers (IPC and AV), independently and in a blind manner. The quality assessment was based on the McMaster Critical Review Form for quantitative studies (Law *et al.* 2003) upon three basic criteria referring to (i) sample size, (ii) measurement and (iii) method of analyses. These three factors were scored as 'a', 'b' or 'c', if no criteria were met, only some criteria were met and all criteria were met respectively.

Results

Study selection process and search results

The study selection process is outlined in Fig. 1. The literature search yielded 10,675 articles, namely 570 from Eurosurveillance, 2224 from Springerlink, 2461 from PubMed/Medline and 5420 from Scopus. From these articles, 4363 were duplicates, leaving a total of 6312. After initial review of all these 6312 studies, 3503 articles were discarded after title and abstract review, while 2751 were discarded, after full screen and/or during the data extraction process, as they did not meet the eligibility criteria set. The publications were related to (i) Salmonella spp., Cryptosporidium spp., Yersinia spp., Q fever, E. coli, Listeria and other bacterial foodborne outbreaks, (ii) laboratory investigation methods, (iii) sanitation methods of fresh produce, and (iv) risk assessment/management of fresh produce. Only 58 research articles met the inclusion criteria and reported a total of 130 fresh produce-borne outbreaks. Also, ProMED reported 388 outbreaks associated with fresh produce consumption, but only 22 (22 of 388, 5·7%) outbreaks were of viral origin and were finally included in this study; the rest were bacterial outbreaks or referred to plant diseases. Finally, 80 articles/records were included.

Assessment of risk of bias

Each sample size, measurement and method of analyses was considered as substantial in the quality assessment process. Only four of the included studies received the maximum score for all criteria set.

Characteristics of the included studies

Of the 152 outbreaks associated with fresh produce recorded in the scientific literature and ProMED-mail, all reported the number of cases. The largest outbreak occurred in schools and kindergartens in Germany, in 2012, where more than 11,000 schoolchildren witnessed mixed gastroenteritis symptoms of NoV infection, due to the consumption of frozen strawberries (ProMED-mail record). The second largest outbreak was recorded in a restaurant, in Pennsylvania, in 2005. Of the 601 patients reported, who contracted HAV after green onion consumption, three died and at least 124 were hospitalized (Wheeler *et al.* 2005a). From 1 January 2013 to 31 May 2013, a total number of 352 cases of HAV were reported in the SEIEVA surveillance system (Integrated Epidemiologic System for Acute Viral Hepatitides, which is a special surveillance program, where clinical information and epidemiological risk factors are collected by Public Health

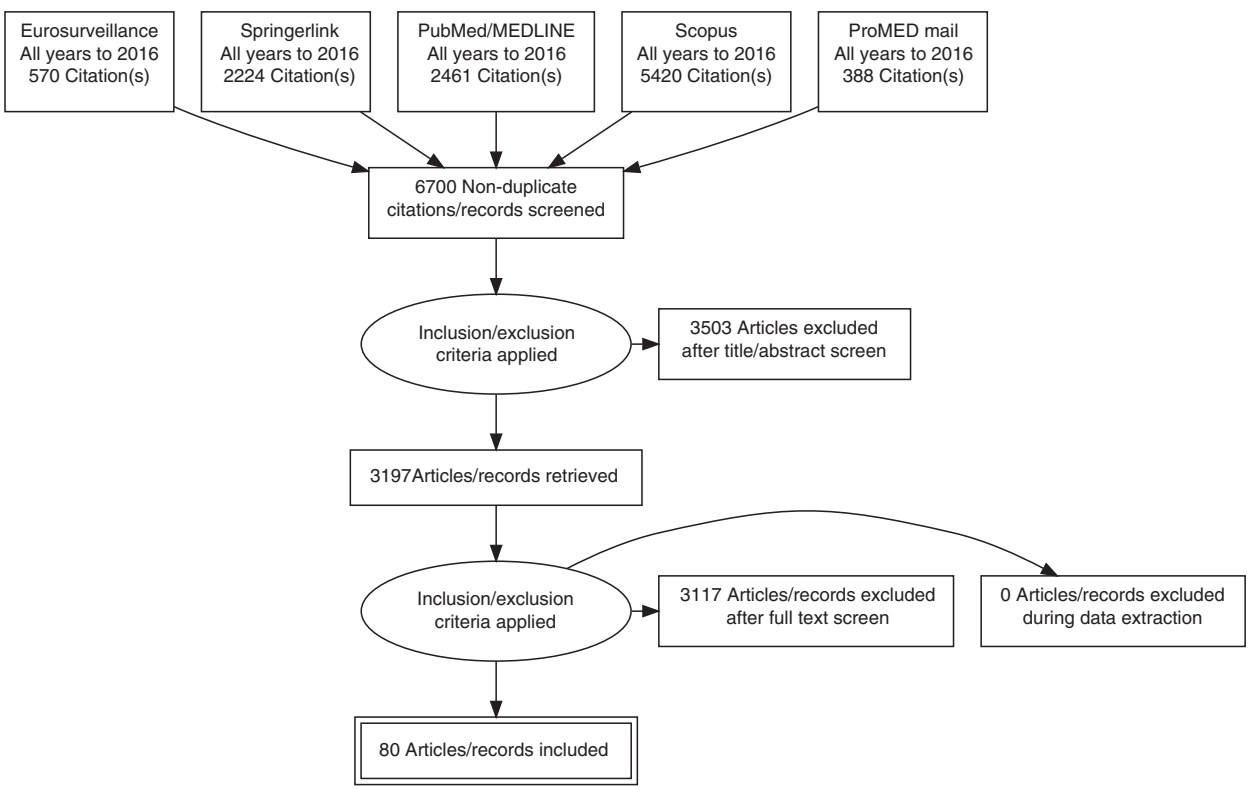

Figure 1 Study selection process.

Service Units) corresponding to a 70, 54 and 34% increase in HAV notifications compared to the same period in 2012, 2011 and 2010 respectively. A total of 159 people were hospitalized. However, no acute liver failures or deaths occurred (Rizzo *et al.* 2013). Also, in May 2013, an outbreak of symptomatic HAV infections occurred in the United States. Of the 165 patients identified from 10 states, 69 (42%) were admitted to hospital, two developed fulminant hepatitis and one needed a liver transplant; no one died (Lynch *et al.* 2009). Almost 10% of the included outbreaks caused by a viral pathogen, namely 899 of 8907 patients, reported hospitalization, whereas in six outbreaks caused by viral pathogens, nine people died. In 62·5% of the outbreaks, the number of the cases was lower than 50, while 7·9% involved between 51 and 100 cases, 7·2% between 101 and 150 cases, 9·9% between 151 and 200 cases and 12·5% over 201 cases.

The yearly distribution of the outbreaks is shown in Fig. 2. Concerning the duration of the outbreak, 113 (74·7%) outbreaks lasted a maximum 1 month, while 8 (5·1%) lasted for more than 2 months. A large number (119, 78·3%) of outbreak studies did not mention the age groups of the cases. In all recorded outbreaks, people of various ages were infected, while their age ranged between 3 and 52 years. Thirty-two outbreaks (21·1%) presented only epidemiological data, while 120 (78·9%) carried out both epidemiological and laboratory investigations with fresh produce sample analyses.

The reported outbreaks occurred in 28 different countries (21 studies documented two or more outbreaks). The geographical distribution of the studies was uneven and is demonstrated in Fig. 3. The majority of the reported outbreaks were in Europe (72·4%) followed by North America (15·8%), Asia (6·6%), Australia (3·3%), Africa (1·3%) and South America (0·7%). The largest number of the outbreaks was reported in both Denmark and Finland (19·1%). The rest were reported in Sweden (13·2%), the United States (12·5%), EU-EFTA countries (4·6%), Norway (3·9%), the Netherlands, Australia, the United Arab Emirates, the United Kingdom and Canada in the same rate (2·6%), Germany (2%), Egypt, France and Italy in the same rate (1·3%) and, finally, India, Korea, Thailand, China, Japan, Brazil, Portugal, New Zealand, Israel, Ireland, Hawaii, Austria and Russia, also, in the same rate (0·7%).

Almost half (74 records, 48·7%) of the outbreaks reported NoV as the pathogen of infection and 46·1% (70 records) of the outbreaks reported HAV, followed by norwalk (four records, 2·6%), the rotavirus (three records, 2%) and sapovirus (one record, 0·7%). Most reported NoV fresh produce outbreaks (63 of 74, 85·1%) occurred in Europe, followed by six outbreaks in Asia (8·1%), four outbreaks in North America (5·4%) and one reported outbreak in South America (1·4%). Furthermore, most reported outbreaks due to the HAV were also reported in Europe (45 outbreaks, 64·3%), followed by North America (18 outbreaks, 25·7%), Australia (five outbreaks, 7·1%) and Africa (two outbreaks, 2·9%). The NoV genogroup I was identified in 59·5% of the cases, the NoV genogroup II was identified in only 16·2% of the cases, while in 8·1% of the cases, the genotype was not mentioned and in 1·4% the genotype was characterized as mixed (of both GI and GII genotypes). In the rest reports/publications, 14·9% of the cases did not characterize the NoV strain. Concerning the HAV cases, the HAV strain was missing in 45·7% of the cases, while 18·6% were of the 1B strain, 15·7% were of the 1A strain, 12·9% were of an unknown subtype and 7·1% were of the 3A strain.

Also, the majority of the fresh produce viral outbreaks (36·1%) occurred during spring. Seasonality was reported in 81·9% of outbreaks and was documented ($P < 0·01$) as follows: 31·7% of NoV outbreaks were reported during spring, 23·8% during summer and 44·5% during winter, while HAV outbreaks mainly occurred during spring and autumn at a rate of 25% and 20% respectively.

The majority of the fresh produce viral outbreaks occurred in schools (18·5%) and restaurants/cafes or caterings (13%). Most NV outbreaks occurred in caterings (20·3%) and schools/childcare facilities (15·6%), followed by restaurants/cafes (12·5%), canteen/meals on the wheels (9·4%), hospital and canteen environments, (7·8%) such as military bases, cruise ships, homes, day-care centres/nursing homes and the British Royal Fleet Auxillary ship (all at the same rate of 3·1%) and hotels, conference centres and private parties (also, at the same rate of 1·6%). In 13·5% of the cases, the place of consumption of the suspicious food product was not specified. Concerning the HAV, most outbreaks (25%) were reported in schools/childcare facilities, followed by home and restaurant/café premises (13·9%). The pathogen distribution upon the place of consumption is summarized in Fig. 4. In almost half of the outbreaks (55·7%), the place where the epidemic occurred was not reported.

Of the total outbreaks, 75 (49·3%) reported the symptoms of the illness. The most common symptoms were mixed symptoms (25%), mixed gastrenteritis symptoms (vomiting, diarrhoea, stomachpain, muscleaches, headache, nausea, chills, etc.) (15·8%), and HAV infection symptoms (fever, dark urine, loss of appetite, malaise, vomiting, pale stools, abdominal pain and/or jaundice) (7·9%). The rest of the cases (0·6%) sporadically reported symptoms like, headache, nausea, muscle aches, chills and stomach pain. More than half of the outbreaks (50·7%) did not involve any symptoms, although the cases were epidemiologically and/or laboratory verified.

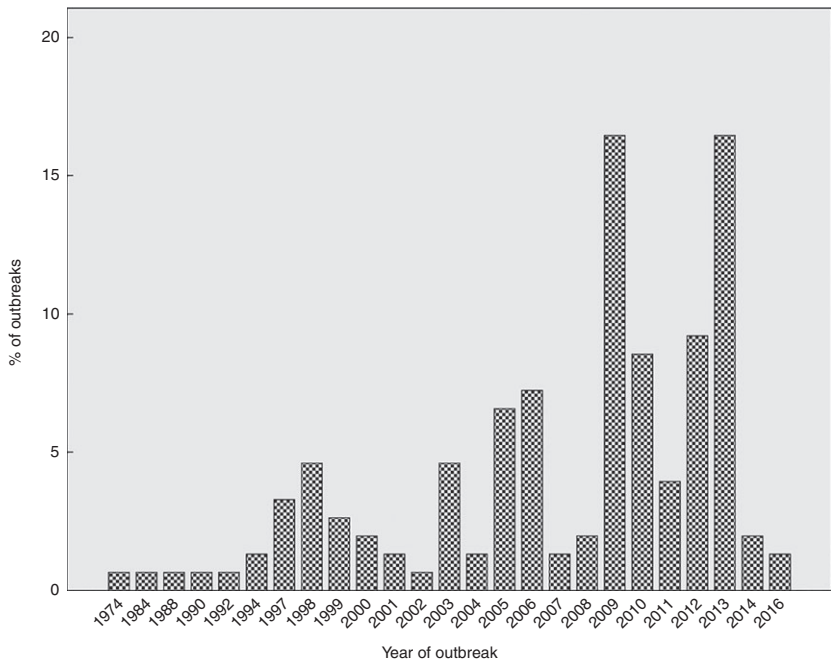

Figure 2 Fresh produce viral oubreaks per year (all years to 2016).

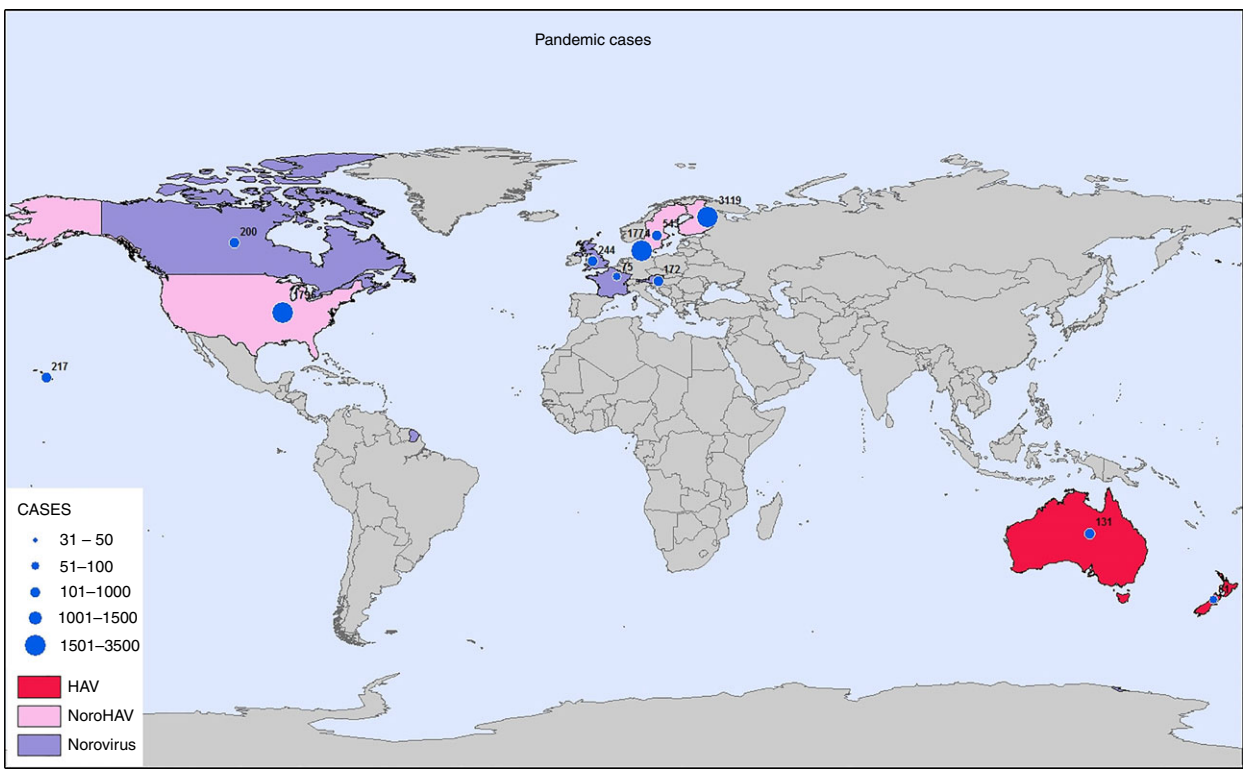

Figure 3 Global distribution of viral outbreaks linked to fresh produce consumption. [Colour figure can be viewed at wileyonlinelibrary.com]

The fresh produce involved in the outbreaks was fruits and vegetables which are listed in Table 2. The most common fresh produce suspected for viral outbreaks was frozen raspberries (23·7%), frozen berries (19·1%) and salad items such as canteen salad, rocket salad and green salad (15·8%). All the outbreaks, except

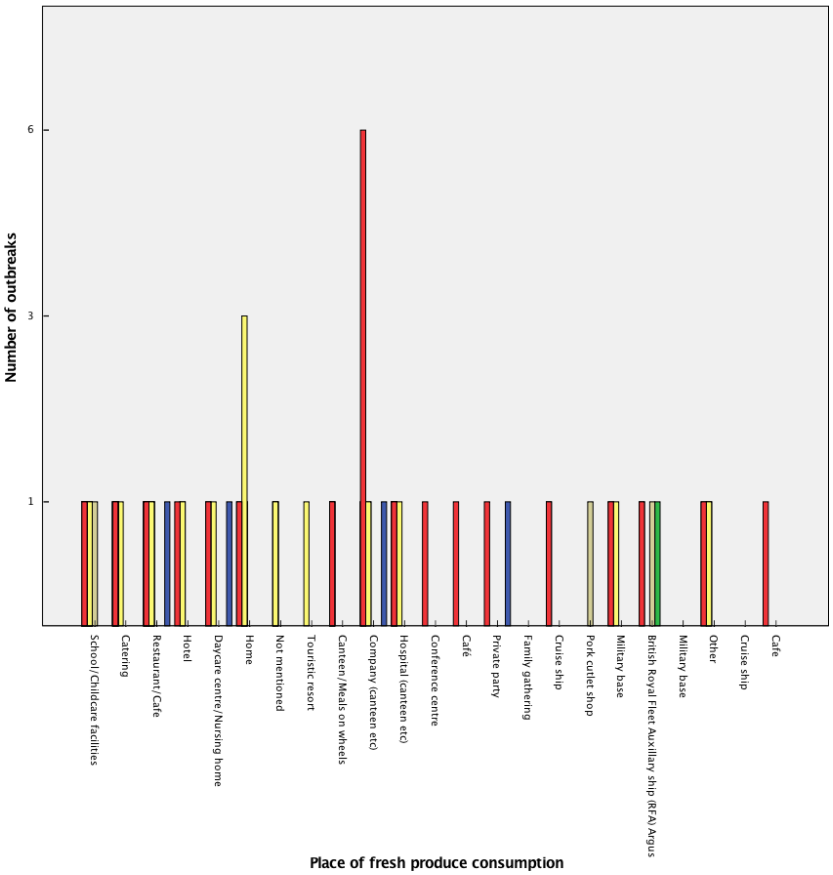

Figure 4 Pathogen distribution upon place of fresh produce consumption. Pathogen: (■), Norwalk; (■), Sapovirus; (■), Rotavirus; (■), Both Nov and HAV; (■), HAV; (■), Nov. [Colour figure can be viewed at wileyonlinelibrary.com]

for one, which were caused by the consumption of frozen raspberries reported the NoV as the vehicle of the infection. Most suspected frozen raspberries (20 of 28, 71·4%) were collected in Poland, while multiple outbreaks of NoV gastroenteritis associated with these fruits have been reported, especially in Europe (PAHO/INPPAZ 1996; Pebody *et al.* 1998; Lund and Snowdon 2000; Food and Drug Administration 2001; Le Guyader *et al.* 2004; Cotterelle *et al.* 2005; Falkenhorst *et al.* 2005; Gallimore *et al.* 2005; Hjertqvist *et al.* 2006; The Organic Industry 2008; Maunula *et al.* 2009; Mulabagal *et al.* 2010; Odriozola-Serrano *et al.* 2010; Mei Soon *et al.* 2012; Olaimat and Holley 2012; Sarvikivi *et al.* 2012; Public Health Laboratory Service 2017), except for one outbreak that took place in Canada, in 1997 (Nygård *et al.* 2001) and one in North America (Gaulin *et al.* 1999). Most reported outbreaks due to frozen berries were reported in Europe (89·7%) (Dentinger *et al.* 2001; Public Health Laboratory Service 2017) followed by North America (6·9%) and Australia (3·4%) (Promed report). The majority of the suspected lettuce (58·8%) caused NoV outbreaks, followed by the norwalk virus (17·6%), the HAV (11·8%), and the rota- and sapovirus (both 5·9%).

Also, the majority of the NoV outbreaks (87·2%) were caused by frozen fresh produces. Nevertheless, the consumption of fresh produce is exclusively associated with the NoV outbreaks. Finally, all the HAV outbreaks were exclusively caused by frozen fresh produces.

The fresh produce-harvesting areas were located in five continents: Europe (19·1%), Asia (7·9%), Africa (4·6%), North America (3·9%) and Australia (0·7%). Of the outbreaks, 63·8% did not report the country of the fresh produce harvesting area. The fresh produce derived from nine different countries such as Poland, Turkey, China, Egypt, France, Canada, Mexico, Bosnia and Australia.

Discussion

This systematic review has studied the distribution and the risk factors of viral outbreaks related to the consumption of fresh produce.

The study has a few limitations which can be categorized into two groups: systematic review limitations and primary literature reporting limitations. The eligibility criteria set in the systematic review and the methodology followed, like the search terms and their combinations, may have influenced the results obtained. It was difficult

Table 2 Type of fresh Produce implicated in viral outbreaks from the scientific literature and ProMED reports

	Scientific literature		ProMED mail	
Vehicle	Frequency	%	Frequency	%
Frozen raspberries	36	27·7	4	18·2
Frozen berries	31	23·9	2	9·1
Salad	26	20·1	3	13·6
Lettuce	7	5·3		
Frozen strawberries	7	5·3	4	18·2
Green onion	3	2·3		
Orange juice	2	1·5	1	4·5
Tomatoes	2	1·5	2	9·1
Pomegranate arier	2	1·5		
Frozen fruit blend	2	1·5		
Frozen semi-dried tomatoes	2	1·5		
Mixed (salad fruits, etc.)	2	1·5	4	18·2
Salad dressing	1	0·8		
Fresh strawberries	1	0·8		
Semi-dried tomatoes	1	0·8	2	9·1
Frozen mango	1	0·8		
Fresh mango	1	0·8		
Dried fruit	1	0·8		
Pumpkin salad	1	0·8		
Orange mousse	1	0·8		
Total	130	100	22	100

to achieve the optimal balance between sensitivity and specificity, as time and resource constraints limited the number of abstracts which could be screened for inclusion. This was due to the fact that we relied on articles mentioning 'fresh produce outbreaks' in their title, abstract or keywords so that they could easily be identified by the search engines. For example, ProMED-mail reported 388 outbreaks associated with fresh produce such as vegetables and fruits, but only 22 were found to be of viral origin; all the others were of bacterial origin or referred to plants per se. It was difficult to make comparisons between outbreaks, as there was substantial variation in case definitions between the outbreaks identified; accounts based on self-reported cases had a substantially higher mean number of cases than those requiring a clinical diagnosis or laboratory confirmation and those that did not report the type of the case definition had, on average, the largest number of cases. The calculation of the attack rate is also likely to have varied by study.

Additionally, it is widely accepted that outbreaks are often not reported, whereas reporting varies upon each country's special characteristics (like primary health system organization, administrative organization of public health services, etc.) and may lead to heterogeneity among countries (Kroneman *et al.* 2006; Bellou *et al.* 2013). Thus, the global distribution of viral outbreaks linked to fresh produce consumption as reported in the scientific literature is also likely to be prone to considerable publication bias. This may bias our results and conclusions, as well. This review also recorded the lack of details in the studies. For example, it was difficult to assess the evidence supporting the classification of the outbreaks as foodborne or the degree of association between fresh produce and disease given the limited amount of information often provided, particularly in the ProMED-mail reports. A quarter (25%) of those which provided the number of cases did not report the type of case definition used, that is, whether they were laboratory-confirmed, clinically diagnosed or self-reported cases.

The number of foodborne illness outbreaks linked to fresh produce which have been reported to the US Centers for Disease Control and Prevention (CDC) have increased during the last years. A part of this increase is due to improved surveillance, but other factors may also come into play. A number of reasons have been proposed for this increased association of foodborne illness with fresh produce. During this same period, there has been a trend towards greater consumption of foods not prepared at home and an increase in the popularity of salad bars (buffets). Greater volumes of intact and chopped, sliced or prepared fruits and vegetables are being shipped from central locations and are distributed over much larger geographical areas to much more people (Berger *et al.* 2010). This, coupled with the increased global trade, potentially increases human exposure to a wide variety of foodborne pathogens and also increases the chances that an outbreak will be detected. Definite reasons for the increase in all kinds of foodborne illnesses during summer time are not fully understood, although abusive temperatures and a higher consumption of fresh produce during the summer months are likely to play a significant role.

The scientific literature suggests that, of those fresh produce linked to foodborne viral outbreaks, the NoV and the HAV occur in the highest numbers of cases. For example, a similar review of produce-associated outbreaks in the United States from 1973 to 1997 found that viruses accounted for only 20% of the outbreaks in which an agent was identified, mostly due to the HAV (Sivapalasingam *et al.* 2004). Since then, improvements in diagnostics have led to a surge in reported NoV outbreaks. The NoV is now widely viewed as the leading cause of foodborne illness and is likely to be a much larger contributor to produce-associated outbreaks (Widdowson *et al.* 2005; Berger *et al.* 2010). Newell *et al.* recognize that awareness and surveillance of viral foodborne pathogens remains poor but emphasis is only placed on the HAV, the NoV, the rotavirus and the SARS (Newell *et al.* 2010). Ahmed *et al.* investigated a NoV global prevalence in gastroenteritis and classified NoV as a key gastroenteritis pathogen associated with almost

20% of all cases of acute gastroenteritis (Ahmed *et al.* 2014). Verhoef *et al.* presented NoV increase in 2006 compared to 2002, in the Netherlands, attributing this increase to different/new variants and different circumstances (Verhoef *et al.* 2008).

Viruses cannot grow in or on food but may sometimes be present on fresh produce as a result of faecal contamination (Seymour and Appleton 2001). This contamination can occur either pre- or postharvest (Beuchat and Ryu 1997; Beuchat 2002; Carter 2005). Preharvest sources include soil, faeces, irrigation water, reconstituted fungicides and insecticides, dust, insects, inadequately composted manure, wild or domestic animals and human handling. Human handling can contribute to postharvest contamination along with harvesting equipment, transport containers, insects, dust, rinse water, ice, transport vehicles and processing equipment (Beuchat 2002).

This review suggests that outbreaks linked to fresh produce occur especially during the spring months. Nevertheless, the transmission of the NoV occurs yearly but with a higher incidence of disease during the winter months and in temperate climates (Schmid *et al.* 2007). Over 80% of all foodborne outbreaks occur from November to April. People can get NoV illness many times during their lifetime, and outbreaks can affect people of all ages and in a variety of settings (ProMed).

However, the symptoms of the disease reported in most viral outbreaks linked to fresh produce consumption were similar and were described as 'mild' gastroenteritis with clinical features consistent with the NoV and the HAV. The NoV was first recognized in association with point-source outbreaks of gastroenteritis, and such outbreaks remain the most common situation in which the NoV has been implicated as an etiologic agent (Treanor and Dolin 2005).

There have been reports of outbreaks where the NoV has been epidemiologically associated with various items of fresh produce, such as washed salads, imported frozen raspberries, green salads, fresh-cut fruits and potato salad (Harris *et al.* 2003). Also, the HAV outbreaks associated with fresh produce, particularly soft fruits and salads, have been reported by several countries. Iceberg lettuce (Mei Soon *et al.* 2012) strawberries (ProMED-mail) (Hutin *et al.* 1999), diced tomatoes (ProMED-mail) (Williams *et al.* 1994; Wadl *et al.* 2010) and salad items (Pebody *et al.* 1998; Nygård *et al.* 2001) have all been implicated. Fresh produce contributes to the transmission of viral infections. There is a lack of information on the survival of viruses on fresh produce related to shelf life and types of packaging. Information is also lacking on the efficiency of current washing and decontamination processes for the removal of viruses. Studies are therefore required to provide this information for the NoV, the NLVs and the HAV in particular. Foodborne outbreaks related to fruit and vegetable products are probably mainly transmitted via two routes. These products can be contaminated by preharvest manipulation (contaminated irrigation water) or by postharvest contamination (infected food handlers, contaminated equipment and process water used). Improving, the understanding of the impact that the fresh produce consumption has on foodborne disease, is an important step towards finding ways to mitigate the risks. At a time, when fresh produce production is predicted to increase both the frequency and the intensity of viral outbreaks linked to fresh produce consumption in many regions, understanding and reducing the impact of these events is vital not only for the health of a majority of people, but also for the growth and development of fresh produce production.

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Conflict of Interest

None.

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