Food safety issues in fresh produce: bacterial pathogens, viruses and pesticide residues indicated as major concerns by stakeholders in the fresh produce chain

S. Van Boxstael[a], I. Habib[a,b], L. Jacxsens[a,d], M. De Vocht[a,c], L. Baert[a], E. Van De Perre[d], A. Rajkovic[a], F. Lopez-Galvez[a], I. Sampers[a,e], P. Spanoghe[f], B. De Meulenaer[d] & M. Uyttendaele[a]

[a] *Laboratory of Food Microbiology and Food Preservation, Faculty of Bioscience Engineering, Ghent University, Coupure links 653, B-9000 Ghent, Belgium;*

[b] *Division of Food Hygiene and Control, Department of Nutrition, High Institute of Public Health (HIPH), Alexandria University, 165 El-Horrya Avenue, Alexandria, Egypt;*

[c] *Department of Communication Science, Faculty Political and Social Sciences, Ghent University, Korte Meer 7-11, Ghent, Belgium;*

[d] *Research group Food Chemistry and Human Nutrition, Faculty of Bioscience Engineering, Ghent University, Coupure links 653, B-9000 Ghent, Belgium;*

[e] *Research Group EnBiChem, Department of Industrial Engineering and Technology, University College West-Flanders (Howest), Graaf Karel de Goedelaan 5, B-8500 Kortrijk, Belgium;*

[f] *Laboratory of Crop Protection Chemistry, Faculty of Bioscience Engineering, Ghent University, Coupure links 653, B-9000 Ghent, Belgium.*

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* **Corresponding author.** Mailing address: Laboratory of Food Microbiology and Food Preservation, Faculty of Bioscience Engineering, Ghent University, Coupure links 653, B-9000 Ghent, Belgium. Phone: +32 09 264 93 95. Fax: +32 09 225 55 10.

Electronic mail address: sigrid.vanboxstael@ugent.be

Abstract (word count = 400)

In January 2011, a workshop was organized by the EU FP7 Veg-i-Trade project to capture opinions of stakeholders on food safety issues in the global fresh produce supply chain. Food safety experts from various stakeholder types in the farm-to-fork chain were represented: farmer related organizations (n=6), fresh produce processing and trading companies (n=17), retail (n=3), consumer organizations (n=2), competent authorities (n=7) and lastly research institutes and universities (n=19). The experts were grouped in nine discussion groups per type of stakeholder and asked to rank food safety issues via a scoring approach according to perceived importance from their stakeholder type point of view. Also information sources for opinion making, appropriate food safety control measures and perceived contextual factors increasingly challenging governance of food safety in fresh produce were ranked according to perceived importance. Although some differences were noted between opinions of the different stakeholders, there was in general an agreement on the main priorities in food safety of fresh produce. Bacterial pathogens were overall considered to be the most important food safety issue for fresh produce, followed by foodborne viruses, pesticide residues and mycotoxins. Alert systems such as the European Commission's Rapid Alert System for Food and Feed (RASFF) were considered as the most important source of information of food safety issues, followed by reports of international organizations (e.g. WHO, EFSA), legislative documents (e.g. EU legislation), national reports (e.g. on monitoring hazards, foodborne outbreaks) and exchange of information between people (informal contacts). Concerning the control measures, the application of good agricultural practices (GAP) was identified to be the most important control measure to assure the safety of fresh produce, followed by the application of good hygienic practices (GHP) and the certification of food safety management systems (FSMS). Increasing international trade and globalization were overall expected to have a large impact on food safety in fresh produce. Other contextual

factors perceived to be important were the food safety policies by governments and the (lack of) food safety knowledge by consumers and other stakeholders of the fresh produce supply chain. Although the various stakeholder groups may conceive issues differently from their proper position in the fresh produce supply chain, no deep disagreements emerged. This type of workshop enhances interaction and communication between stakeholders and contributes to a better understanding of each other's concerns, constraints and motivating interests to deal with the food safety of the increasingly complex and globalized fresh produce supply chain.

Key words

discussion group, fresh produce, food safety issue, control measures, contextual factors, information source

1. Introduction

Fresh produce is an important part of a healthy diet. Its consumption is known to have a protective health effect against a range of illnesses such as cancers and cardiovascular diseases (Block, Patterson, & Subar, 1992; Steinmetz & Potter, 1996; Joshipura et al., 2001). In more than twenty countries (e.g. Canada, the US, Peru, Japan, Brazil and Belgium), fresh produce consumption is encouraged by governmental health agency campaigns. They recommend to consume at least five daily servings of fruit and vegetables (Abadias, Usall, Anguera, Solson, & Vinas, 2008). Despite the beneficial health effects of fresh produce, there is a growing awareness concerning its microbial and chemical food safety (Lynch, Tauxe, V, & Hedberg, 2009; Strawn, Schneider, & Danyluk, 2011). Diseases linked to the sporadic presence of microbial hazards such as *Salmonella* spp., verotoxin producing *Escherichia coli* (VTEC) and norovirus (NoV) increasingly support this allegation (Sivapalasingam, Friedman, Cohen, & Tauxe, 2004; FAO/WHO, 2008; Berger et al., 2010). In the EU in 2009 and 2010, respectively 4.4% and 10% of the foodborne verified outbreaks were linked with the consumption of vegetables, fruits, berries, juices (and products thereof) (EFSA/ECDC, 2012). Other examples concern large outbreaks reported in 2011 such as the VTEC O104:H4 outbreak in Germany) (> 4000 affected persons, including 50 deaths) most likely due to the consumption of contaminated sprouted fenugreek seeds, and the *Listeria monocytogenes* outbreak in US (> 135 affected persons, including 30 deaths) due to consumption of contaminated cantaloupe melons (WHO, 2011b; ProMED-mail, 2011). Such outbreaks have besides very severe consequences for public health also a significant economic impact (Calvin, Avendano, & Schwentesius, 2004; WHO, 2011a). Other food safety issues such as pesticide residues, antimicrobial resistance, wax coatings, nanomaterials and genetically modified organisms are increasingly becoming a concern for the fresh produce supply chain (Tait & Bruce, 2001; Magnuson, Jonaitis, & Card, 2011; Domingo & Gine Bordonaba, 2011). Hence, assuring the safety of fresh produce and alertness to maintain consumer trust in fresh

produce as a healthy food is of paramount importance for stakeholders. This is a challenging task in an increasingly globalized and more complex fresh produce food supply chain. It implies a shared responsibility of the stakeholders within the farm to fork continuum (producers, processors, trading companies, retailers and consumers) and those closely involved in supporting food safety in the supply chain (competent authorities, industry associations, food scientists). Several studies measured the perceptions of consumers on various aspects of food safety (Sparks & Shepherd, 1994; Grunert, 2005; Tonsor, Schroeder, & Pennings, 2009; Nielsen et al., 2009; Soon-Mi et al., 2011). A limited number of studies on opinions of key stakeholders (experts) on food safety policy are available (van Kleef et al., 2006; Sargeant et al., 2007). However, to the authors' knowledge, a survey with farm-to-fork key stakeholders on priorities and challenges on the safety of the fresh-produce chain is lacking. In the present study it was the objective to capture the opinions of food safety experts and perceived importance for public health, economic impact, consumer trust, etc. according to their stakeholder type point of view and their position as an actor within or associated to the fresh produce supply chain with regard to four topics: i) food safety issues, ii) appropriate control measures to keep the fresh produce safe, iii) perceived contextual factors impacting on the food safety of fresh produce and iv) information sources for stakeholders to get informed about food safety. Data collection for each of the topics was performed via discussion groups containing food safety experts grouped per type of stakeholder: farmer related organizations, fresh produce processing and trading companies, food safety authorities, food science researchers, retailers and consumer organizations. The obtained information within our study gives insight into the current food safety priorities and challenges of the fresh produce chain and provided an opportunity to exchange opinions between various stakeholders of the fresh produce chain.

2. Materials and Methods

2.1. Participants and procedure

A total of 54 international experts participated (75 were initially invited) to a workshop that was held on January 28th, 2011 at the Faculty of Bio-Science Engineering, Ghent University (Belgium). The participants all have a background in food safety and were recruited based on their activities in the fresh produce supply chain and/or involvement with the EU FP7 project Veg-i-Trade. Representatives from companies/organizations/institutions located in nine different countries worldwide participated. The food safety experts were divided in nine groups of five to seven persons based on their expertise: one group with experts from fresh produce farmer related organizations [*primary production*], three groups with food safety experts of fresh produce processing and trading companies [*industry*], three groups with food safety scientists from universities and research institutes [*scientists*], one group with experts from food safety authorities [*authorities*] and one group containing food safety experts from retail and consumer organizations [r*etail/consumer organizations*]. The number of participants within each group and the countries in which their affiliated companies/institutions/organizations are located is presented in Table 1. Nine separate discussion tables were installed in a large meeting room. Each table was attended by the members of a specific discussion group and a moderator of the scientific research staff of the Association Ghent University (AUGent). The group discussions (in English) were run according to a standardized procedure. To facilitate a common starting point, the concepts and a list of choices of i) fresh produce food safety issues and ii) information sources were explained to them and subsequently two alphabetically ordered short lists containing respectively 16 food safety issues (see table 2a) and 13 information sources (see table 2b) were introduced by a AUGent researcher via a PowerPoint presentation. A food safety issue was defined in a broad sense as ‘a concept that is wider than the definition of a food safety

hazard by the Codex Alimentarius (biological, chemical or physical agent in a food, or the condition of, with the potential to cause an adverse health effect (Codex Alimentarius, 1997) and included also health, quality and emerging issues. An information source was defined as 'a source of information (e.g. observations, people, reports, organizations) used for food safety opinion making'. The lists with topics were drawn up from beforehand by AUGent researchers based on grey and scientific literature : food safety issues (EC, 2010; Baert et al., 2011a), control measures (Jacxsens, Devlieghere, & Uyttendaele, 2009), information sources (EFSA, 2011a) and contextual factors (Baert et al., 2012; Noteborn & Ooms, 2005). After introduction of the short lists, the following questions were asked to each discussion group '*Please rank the 5 most important food safety issues according to your stakeholders group (1 = most important, 2=second most important,…)' and 'Please rank the 5 most important information sources for making up your opinion on the food safety issues by your stakeholders group (1 = most important, 2= second most important,..).* Thus each stakeholder type was deemed to discuss and base their ranking upon perceived importance from their position and job experience point of view involved or associated to the fresh produce supply chain (e.g. as a scientist, manager running a business or decision makers from competent authorities). The groups were allocated 45 minutes for this group discussion. The moderators from AUGent noted down the consensus Top 5 and also the opinions of the different members of each discussion group. This procedure was repeated two times for the two remaining other topics i.e. i) control measures for assurance of the safety of fresh produce (15 items, see table 2c) and ii) contextual factors affecting the safety of the fresh produce chain (15 items, see table 2d). A control measure was defined as 'a measure of managerial and/or technical nature taken to control food safety hazards along the food chain'. A contextual factor was defined as a technical, societal, economic, political or legislative factor inside or outside the supply food

chain having a direct or indirect impact on the safety of the food. Each of the discussions for the latter two topics lasted approximately thirty-five minutes.

2.2. Data analysis

The top 5 for the four topics (food safety issues, information sources, control measures and contextual factors) by the nine groups were collected. Subsequently an overall ranking of the items based on equal weighting of the opinions of each type of discussion group was calculated (five types: primary production, industry, authorities, scientists, retail/consumer organizations). In summary, a weighting factor (WF) equal to 5, 4, 3, 2, 1 was assigned to the items that were selected for the positions 1, 2, 3, 4, 5 respectively in the top 5's. Items that did not occur in any Top 5, received a WF=0. Next, for each item, a score was calculated as the total sum of WFs and WFs/3 depending on whether the item occurred in a top 5 of a single [primary production, authorities, retail/consumer organization] or threefold [industry, scientists] represented stakeholder group type, respectively. The resulting sum for each item was divided by five, which resulted in an average importance score between 0 (least important item) and 5 (most important item). The approach of assigning a WF or WF/3 depending on whether a group was single represented or threefold allowed to obtain an average importance score for each item reflecting equally the ranking of each of the five stakeholder group types.

3. Results

3.1. Fresh produce food safety issues

Among the list of predefined food safety issues, the items bacterial pathogens (e.g. *Salmonella*, VTEC), foodborne viruses (e.g. Norovirus, Hepatitis A) and pesticide residues (e.g. chlormequat) were identified as the three most important concerns (Table 2a). Next, mycotoxins (e.g. aflatoxins, patulin) and process contaminants (e.g. disinfection by-products trihalomethanes) belonged also to the overall top 5. A common criterion for all the stakeholder groups for prioritization of the food safety issues concerned the estimated health

risks of the issues/hazards for the consumer. However, also several other arguments were noted such as the potential economic implications e.g. recall costs or overall decrease in sales in case of foodborne disease outbreaks reported in the broad media [*primary production, industry*]. Also whether the specific issues are well covered by EU/national legislation was a motivation by some participants to attribute an important role to a hazard. For hazards for which specific EU criteria are in place (e.g. pesticide residues on fresh produce (EP and Council, 2005), Salmonella in ready-to-eat pre-cut fruits and vegetables (EC, 2005), the attributed importance was deemed to be higher [*industry*]. Other ranking argumentations were related to food safety concerns by consumers and various non-governmental organizations, playing an important role as a factor in competitiveness between companies [*industry, retail*]. This argumentation was in particular cited by several participants [*primary production, industry*] for the hazard pesticides but remarkably, pesticide residues were not selected as a Top 5 item by the retail/consumer organization group. Other participants emphasized that '*particular attention should go to control of residues of non-authorized pesticides on vegetables and fruits that are imported into the EU*' [*authorities*]. Some participants [*scientists*] were of the opinion that 'mycotoxins represent an emerging issue for fresh produce'. They argued that '*although the current knowledge on mycotoxins on fresh produce is limited, the food safety risk may be larger than is currently known'*. It was also mentioned that '*due to the trend of using less fungicides, the amount of mold growth on fresh produce might increase and hereto linked the potential mycotoxin production'* [*scientists*]. Related to process contaminants (ranked as fifth important item), the example of disinfection by-products (e.g. trihalomethanes) that are formed during treatment with chlorine based disinfectants of process water to control microbial contamination of the water was noted. The motivation for not taking up genetically modified foods (GMO's) in the top 5's was that according to some participants [*industry, scientists*] '*the majority of GMO's should not be*

considered as a food safety problem'. For nanomaterials and antimicrobial resistance, although the potential severity of it were deemed not to be underestimated, participants found it *to early to take it up in the top 5* [s*cientists*]. It was emphasized that more scientific research and risk assessments on these topics are required. The issue was also raised that *despite the chemical and microbiological food safety risks linked to the consumption of fresh produce, the main risk may be the insufficient consumption of nutritional healthy fruits and vegetables and leading to a higher risk of heart diseases and cancer* [*industry*].

3.2. Information sources

Alert systems were overall identified as the most important information source for food safety (table 2b). Although several rapid alert systems are frequently consulted such as the Rapid Alert System for Food and Feed (RASFF), ProMED- Mail and INFOSAN, most participants considered the European Commission's RASFF as the most important system to maintain up to date with the latest evolutions on food safety. International reports were also found to be a major information source by all groups except by the fresh produce processing groups. Most of the participants referred to documents of the European Food Safety Authority (EFSA) but also to reports from the World Health Organization (WHO) and Food and Agriculture Organization (FAO). Besides the international reports, also national reports such as surveillance reports of national public health authorities or monitoring reports of food safety agencies are often consulted. However, it was argued that '*the accessibility of these reports is limited because they are generally only published in the national languages*' (in contrast to international reports that are mainly written in English) [*authorities*]. Legislation on food safety is considered to be an important information source by the industry and the retail/consumer organization groups. The national guides to good practices elaborated by industry associations as an incentive to comply with the Hygiene Regulation (EC) 852/2004 (EP and Council, 2004) were also considered as "legislative documents" because '*they*

contain an up-to-date overview of the legislation' [*industry*]. Several differences between the selection preferences for the information sources among the different stakeholders were observed. For example scientific literature was selected as a top 5 information source by the three scientists groups and the food safety authorities group but not by any of the other groups while the item 'industry-own-information' and quality standards were only selected by the primary production and/or processing industry groups. Concerning scientific articles, it was noted that '*because of the long time period between submission and acceptance, the availability of this information is late'* [*scientists*]. Besides the 'paper media', 'spoken media' such as informal face-to-face contacts and networks were also considered to be an important information source by several participants [*scientists*].

3.3. Control measures

The application of "Good Agricultural Practices" (GAP) emerged as the main control measure to control food safety hazards within the fresh produce supply chain (Table 2c). Next, the application of "Good Hygienic Practices" (GHP) was found to be the overall second most important measure). GHP distinguishes itself from GAP being applicable to the whole farm to fork continuum and not to the production process. The application of certified food safety management systems (FSMS) was overall ranked at the third place. Certification of food safety management systems is an additional step to the application of GAP and/or GHP implemented in these systems. Two main arguments were put at the fore to select this item. The first was that *'the verification and certification of food safety systems by an outsider, a third party, results in better food safety management systems and subsequently in a safer food chain'* [*authorities, industry*]. The second argument was that '*compliance with certified food safety management systems is from a commercial point of view very important for gaining consumer trust and an aspect of brand or supplier image protection'. It is considered to be a license to trade/sell'* [*retail*]. The performance of microbiological and chemical analyses on

fresh produce (product control) was selected as a top 5 item by four discussion groups [*primary production*, *retail/consumer*, *industry*, *authorities*]. Some participants noted that '*product control will become more important when the proportion of imported products compared to local products will increase'* [*authorities, primary production*].

3.4. Contextual factors

In the farm to fork continuum, food safety is influenced by several contextual factors within and outside the food chain among which globalization and the growing international trade was attributed the highest impact (table 2d). Arguments for this selection were that '*fresh produce production, processing and trade within a globalized context puts pressure on the stakeholders from the fresh produce chain in several ways, for example on the price setting (e.g. raw materials)*' [*primary production*] but also on '*the demands for food safety of products sourced globally*' [*industry, authorities*]. Several participants argued that '*within a globalized world, the assurance of food safety will be a greater challenge'* [*authorities*]. The impact of public health policy, food safety policy and agriculture policy by governmental competent authorities (governmental policy) was found to be the overall second most important contextual factor. The item knowledge on food safety was also found to be a major contextual factor and was interpreted in a broad sense by the participants: by some discussion groups [*authorities, consumer organization/retail*], it was mainly seen as the knowledge (or the lack of knowledge) by consumers but by other discussion groups it was interpreted as the knowledge on food safety by the fresh produce processing industry and scientists. Some participants argued that '*the more we know about food safety, the more food safety issues will arise'* [*primary production*]. The demand of consumers as a pressure on food safety was identified as an important contextual factor by three groups [*primary production, industry, scientists*] among which primary production identified it as the most important factor while food safety reports in the popular news media were selected as a top 5 item by only one

discussion group [*industry*]. It was noted that consumers can be informed by a very broad range of channels (broad news media), that *these channels are not always providing science-based information, but may have a major influence on the consumer's opinions and therefore impact on the economic activities of various stakeholders* (the example of yearly reports on pesticides by various non-governmental organizations was given) [*primary production*]. Besides this, *these reports may also influence the food safety policy by processing and retail companies e.g. on frequency and type of hazards that are analyzed* [*industry*]. Availability of alternative processing and storage techniques was identified by two discussion groups as the most important contextual factor [*retail/consumer organization*, *industry*]. The argumentation for this was that *as conventional processing techniques like thermal heating can influence product quality of fruits and vegetables, there is an ongoing search for alternative techniques*. In fact, it was the opinion of some participants that *these new (non-thermal) processing techniques, for example high pressure or oscillating magnetic fields, can have a positive effect on the food safety output, but also a negative effect when the obtained (estimated) reduction in microbial load is not very well assessed and validated* [*industry*]. The main argument for selecting the item climate change as a top 5 contextual factor by five discussion groups concerned the relation between climate change and water quality and availability. The example of the increased microbiological health risk after water floods was given as the floods might impact negatively on the microbiological quality of the irrigation water [*authorities*].

4. Discussion and conclusion

This meeting organized by EU FP7 Veg-i-Trade on January 28th 2011 provided an opportunity to capture the opinions from various key stakeholders in the fresh produce supply chain on four food safety related topics: food safety issues, control measures, contextual factors and food safety information sources. During this workshop, experts dealing with the assurance of food safety in the field (*primary production*, *industry* and *retail*), performing research on it (*scientists*), developing food safety policy and enforcing legislation (*authorities*) or assisting consumers (*consumer organizations*) participated. The experts all have a scientific background but operate within different types of organizations. The procedure that was applied during the workshop consisted of offering pre-defined lists containing items to rank according to importance as a starting point for the group discussions. This quantitative approach is different from the one in frequently organized open sessions or working groups designed to capture the opinions of experts in a qualitative manner resulting in consensus reports (Havelaar et al., 2010; EFSA, 2011a). Although the experts originated from companies/institutions/organizations located worldwide (nine different countries), 85% lie in the EU from which 57% in Belgium. Consequently, the results and opinions should be viewed and interpreted mainly from a European point of view. Besides this, the conclusions and rankings are representative for the participating farm-to-fork fresh produce stakeholders. Although it can be expected that the overall conclusions would be identical with a similar setting of workshop participants, deviations of the rankings are likely.

It can be assumed that farmers, traders and processors would use criteria for ranking food safety items based on socio-economic impact and client customer relationships whereas consumer organizations and also retailers would primarily take into account consumer trust and potential negative effect for the business as criteria. On the other hand it can be expected that competent authorities will put the focus on public health although economic impact is

also a criterion to be taken into account. Scientists would be expected to focus mainly on public health risk based on the currently available scientific knowledge and risk assessments. During the discussions it was observed that, although it was not specifically asked for it, criteria for prioritization of food safety issues were multidimensional, consisting of a broad range of scientific and other arguments (see 3.1) and were inspired on several information sources (see 3.2). In general, limited disagreements emerged on the ranking of the food safety issues. A similar observation was done in a study by Van Kleef et al. (2006) who found also limited differences in the way food safety experts from industry, government, consumer organizations, research institutes and universities perceive different aspects of food safety management. They observed the experts more as a homogenous group, this in contrast to consumers which they considered as a heterogeneous group (van Kleef et al., 2006).

Rapid Alert Systems such as the Rapid Alert Systems for Food and Feed of the European Commission (RASFF) or ProMED-mail were overall identified as the most important information source for staying up to date with the most recent evolutions on food safety of fresh produce. These systems contain two types of information: foodborne disease outbreaks and non-compliances with criteria or standards. In order to obtain a better understanding and interpretation of the obtained results, the EC RASFF databank was consulted and the share of notifications by hazard type (e.g. bacterial pathogens, pesticide residues,...) for three categories 'fruits and vegetables', 'herbs and spices' and 'nuts, nut products and seeds' calculated for the period 2008-2010 and 2011 (Table 3). Bacterial pathogens were identified by the discussion groups as the most important challenge for fresh produce. However, Table 3 shows that for the category fruits and vegetables (period 2008-2010), only a moderate share of notifications (3.9%) is due to bacterial pathogens while the total number of notifications for pesticide residues is about tenfold larger (39.2%). In the category herbs and spices, bacterial hazards represent a larger share of the notifications

(24.9%) compared to pesticide residues (12.1%). For viruses, considered as the second most important concern by the discussion groups, the number of alerts related to the categories fruits and vegetables and herbs and spices is very low representing 1.2% and 0.0%, respectively. One of the explanations why experts might classify bacterial pathogens and viruses as the relatively most important concerns is because if an outbreak occurs, consequences are in many cases quite severe having both from a human health point of view and economic point of view (Roberts, 2000; Abe, Yamamoto, & Shinagawa, 2002).

Alert systems contain also information on non-compliance of food products with criteria (e.g. *Salmonella* in pre-cut fruit (EC, 2005); pesticide residues on vegetables (EP and Council, 2005) or standards (e.g. on sanitary aspects). If no criteria are in place, it is more unlikely that the presence of a certain type of hazard will be reported to a rapid alert system unless it is linked to a large outbreak. This may be because these criteria serve as a reference point on how to proceed in case of a non-compliance. But before official criteria can be put in place, standardized detection methods need to be available and require also an in-depth risk assessment of the hazard. For bacterial pathogens (e.g. *Salmonella*) several standardized procedures are available while for foodborne viruses such as NoV, detection methods (RT-PCR) have strongly improved during the last decade. However, although NoV genomic sequences have been regularly detected in fresh produce in several countries, the actual risk from NoV positive produce is still unknown (Baert et al., 2011b). In the case of parasites, standardized methods for detection in fresh produce are currently not available (Skotarczak, 2009) and they were also not notified to the RASFF-systems in the categories fruits, vegetables and herbs (table 3). These may be one of the elements why although several parasite outbreaks (e.g. Cryptosporidium, Cyclospora) linked to fresh produce are described (Sivapalasingam et al., 2004; EFSA, 2010) the importance of parasites for fresh produce was estimated to be low by the experts during our workshop.

Besides the availability of standardized detection methods and criteria, whether a hazard is well known and/or assessed appears also to be an important driver to attribute importance to food safety issues. This can be illustrated via the example of mycotoxins.

Table 3 shows a very high share of notifications on mycotoxins (mainly aflatoxins and ochratoxin A) in the categories nut and nut products (83.7%), fruits and vegetables (18.5%) and herbs and spices (36.3%). The notifications of the latter two categories are almost entirely linked to the dried plant products such as dried figs, raisins, chilli powder, paprika power and not linked to *fresh* vegetables, fruits and herbs, being the subject of the workshop. During the workshop, mycotoxins were considered by the scientists as an important and emerging issue for fresh produce (e.g. alternariol on tomatoes) while by the fresh produce processing experts the importance of mycotoxins was estimated as low which may be due to their (self-declared) limited knowledge of the hazard mycotoxin on fresh produce In the scientific literature some studies indicate the potential presence of mycotoxin producing fungi on fruits, fruit salads and vegetables (Tournas & Katsoudas, 2005; Tournas, Heeres, & Burgess, 2006; Ostry, 2008). However, scientific literature, international and national reports were not selected as an important information source by the experts from fresh produce processing and trading companies who noted to consult other information sources (rapid alert systems, legislation, industry own information and quality standards) containing currently limited information on mycotoxins on fresh produce. This finding confirms the importance of two way risk communication activities, such as this discussion forum, on hazards and risks to disseminate the information on emerging issues in a timely way (EFSA, 2009).

Concerns by consumers (lay people) and various NGOs that impact on consumer trust were also noted to impact the prioritization order of the experts. In literature, a distinction is made between objective food safety and subjective food safety. Objective food safety by scientists and food experts refers to the technical assessment of the risk of consuming a

certain food while subjective food safety is in the mind of the consumer (Grunert, 2005). It is widely acknowledged that objective and subjective safety (or risk) deviate in many cases (Sparks & Shepherd, 1994; Hansen, Holm, Frewer, Robinson, & Sandoe, 2003). The main concerns of EU consumers are pesticide residues in fruits, vegetables and cereals (31% very worried) and in a lesser degree bacterial pathogens and viruses (22% very worried) (EC, 2010). Man-made chemicals such as pesticides are regarded as 'unnatural' by consumers and thus more unacceptable while bacterial pathogens and viruses are more accepted as a fact of life as long as death or permanent harm do not occur (Hansen et al., 2003; Havelaar et al., 2010). Despite the larger number of RASFF alerts on pesticide residues (see above and table 3), the experts during our workshop assessed bacterial pathogens and viruses as more important food safety issues than pesticide residues. The experts are aware of the fact that the Maximum Residu Limits (MRL's) do not correspond with toxicological safety but as today's focus by many stakeholders (for a range of reasons such as competiveness, trend towards natural,…) is on pesticide residues also indirect pressures such as subjective food safety by consumers may play a role in the expert's rankings.

Several contextual factors affect food safety from which some increase and others decrease the risk (Havelaar et al., 2010). Among the discussed contextual factors during the workshop, globalization and the growth of international trade, governmental policy and also lack of food safety knowledge were perceived as having the largest impact on the food safety of fresh produce. Globalization is resulting in a more complex food chain and greatly increases the challenges for food safety (Lineback, Pirlet, Van Der Kamp, & Wood, 2009; Havelaar et al., 2010; Quested, Cook, Gorris, & Cole, 2010). The multiple outbreaks linked to imported products reported globally reflect these challenges (e.g. Hepatitis A outbreak (2003) in the US linked to green onions imported from Mexico (Wheeler et al., 2005), *Salmonella* Senftenberg outbreak (2008) in the US linked to imported Jalapeño and Serrano peppers from

Mexico (Behravesh et al., 2011), *E. coli* O104:H4 outbreak (2011) linked to sprouted fenugreek seeds imported from Egypt to France and Germany in 2011 (EFSA, 2011b) and the Shigella (2011) outbreak in Norway linked to basil imported from Israel (Guzman-Herrador et al., 2011). The importance of the policy by governmental agencies on food safety policy was also recognized by the experts. Inspection programs will contribute to the food safety of the chain. Besides this, information campaigns on how to handle and wash vegetables and fruits (e.g. the vegetable best served washed campaign by FSA (FSA, 2011)) are targeted to increase awareness and food safety knowledge by consumers. However, in order information campaigns to be successful, a whole range of aspects such as consumer knowledge or socio-cultural factors and identification of the appropriate media needs to be taken into account (Jacob, Mathiasen, & Powell, 2010). Lack of food safety knowledge can in general be divided into two domains : i) research gaps and ii) lack of implementation of food safety knowledge by the different stakeholders. Related to the first domain, several research gaps of food safety of fresh produce were identified more than a decade ago (De Roever, 1998) and since then research knowledge increased strongly on topics such as pathogen/produce interactions and ecology (Heaton & Jones, 2008; Lynch et al., 2009; Critzer & Doyle, 2010). Related to the second domain, as mentioned above, several initiatives by governments and other organizations were initiated to increase the food safety knowledge of the consumers but also of producers, processors, traders and retailers (e.g. training programs, self-checking guides

The crucial role of a good agriculture system (implementing general practices to improve the food safety of fresh fruits and vegetables in the harvesting, sorting, cultivation and storage) to prevent contamination is generally recognized (Beuchat & Ryu, 1997; De Roever, 1998; da Cruz, Cenci, & Maia, 2006). Also the application of good hygienic practices be it by workers on the field, by personnel from processing industry or the consumers is also considered to be a key step in assuring the safety of fresh produce (De Roever, 1998;

Brackett, 1999). Within our workshop, An integrated food safety approach containing the application of good agricultural practices (GAP) and good hygienic practices (GPH) were also identified as the most important control measure strategy. Besides these two important control measures, certification of food safety management systems by third-parties was also considered to be an important control measure for assuring food safety and quality on the one hand but also as a license to trade by the food retailers on the other hand. Third party certification (e.g. Global GAP) is in general accepted to increase food safety because the auditors are independent and have no stake in the outcome of the transaction (Hatanaka, Bain, & Busch, 2005).

Several monitoring programs are in place by competent authorities, industry, farmer organizations and traders. By the scientists, product control was not considered as an important control measure, suggesting that they are familiar with the limitations related to sampling and product analysis from a statistical point of view, in particular for microbial hazards (Pinto, Costafreda, I, & Bosch, 2009; Jongenburger, Reij, Boer, Gorris, & Zwietering, 2011). Other stakeholders such as the competent authorities were convinced that because of growing international trade, border controls of product will become increasingly important as an additional measure to assure food safety. A regulatory framework to operationalize this concern is already in place in the EU: currently, the European Commission performs risk analysis, leading to an increased border control of imports depending upon their origin. Examples are an increased analysis frequency on *Salmonella* on basil from Thailand or on pesticide residues on tomatoes originating from Turkey (EC, 2009).

In conclusion, within our study, opinions of key stakeholders of the fresh produce chain on food safety issues, appropriate control measures, contextual factors and information sources were captured. Small groups of different stakeholder types among the fresh produce farm to fork chain were invited to discuss and obtain a consensus in ranking of items.

The fresh produce chain is complex and is increasingly being challenged by several contextual factors among which globalization and international trade emerged as the most important one. An integrated farm to fork approach is of paramount importance to reduce fresh produce food safety risks as low as possible. With the focus on risk reduction and not elimination (because fresh produce concern raw agricultural commodities that do not receive treatment to eliminate pathogens) the application of good agricultural practices combined with good hygienic practices were confirmed to be among the main pillars for controlling the safety of fresh produce. The currently most important fresh produce issues are identified to be pathogens, viruses and pesticide residues while alert systems such as the European Commission's RASFF are the most often consulted information sources for forming food safety opinions.

Apart from the ranking and data collection of food safety issues, information sources, appropriate control measures and perceived contextual factors, this workshop enabled exchange of information between scientists, authorities and all actors in the fresh produce supply chain : concerns and experiences in food safety issues could be shared. This type of workshop enhances interaction and risk communication between stakeholders and contributes to a better understanding of each other's concerns, constraints and motivating interests to deal with the food safety of the increasingly complex and globalized fresh produce supply chain.

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Table 1. Number of experts in the discussion groups and the countries in which their affiliated companies/institutions/organizations are located

	N°[1]	BE[2]	ES[3]	FR[4]	NL[5]	UK[6]	EG[7]	IND[8]	NO[9]	SA[10]
Farmer related organizations	**6**	3			2				1	
Trade & processing industry group 1	**6**	4			1	1				
Trade & processing industry group 2	**5**	2	1		1				1	
Trade & processing industry group 3	**6**	4	1		1					
Retail/consumer organizations	**5**	5								
Food safety authorities[a]	**7**	4			1	1			1	
Scientists group 1	**7**	3		1	1		1			1
Scientists group 2[a]	**6**	2	1					1	1	1
Scientists group 3	**6**	4			2					

[1] Number of experts in the focus groups, [2] Belgium, [3] Spain, [4] France, [5] Netherlands, [6] United Kingdom, [7] Egypt, [8] India, [9] Norway, [10] South-Africa,

[a] focus group contains one expert affiliated to the European Commission.

Table 2. Top 5 by the nine groups and average weighted importance score for food safety issues, information sources, control measures and contextual factors

			Top 5 items								
	S[1]	**N°[2]**	**PrPr[3]**	**Ind1[4]**	**Ind2[4]**	**Ind3[4]**	**Re/Co[5]**	**FSA[6]**	**Sci1[7]**	**Sci2[7]**	**Sci3[7]**
a) ***Food safety issues***											
Bacterial pathogens	**4.8**	**9**	*1*	*1*	*2*	*1*	*1*	*1*	*2*	*2*	*1*
Viruses	**2.6**	**7**	*3*	*4*		*2*		*2*	*1*	*3*	*2*
Pesticide residues	**2.4**	**7**	*2*	*2*	*1*	*5*		*4*		*4*	*3*
Mycotoxins	**1.5**	**5**	*4*					*3*	*3*	*1*	*4*
Process contaminants	**1.0**	**2**		*3*			*2*				
Heavy metals	**0.8**	**5**	*5*	*5*			*5*	*5*	*4*		
Migrants from food contact materials	**0.7**	**2**					*3*		*5*		
Additives	**0.4**	**1**					*4*				
Allergens	**0.3**	**3**			*5*	*4*				*5*	
Physical hazards	**0.2**	**1**				*3*					
Quality and freshness of fresh produce	**0.2**	**1**			*3*						
Not a balanced and healthy diet	**0.1**	**1**			*4*						
Parasites	**0.1**	**1**									*5*
Antimicrobial resistance	**0**	**0**									
Genetically modified food	**0**	**0**									
Nanomaterials	**0**	**0**									
b) Information sources											
Alert Systems	**3.1**	**8**	*1*	*4*	*3*	*3*		*1*	*3*	*5*	*2*
International reports	**2.1**	**6**	*5*				*4*	*2*	*2*	*2*	*4*
Legislation on food safety and legislative documents	**1.7**	**3**		*1*	*1*		*1*				
National reports	**1.4**	**3**					*3*	*3*			*3*
Information exchange via face to face and informal networks	**1.3**	**3**			*4*		*2*			*1*	
Scientific Literature	**1.1**	**4**						*5*	*1*	*3*	*1*
Popular news media magazines	**1.0**	**3**	*2*						*5*	*4*	
Farmer/Industry Own information	**1.0**	**4**	*3*	*3*	*5*	*1*					
Food quality/safety conferences	**0.7**	**4**		*5*		*4*		*4*	*4*		
Quality assurance standards	**0.5**	**2**		*2*	*2*						
Professional Journals	**0.5**	**2**	*4*			*5*					
Education by training	**0.3**	**2**					*5*				*5*
Information by fresh produce stakeholder associations	**0.3**	**1**				*2*					

[1.] Average weighted importance score among the five stakeholder type groups (for calculation see material methods, score 0= least important; score 5 = most important), [2] N° Number of groups that selected the particular item in their top 5; [3] Farmer related organizations, [4] Fresh produce processing & trading companies group 1, 2 and 3, [5] Retail and consumer organizations, [6.] Food safety authorities, [7] Sci Scientists from universities and research institutes group 1, 2 and 3.

Table 2. Continued

			Top 5 items								
	S[1]	**N°[2]**	**PrPr[3]**	**Ind 1[4]**	**Ind 2[4]**	**Ind 3[4]**	**Re/Co[5]**	**FSA[6]**	**Sci 1[7]**	**Sci 2[7]**	**Sci 3[7]**
c) ***Control measures***											
Good agricultural practices	**3.9**	**8**	*1*	*1*	*2*	*1*		*1*	*1*	*1*	*2*
Good hygienic practices	**2.7**	**7**	*2*	*3*		*2*		*2*	*3*	*2*	*3*
Certification of food safety management systems	**2.2**	**6**	*5*		*4*	*4*	*1*	*3*		*4*	
Product Control	**1.5**	**4**	*3*	*5*			*3*	*5*			
Setting criteria/limits	**1.4**	**3**					*2*	*4*		*3*	
Good handling practices	**0.7**	**4**		*4*		*3*			*2*		*4*
Food safety/risk communication	**0.4**	**1**	*4*								
Tracking and tracing	**0.4**	**1**					*4*				
HACCP	**0.4**	**2**			*1*						*5*
Training and capacity building	**0.4**	**2**								*5*	*1*
Technical intervention	**0.3**	**2**		*2*		*5*					
Supplier selection	**0.2**	**1**			*3*						
Reflection and management	**0.2**	**1**					*5*				
Research & risk assessment	**0.1**	**2**			*5*				*5*		
Process control	**0.1**	**1**							*4*		
d) Contextual factors											
Globalisation and International trade	**3.5**	**8**	*2*		*1*	*1*	*3*	*3*	*2*	*1*	*3*
Governmental policy	**1.8**	**3**					*2*	*2*	*3*		
Food safety knowledge	**1.6**	**8**	*3*		*2*	*4*	*4*	*4*	*4*	*5*	*4*
Consumer demand	**1.5**	**3**	*1*	*4*						*3*	
Availability of alternative production techniques	**1.4**	**3**		*1*		*5*	*1*				
Legislation and enforcement by government	**1.2**	**2**						*1*		*4*	
Climate change	**1.1**	**6**	*5*	*5*		*2*	*5*	*5*		*2*	
Economical/financial climate	**0.9**	**2**			*3*						*1*
Price of food material	**0.7**	**3**	*4*		*5*	*3*					
Eating habits	**0.3**	**1**							*1*		
Natural distasters	**0.3**	**1**									*2*
Alternative detection methods	**0.3**	**1**		*2*							
Changes in biodiversity	**0.2**	**1**		*3*							
Demography	**0.1**	**2**							*5*		*5*
Popular news media	**0.1**	**1**			*4*						

[1.] Average weighted importance score among the five stakeholder type groups (for calculation see material methods, score 0= least important; score 5 = most important), [2] N° Number of groups that selected the particular item in their top 5; [3] Farmer related organizations, [4] Fresh produce processing & trading companies group 1, 2 and 3, [5] Retail and consumer organizations, [6.] Food safety authorities, [7] Sci Scientists from universities and research institutes group 1, 2 and 3.

Table 3. Notifications to the EC RASFF system for the categories 'fruits and vegetables', 'herbs and spices' and 'nuts, nut products and seeds' during the period 2008-2010 and 2011

	Fruits and vegetables		**Herbs and spices**		**Nuts, nut products and seeds**	
	2008-2010 (n=1338)	**2011 (n=669)**	**2008-2010 (n=452)**	**2011 (n=197)**	**2008-2010 (n=1985)**	**2011 (n=522)**
Pesticide residues	39,2%	45,7%	12,1%	15,7%	0,5%	0,4%
Mycotoxins	18,5%	13,6%	36,3%	31,5%	83,7%	60,9%
Bacterial pathogens	3,9%	16,7%	24,9%	32,0%	3,6%	2,3%
Additives	9,0%	3,9%	0,6%	0,0%	0,6%	0,4%
Hygiene/quality hazard	12,5%	7,8%	5,3%	8,6%	5,3%	30,1%
Physical hazards	4,9%	2,1%	0,6%	0,5%	0,2%	0,0%
Heavy metals	1,8%	1,3%	0,0%	1,0%	0,0%	0,0%
Viruses	1,0%	1,2%	0,0%	0,0%	0,0%	0,0%
Chemical hazard	4,9%	3,0%	0,8%	0,5%	0,5%	0,6%
Parasites	0,0%	0,0%	0,0%	0,0%	0,0%	0,0%
Unautorized colour	0,0%	0,0%	15,4%	8,1%	0,3%	0,2%
Other	4,4%	4,6%	4,0%	2,0%	5,2%	5,2%
Total	**100,0%**	**100,0%**	**100,0%**	**100,0%**	**100,0%**	**100,0%**