SCIENTIFIC OPINION

Scientific Opinion on the risk posed by pathogens in food of non-animal origin. Part 2 (*Salmonella* and Norovirus in berries)[1]

EFSA Panel on Biological Hazards (BIOHAZ)[2, 3]

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ABSTRACT

Berries are a perishable food which can be consumed as fresh or minimally-processed as well as a frozen ingredient added to many foods. Strawberries, raspberries, blackberries and blueberries are the most commonly consumed in the EU. Risk factors for berry contamination by *Salmonella* and Norovirus were considered in the context of the whole food chain. Available estimates of the prevalence of these pathogens in berries were evaluated together with mitigation options relating to prevention of contamination and the relevance of microbiological criteria. It was concluded that each farm environment represents a unique combination of risk factors that can influence occurrence and persistence of pathogens in berry production. Appropriate implementation of food safety management systems including Good Agricultural Practices (GAP), Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP), should be primary objectives of berry producers. There is currently insufficient evidence to justify the establishment of microbiological criteria for *Salmonella* for fresh or frozen berries. Outbreaks associated with Norovirus in frozen raspberries and strawberries are an emerging public health risk, although it is not known if in these outbreaks contamination occurred at minimal processing or during primary production. It is currently not possible to assess the suitability of an EU-wide Norovirus Hygiene Criterion at primary production for raspberries and strawberries. Microbiological criteria for Norovirus in berries are useful for validation and verification of food safety management systems, including HACCP-based processes and procedures, and can be used to communicate to food business operators and other stakeholders what is acceptable or unacceptable, however there is insufficient data to provide a risk base for establishing a Process Hygiene and Food Safety Criteria for Norovirus in berries. Collection of appropriate data and subsequent risk-based development of microbiological criteria to support improved control of Norovirus in frozen raspberries and strawberries should be considered as a priority.

KEY WORDS

berries, frozen, microbiological criteria, microbiological risk factors, mitigation options, Norovirus, *Salmonella*

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SUMMARY

The European Commission asked EFSA's Panel on Biological Hazards (BIOHAZ Panel) to prepare a scientific Opinion on the public health risk posed by pathogens that may contaminate food of non-animal origin (FoNAO). The outcome of the first and second terms of reference, addressed in a previous Opinion, were discussed between risk assessors and risk managers in order to decide which food/pathogen combinations should be given priority for the other three terms of reference. This is the second Opinion out of five and addresses the risk from *Salmonella* and Norovirus in berries. The addressed terms of reference are to: (i) identify the main risk factors for berries, including agricultural production systems, origin and further processing; (ii) recommend possible specific mitigating options and to assess their effectiveness and efficiency to reduce the risk for humans posed by *Salmonella* and Norovirus in berries and (iii) recommend, if considered relevant, microbiological criteria for *Salmonella* and Norovirus in berries.

Berries, for the scope of this Opinion, are defined according to commercial production and consumption as small, spherical or ovoid, fleshy and juicy fruits. This food commodity is often consumed as a perishable product receiving no or only minimal processing. Berries are also consumed as highly processed products such as components of jams, preserves, heat treated fruit juices or purées and dried fruits which can be shelf-stable, having undergone heating or drying: such products are outside the scope of this Opinion. Despite the wide variety of plant species grown for berry production, the most important types for the fresh market in the EU are strawberries, raspberries, blackberries and blueberries. Berries can be produced by small herbaceous plants (e.g. strawberry), bushes (e.g. blackberry, blackcurrant, blueberry, gooseberry, raspberry) or small trees (e.g. mulberry, elderberry). Berries are produced using various systems, depending on the type of berry, the intended use (e.g. fresh market or for processing including freezing), the geographical origin and the economic choices of the growers. Plants can be grown in soil or soil-less cultures in protected environments or in open fields. Berries are harvested during the fruiting season. Those consumed fresh are usually manually harvested and, to avoid mechanical damage, can be directly picked and placed in their final packaging for sale to caterers or consumers. Berries for freezing can be either manually or mechanically harvested. The internal contents and juices of berries have generally a low pH and can contain antimicrobial phenolic compounds. After harvest, berries are sorted, packaged and stored. Berries may be subjected to minimal processing such as cleaning, cutting, mashing and washing as well as freezing. Fresh and frozen berries intended for sale are normally not subjected to physical interventions that will eliminate or substantially reduce the occurrence of *Salmonella* and Norovirus. There is some information on the risk factors and mitigation options for *Salmonella* and Norovirus contamination of strawberries and raspberries, but there is little or no information for other berries. A particular feature of berries is their widespread use as a frozen ingredient in many diverse food products and preparations. Mixing batches of frozen fruit, including mixtures of different berry species, can present difficulties in traceability.

For the identification of the main risk factors for *Salmonella* and Norovirus in berries, including agricultural production systems, origin and further processing, the BIOHAZ Panel concluded that the risk factors for the contamination of berry fruits at primary production with *Salmonella* are poorly documented in the literature, with limited available data, but are likely to include the following, based on what is known for other pathogens or other types of fresh produce: (1) environmental factors, in particular proximity to animal rearing operations and climatic conditions that increase the transfer of pathogens from animal reservoirs to berries; (2) contact with animal reservoirs (domestic or wild life) gaining access to berry fields; (3) use of untreated or insufficiently treated manure or compost; (4) use of contaminated agricultural water either for irrigation or for application of agricultural chemicals such as fungicides and (5) contamination and cross-contamination by harvesters, food handlers and equipment at harvest or post-harvest.

The risk factors for the contamination of berry fruits at primary production with Norovirus are also poorly documented in the literature, with limited available data, but are likely to include the following, based on what is known for other pathogens or other types of fresh produce: (1) environmental factors, in particular climatic conditions (e.g. heavy rainfall) that increase the transfer of Norovirus from

sewage or sewage effluents to irrigation water sources or fields of berries; (2) use of sewage-contaminated agricultural water, either for irrigation or for application of agricultural chemicals such as fungicides and (3) contamination and cross-contamination by harvesters, food handlers and equipment at harvest or post-harvest.

There is no information on the potential for *Salmonella* or for Norovirus to internalise within berry fruit or plants. For both *Salmonella* and Norovirus, processes at primary production which wet the berries represent the highest risk of contamination with both pathogens, and these include spray application of agricultural chemicals such as fungicides and, if it is applied, the use of overhead irrigation. *Salmonella* and Norovirus may show some persistence on the surface of berries. Decline has been reported for *Salmonella* on fresh and frozen strawberries. Evidence from outbreaks indicates that Norovirus can persist for a prolonged time period in frozen raspberries and strawberries.

During minimal processing, contamination and cross-contamination via equipment, water (if washing is applied) and particularly via food handlers are the main risk factors for berries for both *Salmonella* and Norovirus. For *Salmonella*, this risk of cross-contamination during washing is reduced if disinfectants are properly used within the washing tank. The effectiveness of disinfectants against Norovirus is not fully defined due to the lack of an infectivity assay.

Norovirus does not multiply in foods. Storage temperature influences the risk only to the extent of its persistence on the surface of contaminated berries. However since it is not possible to perform infectivity assays, there is no information on the relative persistence of Norovirus on berries at different storage temperatures. *Salmonella* was not able to grow on fresh strawberries and the influence of storage temperature on its survival is not known. There is no specific information on the fate of *Salmonella* on other fresh berries.

For the recommendation of possible specific mitigating options and the assessment of their effectiveness and efficiency to reduce the risk for humans posed by *Salmonella* and Norovirus in berries, the BIOHAZ Panel concluded that: appropriate implementation of food safety management systems including Good Agricultural Practices (GAP), Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) should be the primary objective of operators producing berries. These food safety management systems should be implemented along the farm to fork continuum and are applicable to the control of a range of microbiological hazards. Attention should be paid to the selection of the water sources for irrigation, agricultural chemicals (e.g. fungicides) and in particular to the avoidance of the use or the ingress of water contaminated by sewage. Production areas should be evaluated for hazards that may compromise hygiene and food safety, particularly to identify potential sources of faecal contamination. If the evaluation concludes that contamination in a specific area is at levels that may compromise the safety of crops, intervention strategies should be applied to restrict growers from using this land for berry production until the hazards have been addressed. Each production environment (including open field, enclosed or greenhouse production, and wild areas) should be evaluated independently for hazards as each represents a unique combination of numerous characteristics that can influence occurrence and persistence of pathogens in or near fields for growing berries.

Among the potential interventions, both water treatment and efficient drainage systems that take up excess overflows may be needed to prevent the additional dissemination of contaminated water. Since *E. coli* is an indicator microorganism for faecal contamination in irrigation water, growers should arrange for periodic testing to be carried out to inform preventive measures. A high proportion of berries consumed in the EU are imported from non EU countries, mostly as frozen berries, and attention should be paid to the application of these mitigation options during production and processing in the countries of origin. Food safety management based on GMP and HACCP principles should applied by processors, distributors, retailers and caterers involved in production of ready-to-eat berries. Mitigation strategies aiming to reduce risks of microbial contamination for all water used during processing and only potable quality water should be used. This should include wash-water where used, as well as that used for other purposes (including ice). All persons involved in the handling of berries should receive hygiene training appropriate to their tasks and receive periodic assessment while performing their duties to ensure tasks are being completed with due regard to good hygiene and hygienic practices. As *Salmonella* has reservoirs in domestic as well as wild animals, birds and humans, the main mitigation options for reducing the risk of contamination of berries are to prevent direct contact with faeces as well as indirect contact through slurries, sewage, sewage sludge, and contaminated soil, water, equipment or food contact surfaces. Although *Salmonella* declines during freezing of whole berries and berry products, it is not possible to use freezing as a critical control point to ensure the absence of this pathogen. The only reservoir for Norovirus is humans, therefore avoiding the use of sewage-contaminated water at all stages of the supply chain is an important mitigation option for reducing the risk of Norovirus contamination on berry fruits. Compliance with hygiene requirements, in particular hand hygiene, is an absolute necessity for food handlers at all stages of the berry production and the supply chain to reduce the risks of both *Salmonella* and Norovirus contamination.

For the recommendation, if considered relevant, of microbiological criteria for *Salmonella* and Norovirus in berries throughout the production chain, the BIOHAZ Panel concluded that: from 2007-2011, one *Salmonella* outbreak was reported which was associated with fresh raspberry juice. For Norovirus in berries the situation is different and outbreaks associated with Norovirus in frozen raspberries and strawberries are an emerging public health risk: between 2007 and 2011, there were 27 Norovirus outbreaks associated with raspberries (19 outbreaks implicated frozen raspberries, but no additional information has been reported for the remaining 8 outbreaks) and one outbreak associated with strawberries was reported in the EU. In addition a further Norovirus outbreak in Finland (9 cases) associated with berries was reported in 2011, 103 cases of hepatitis A were reported in 2012-13 in Denmark, Finland, Norway and Sweden associated with frozen strawberries and a large outbreak of 10,952 Norovirus cases were reported in Germany in 2012 associated with consumption of imported frozen strawberries in 2012. It is not known if in these outbreaks contamination by Norovirus occurred at minimal processing or if it occurred during primary production. Therefore, on considerations of public health risk, prevention of Norovirus contamination of raspberries and strawberries throughout production and minimal processing, particularly those intended for freezing, should be of high priority for processors.

There is no routine or regular monitoring of berry fruits for the presence of *Salmonella* in EU Member States and there is only very limited prevalence data on *Salmonella* contamination of berries in the peer-reviewed literature, which only relates to fresh strawberries. There is limited data relating to the testing of strawberries or strawberry juices, however no information pertaining to contamination of other types of berries is available. There has been no routine or regular monitoring of berry fruits for the presence of Norovirus in most of the EU Member States and there is very limited prevalence data on Norovirus contamination of berries (not involved in foodborne outbreaks) in the peer-reviewed literature. There are limited studies that have enumerated *E. coli* on berries. All studies examined strawberries, except for one study which included other types of berries (blueberries, raspberries). None of these studies were undertaken in the EU.

The current legal framework does not include microbiological criteria applicable at the primary production stage (Hygiene Criteria). It is currently not possible to assess the suitability of an EU-wide *E. coli* Hygiene Criterion at primary production for berries. However, using *E. coli* as an indicator of recent human or animal faecal contamination is likely to be useful for verification of GAP and GHP when applied to berries in individual production sites (e.g. to assess clean water used for irrigation and other water uses such as for the application of pesticides and fertilizers, and screening food handlers' hands) for example during prerequisite compliance audits, where epidemiological studies indicated a higher risk of infection or at the discretion of the food business operator. In the absence of reliable indicators for Norovirus contamination of berries and despite the limitations of current Norovirus detection methods, detection of Norovirus genomic copies in raspberries and strawberries may be useful for verification of GAP and GHP when applied to berries, for water used for irrigation (as well as for other water uses such as for the application of pesticides and fertilizers), and to screen food handlers' hands in individual production sites, for example during prerequisite compliance audits, where epidemiological studies indicated a higher risk of infection or at the discretion of the food business operator. It is, however, currently not possible to assess the suitability of an EU-wide Norovirus Hygiene Criterion at primary production for raspberries and strawberries, but this should be considered for the future, as well as for other berry fruits if additional public health risks are identified.

Currently there are no Process Hygiene criteria covering whole frozen berries and for these products there are no available data on occurrence of *E. coli* or *Salmonella.* It is therefore not possible to assess the suitability of an EU-wide *E. coli* Process Hygiene Criterion for whole frozen berries. However, using *E. coli* as an indicator for verification of GMP and food safety management systems (including HACCP) might be useful for frozen berries in individual processing premises e.g. during food safety management audits, where epidemiological studies indicated a higher risk of infection or at the discretion of the food business operator.

Microbiological criteria for Norovirus in berries are useful for validation and verification of food safety management systems, including HACCP-based processes and procedures, and can be used to communicate to food business operators and other stakeholders what is acceptable or unacceptable viral load for berries to be placed on the market. Although noroviruses can be detected in berries, prevalence studies are limited, and quantitative data on viral load are scarce, thus it is currently not possible to provide a risk base for establishing a Process Hygiene Criterion for these foods. However, on the basis of the emerging public health risk, the collection of appropriate data and subsequent development of a Norovirus Process Hygiene Criterion for frozen raspberries and strawberries should be considered as a priority.

On the basis of public health risk, there is currently insufficient evidence to justify the establishment of a Food Safety Criterion for *Salmonella* for fresh and minimally processed berries (including frozen berries).

For frozen raspberries and strawberries there is epidemiological evidence from outbreaks to identify this food as associated with emerging public health risks. However, the prevalence studies on Norovirus in frozen berries are limited. In addition, quantitative data are scarce; thus it is currently not possible to provide a risk base for establishing a Food Safety Criterion for these foods. Real time RT-PCR does not discriminate between infectious and non-infectious Norovirus and therefore presents a greater level of uncertainties than for most bacteria since it may overestimate or underestimate the risk. For fresh or frozen berries other than raspberries and strawberries there is no epidemiological evidence or prevalence data to support the establishment of a Food Safety Criterion on the basis of public health risk, but this may need to be re-evaluated if additional information becomes available.

The BIOHAZ Panel also recommended that: (1) more detailed categorization of food of non-animal origin should be introduced to allow disaggregation of the currently reported data collected via EFSA’s Zoonoses database on prevalence and enumeration of foodborne pathogens; (2) ISO technical specifications for Norovirus detection and quantification on berries should be further refined with regard to sampling, sample preparation, limit of detection, quantitative accuracy and interpretation of results. Such developments will allow the collection of data to support the development of Process Hygiene and Food Safety Criteria for berries; (3) there is a need for targeted surveys on the occurrence of Norovirus in different types of berries both at primary production, after minimal processing (including freezing) and at the point of sale. Where possible, these surveys should use methods which provide an indication of virus infectivity, together with studies to identify the level of hazard control and efficacy of application of food safety managements, including HACCP, that has been achieved at different stages of production systems; (4) there should be evaluation of procedures such as sanitary surveys, training, observational audits and other methods to verify agricultural and hygiene practices (including food handlers’ hand hygiene) for berries at primary production. Evaluation of systems for monitoring of water used in primary production should be prioritised; (5) further data should be collected to evaluate the suitability of bacterial or viral indicators for Norovirus and other relevant microbiological hazards in berries and in berry production and processing environments; (6) research should be undertaken with the aim of a) developing infectivity assays for Norovirus and b) determining whether Norovirus can internalise within berries during crop production during natural exposure; (7) there is a need for more research on decontamination treatments effective against all relevant microbiological hazards for ready-to-eat berries particularly those intended to be frozen and (8) collection of appropriate data and subsequent risk-based development of a Process Hygiene Criterion or Food Safety Criterion to support improved control of Norovirus in frozen raspberries and strawberries should be considered as a priority.

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BACKGROUND AS PROVIDED BY EUROPEAN COMMISSION

In May 2011 a major outbreak of Shiga toxin-producing *Escherichia coli* (STEC[4]) O104:H4 occurred in Germany. About 4,000 people were reported ill with symptoms and the outbreak resulted in the death of more than 56 people. Other countries reported a certain number of people becoming ill by the same strain, most of whom had recently visited the region of northern Germany where the outbreak occurred. At the end of June 2011, there was a second cluster in Bordeaux, France, which was caused by the same *Escherichia coli* strain. In both cases, investigations pointed to the direction of sprouted seeds.

According to the 2009 Zoonoses Report[5], the majority of verified outbreaks in the EU were associated with foodstuffs of animal origin. Fruit and vegetables were implicated in 43 (4.4 %) verified outbreaks. These outbreaks were primarily caused by frozen raspberries contaminated with Norovirus.

According to the US Centre for Disease Control and Prevention (CDC) 2008 report on surveillance for food borne disease outbreaks[6], the two main commodities associated with most of the outbreak-related illnesses originating from food of plant origin were fruits-nuts and vine-stalk vegetables. One of the main pathogen-commodity pair responsible for most of the outbreaks was Norovirus in leafy vegetables. The pathogen-commodity pairs responsible for most of the outbreak-related illnesses were *Salmonella* spp. in vine-stalk vegetables and *Salmonella* spp. in fruits-nuts. In addition, as recently as September 2011, a multistate outbreak of listeriosis linked to cantaloupe melons caused 29 deaths in the US.

Regulation (EC) No 852/2004 on the hygiene of foodstuffs[7] lays down general hygiene requirements to be respected by food businesses at all stages of the food chain. All food business operators have to comply with requirements for good hygiene practice in accordance with this Regulation, thus preventing the contamination of food of animal and of plant origin. Establishments other than primary producers and associated activities must implement procedures based on the Hazard Analysis and Critical Control Points (HACCP) principles to monitor effectively the risks.

In addition to the general hygiene rules, several microbiological criteria have been laid down in Regulation (EC) No 2073/2005[8] for food of non-animal origin.

Following the STEC O104:H4 outbreak in Germany and France, the Commission already has asked EFSA for a rapid Opinion on seeds and sprouted seeds. EFSA adopted a scientific Opinion on the risk posed by STEC and other pathogenic bacteria in seeds and sprouted seeds on 20 October 2011. The current mandate intends to supplement the adopted Opinion.

In view of the above, there is a need to evaluate the need for specific control measures for certain food of non-animal origin, supplementing the general hygiene rules.

TERMS OF REFERENCE AS PROVIDED BY EUROPEAN COMMISSION

EFSA is asked to issue scientific Opinions on the public health risk posed by pathogens that may contaminate food of non-animal origin such as fruit, vegetables, juices, seeds, nuts, cereals, mushrooms, algae, herbs and spices and, in particular:

1. To compare the incidence of foodborne human cases linked to food of non-animal origin and foodborne cases linked to food of animal origin. This ToR should provide an indication of the

[4] Also known as Verocytotoxin-producing *Escherichia coli* (VTEC).
[5] EFSA Journal 2011;9(3):2090
[6] www.cdc.gov/mmwr/preview/mmwrhtml/mm6035a3.htm?s_cid=mm6035a3_w
[7] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 30.4.2004, p. 1-54.
[8] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. OJ L 338, 22.12.2005, p. 1-26.

proportionality between these two groups as regard humans cases and, if possible, human burden.

2. To identify and rank specific food/pathogen combinations most often linked to foodborne human cases originating from food of non-animal origin in the EU.

3. To identify the main risk factors for the specific food/pathogen combinations identified under ToR 2, including agricultural production systems, origin and further processing.

4. To recommend possible specific mitigating options and to assess their effectiveness and efficiency to reduce the risk for humans posed by food/pathogen combinations identified under ToR 2.

5. To recommend, if considered relevant, microbiological criteria for the identified specific food/pathogen combinations throughout the production chain.

The Commission would like an Opinion on the first and second terms of reference by the end of December 2012. The outcome of the first and second terms of reference should be discussed between risk assessors and risk managers in order to decide which food/pathogen combinations should be given priority for the other terms of reference. The Commission would like an Opinion on the other terms of reference by the end of 2013.

Clarifications of the Terms of Reference 3 to 5 of the request on the risk posed by pathogens in food of non-animal origin

Background as provided by European Commission

On 23 January 2012, a request was provided to the European Food Safety Authority (EFSA) to issue scientific Opinions on the public health risk posed by pathogens that may contaminate food of non-animal origin (FNAO).

The BIOHAZ Panel of EFSA adopted during its meeting on 6 December 2012 an Opinion on the first and second terms of reference, focussing on

- the comparison of the incidence of foodborne human cases linked to FNAO and foodborne cases linked to food of animal origin;

- identifying and ranking specific food/pathogen combinations most often linked to foodborne human cases originating from FoNAO in the EU.

It was agreed in the original request that the outcome of the first and second terms of reference should be discussed between risk assessors and risk managers in order to decide which food/pathogen combinations should be given priority for the other terms of reference addressing risk factors, mitigation options and possible microbiological criteria.

The first Opinion of EFSA under this request identifies more than 20 food/pathogen combinations in its five top ranking groups. The Opinion also contains a preliminary assessment of risk factors linked to certain examples of FoNAO (e.g. tomatoes, watermelons and lettuce), representing specific production methods for several FoNAO. Several risk factors and mitigation options may be common for several food/pathogen combinations due to similar production methods. It seems therefore opportune to combine the risk assessment of such food/pathogen combinations. When risk factors and mitigation options are identified as more specific to the individual food/pathogen combination, then these should be considered to supplement this approach and added where possible within the, Opinions. Alternatively, it is worth mentioning that a reference could be made if such specific risks have already been addressed in previous Opinions.

TERMS OF REFERENCE AS PROVIDED BY EUROPEAN COMMISSION

EFSA is asked, in accordance with article 29 of Regulation (EC) No 178/2002[9], to provide scientific Opinions on the public health risk posed by pathogens on food of non-animal origin as regards risk factors, mitigation options and possible microbiological criteria. When considered more appropriate e.g. because of low prevalence of the pathogen or in view of a broader process control, indicators may be proposed as process hygiene criteria. When addressing mitigation options at primary production, attention should be paid to Article 5(3) of Regulation (EC) No 852/2004[10], which laid down that the application of hazard analysis and critical control pints (HACCP) principles shall only be applied to food business operators after primary production and associated activities[11]. This provision does, however, not exclude proposing microbiological criteria in accordance with terms of reference 5 when considered relevant.

EFSA is requested to provide Opinions in line with the agreed terms of Reference 3 to 5 (EFSA-Q-2012-00237) for the following food/pathogen combinations with a similar production system:

(1) The risk from *Salmonella* and Norovirus in leafy greens eaten raw as salads.
Cutting and mixing before placing on the market should be included as potential risk factor and specific mitigation options proposed if relevant.

(2) The risk from *Salmonella*, *Yersinia*, *Shigella* and Norovirus in bulb and stem vegetables, and carrots.

(3) The risk from *Salmonella* and Norovirus in tomatoes.

(4) The risk from *Salmonella* in melons.

(5) The risk from *Salmonella* and Norovirus in berries.

9 OJ L 31, 1.2.2002, p.1

10 Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 30.4.2004, p. 1-54.

11 See guidance at: http://ec.europa.eu/food/food/biosafety/hygienelegislation/guidance_doc_852-2004_en.pdf

ASSESSMENT

1. Introduction

Berries represent a fresh food commodity, which is widely consumed and generally free from noxious substances such as poisonous chemicals, toxins and pathogenic organisms. This food commodity is often consumed as a highly perishable product receiving only minimal processing. Berries are also consumed as highly processed products such as a component of jams, preserves, heat-treated fruit juices and dried fruits that can be shelf-stable and have undergone heating or drying: such products are outside the scope of this Opinion. The previous EFSA Opinion (EFSA Panel on Biological Hazards (BIOHAZ), 2013), risk ranked the combination of raspberries together with *Salmonella* spp. and Norovirus as the fourth most often linked to foodborne human cases originating from food of non-animal origin (FoNAO) in the EU. In addition, the combination of strawberries and other berries with Norovirus were risk ranked as the sixth most often linked to foodborne human cases originating from FoNAO in the EU.

The main risk factors, together with their mitigation options are applicable to all points in the food chain. However since berries may not include processing steps or control points which will ensure inactivation or removal of biological hazards, it is particularly important to consider risk factors (and consequentially mitigation options) at the point of production. This is similar to other foods of non-animal origin, which are minimally processed and often sold as ready-to-eat, as well as with some foods of animal origin (e.g. unpasteurised dairy products, shellfish and meats which are eaten raw).

The approaches used in this Opinion are:

1. To provide a descriptive analysis similar to that for leafy greens (EFSA BIOHAZ Panel, 2014) of the whole production process representative for a typical range of berries which considers their origins in agricultural production, growing, harvesting, processing, distribution, retail, catering and handling in domestic environments. Risk factors for contamination by *Salmonella* spp. and Norovirus will be considered in the context of their cultivation and harvesting, processing, distribution and retail/catering/domestic environments. In discussions with the EU Commission it was agreed that for all the FoNAO considered in the related Opinions, only minimally processed products will be considered (which includes cutting, washing, peeling, shredding, freezing, mashing and unpasteurized juicing). Products undergoing thermal treatments (including blanching as well as shelf-stable juices) as well as other processing treatments are not considered in the scope of these Opinions.

2. The Opinion includes separate sections, which assess specific mitigation options to reduce contamination of berries by *Salmonella* spp. or Norovirus and to reduce the risk of exposure through food consumption. Assessment of the mitigations options was performed in a qualitative manner similar to that performed for the Scientific Opinion on the risk posed by Shiga toxin-producing *Escherichia coli* (STEC) and other pathogenic bacteria in seeds and sprouted seeds (EFSA Panel on Biological Hazards (BIOHAZ), 2011c), and include consideration of generic mitigation options previously identified for leafy greens eaten raw as salads (EFSA BIOHAZ Panel, 2014) as well as those specific for berries.

3. Sampling and analytical methods for the detection of *Salmonella* spp. and Norovirus (together with the use of *Escherichia coli* as an indicator organism) in berries were considered similarly to those identified for leafy greens (EFSA BIOHAZ Panel, 2014). A summary of available data on estimates of prevalence for *Salmonella*, Norovirus and *E. coli* in berries is presented. The relevance of microbiological criteria applicable to production, processing and at retail/catering were considered. Microbiological criteria in domestic settings were not considered.

2. Production of berries

2.1. Definition of berries

Berries, for the scope of this Opinion, are defined according to commercial production and consumption as small, spherical or ovoid, fleshy and juicy fruits. This does not correspond to the botanical definition of berries (true berries), which refers to fruits formed by the transformation of the whole ovary. Many true berries are not included in the commercial category of berries (e.g. tomatoes, melons, grapes), and some fruits included in the commercial and common usage category of berries used here are not true berries but are aggregate or accessory fruits (e.g. blackberry, raspberry, strawberry). Examples of true berries among commercial crops are currants and blueberries. UNECE (2010) have specified the main types of commercial berries, which include the following species or hybrids:

- raspberry (*Rubus idaeus* L.)
- blackberry (*Rubus fruticosus* L. agg.)
- loganberry, tayberry, boysenberry (*Rubus loganobaccus* L. H. Bailey)
- cloudberry (*Rubus chamaemorus* L.)
- currant (*Ribes rubrum* L., *Ribes nigrum* L.)
- jostaberry (*Ribes* x *nidigrolaria* Rud.Baur & A.Bauer).
- gooseberry (*Ribes uva-crispa* L.)
- bilberry (*Vaccinium myrtillus* L.)
- blueberry (*Vaccinium corymbosum* L., *Vaccinium formosum* Andrews, *Vaccinium angustifolium* Aiton, *Vaccinium virgatum* Aiton)
- cowberry, lingonberry (*Vaccinium vitis-idaea* L.)
- cranberry (*Vaccinium macrocarpon* Aiton)
- wild cranberry (*Vaccinium oxycoccos* L.)

In addition to the above list, strawberries (*Fragaria* spp.) are considered in this Opinion. Berries were previously defined (EFSA Panel on Biological Hazards (BIOHAZ), 2013) to include: açai berry, barberry, bearberry, bilberry, blackberry, blackcurrant, blueberry, boysenberry, cape gooseberry, chokeberry, cloudberry, cranberry, cowberry, elderberry, goji berry, gooseberry, huckleberry, juneberry, juniper berry, lingonberry, loganberry, marionberry, mulberry, nannyberry, ollaliberry, oregon grape, raspberry, red currant, salmonberry, sea-buckthorn berry, serviceberry, strawberry and tayberry.

Despite the wide varieties of plant species grown for production, the most important fruit for the fresh market in the EU are strawberries, raspberries, blackberries and blueberries (Freshfel 2013, Appendix A). Berries can be produced by small herbaceous plants (e.g. strawberry), bushes (e.g. blackberry, blackcurrant, blueberry, gooseberry, raspberry), or small trees (e.g. mulberry, elderberry). Overall there is some information on the risk factors and mitigation options for *Salmonella* and Norovirus contamination of strawberries and raspberries, but there is little or no information for other berries.

2.1.1. Propagation

Cultivated berries are usually propagated from plants and not from seeds: small plants with naked roots, which depending on the type of berry, are propagated in soil or in artificial substrates, or obtained from *in vitro* cultures, or from cuttings. Most types of berry are grown as perennials, but some (e.g. strawberries) are often grown as annuals. Plants can be grown in soil or soil-less cultures in protected environments or in open fields. After propagation, plants can be planted directly or stored refrigerated prior to planting (Freshfel information, Appendix A).

2.2. Description of production systems

Berries are produced using various systems, depending on the type of berry, the intended use (e.g. fresh market or for processing including freezing) the geographical origin and the economic choices of the growers. Planting can be done in autumn or spring, depending on the species of berry or the climate. Berry production can be in the same year, in the case of herbaceous plants (e.g. strawberries), or after 1-2 years and continuing for several years in the case of bushes (e.g. raspberries). As well as commercial production by cultivation, harvest from the wild occurs (e.g. blueberries). Domestic production occurs but is outside the scope of this Opinion.

2.2.1. Open field production

Berries intended for processing (including for preserves or freezing) are almost all grown in open fields (Freshfel information, Appendix A). The share of berries intended for the fresh market and grown in open field is not known, although it is presumed to be the minority of production in countries with intensive production such as Spain, Italy, France, Belgium (Freshfel information, Appendix A), and also occurs in other countries (Chambre d'Agriculture de Lorraine, 2005). Open field production is likely to be more common in third countries exporting to Europe (e.g. raspberries in Morocco, (Chemonics International, 2006)). Berries can also be picked commercially from the wild (e.g. forests, upland grasslands and bogs). Harvest of berries (particularly bilberries and blackberries) can also take place from forests and other land, including from public areas where biosecurity is minimal.

2.2.2. Greenhouse, protected and hydroponic productions

Protected cultures (those not grown in completely enclosed greenhouse environments but grown under some sort of cover) can be used to reduce damage caused by poor weather conditions, animals and birds. Protection can also extend or accelerate the production period, which may be advantageous when the prices of berries on the market are at their highest. This is particularly important for strawberries, but also exists for other types of berries such as raspberries or blackberries. In protected culture, plant development usually takes place in soil. This is the case with most raspberry production although soil-less raspberry cultivation also exists (EFSA, 2014). Most strawberry production is in protected cultivation using soil or soil-less systems (Freshfel information, Appendix A). Soil-less, hydroponic cultivation of strawberries or cultivation on soil environments varies within the EU and may be dependent on the production season (EFSA, 2014).

Various methods and techniques developed for growing plants without soil are collectively called soil-less systems. These methods include a great diversity of systems, from the purely hydroponic, which are based on the supply of water and nutrients only (e.g. nutrient film technique or NFT), to those based on artificial mixes that contain various proportions of different substrates which can be either inert (e.g. rockwool slabs, polyurethane chunks, and perlite) or non inert (e.g. gravel culture, sand culture, and peat bags) (Papadopoulos, 1991).

Whilst soil or artificial substrates are the main cultivation method in South West France (Chambre d'Agriculture Dordogne, 2013), soil-less culture is the dominant production method in Northern Italy and South of Spain and represents almost 100 % of cultivation (EFSA, 2014). For strawberry production in soil-less systems, the use of coco peat is widely used as an alternative growth substrate to soil in situations where there is a shortage of suitable soil and there are possibilities of applying procedures to the irrigation water to control plant pathogens (EFSA, 2014), although it has not been shown what effects these procedures have on human foodborne pathogens. For soil-less cultivation, growth generally takes place in raised beds above ground level to facilitate production labour and picking (EFSA, 2014).

2.2.3. Water Sources and irrigation systems

Although the need for irrigation will depend on climate, water availability is particularly important during fruit development for example for raspberries (Chambre d'Agriculture de Lorraine, 2005). Irrigation can be done by drip irrigation or using sprinklers (Freshfel information, Appendix A). Drip irrigation is preferable and usually used (Chambre d'Agriculture Languedoc Roussillon, 2012). However, sprinkler (overhead) irrigation is occasionally used. In cold climates, overhead irrigation can also provide frost protection (Domoto et al., 2008). Sources of water used for irrigating berries include well water, borehole water, surface water, reservoirs, or potable quality water in the case of hydroponic culture, but their respective importance in terms of volumes and frequency of use is not known (Freshfel information, Appendix A).

2.2.4. Different types of fertilisation, organic/manure/compost

For soil culture, the soil can be covered with a plastic or fabric mulch and the berry plants are grown on ridged surfaces. The application of manure (Chambre d'Agriculture Languedoc Roussillon, 2012), or preferably compost in the autumn or spring is recommended to maintain a high level of organic matter in the soil (e.g. for raspberries) (Chambre d'Agriculture de Lorraine, 2005; Chemonics International, 2006). In addition, chemical fertilization can be applied in different ways, for example directly in the soil, through irrigation water (fertigation), or through spraying.

2.2.5. Harvesting

Berries are harvested during the fruiting season. Harvest from open field production is usually in the summer or the beginning of the autumn, and can last for several weeks for the same areas of land, with picking every one or two days. In protected or enclosed cultivation, it is more variable depending on the climate and the presence of heating systems. For some types of berries (e.g. strawberries and raspberries) it is possible to harvest twice a year. For instance, in South West France protected culture enables strawberries to be harvested from the same plants in early spring and in mid-summer (Chambre d'Agriculture Dordogne, 2013).

The right moment for harvesting berries can best be determined on the basis of the colour of the berries, and optimally on the basis of their sugar and acid content. Berries are generally harvested when almost ripe, because the quality quickly decreases after harvest. Most berries intended for the fresh market are manually harvested to minimize bruising (which can lead to rapid mould growth) although the process is very labour intensive. For instance, with open field raspberries, harvest from 1 ha requires around 2 500 hours of labour (Chambre d'Agriculture de Lorraine, 2005). This means that except for very small producers, seasonal workers are frequently used for harvesting berries. In Western Europe, pickers frequently come from both outside as well as within the EU (Freshfel information, Appendix A). To avoid mechanical damage, fruits can be directly picked and placed in their final packaging for sale to caterers and consumers. Mechanical harvesting exists for some berries intended for processing (e.g. raspberries for jam, purées or juices).

In farms, which are close to urban areas, consumers using a ‘pick your own’ system may harvest berries themselves.

2.2.6. Post-harvest

Some berries have high respiration rates (such as raspberries and blackberries) making them highly perishable. Enzymes and biochemical reactions play an important role in the ripening process but also accelerate spoilage of damaged fruits and increase susceptibility of berries to microbial contamination after harvest. After harvest, cooling (i.e., rapid removal of field heat) should ideally be rapidly applied (e.g. within the first 2 hours) to preserve the quality and freshness of the berries, particularly for those intended to be shipped fresh for long distances. Pre-cooling can be done using forced air cooling (Chemonics International, 2006). Fruits must always be kept dry to prevent soft rot development, thus precluding the use of any washing steps at this stage for many types of berries. In addition, most berries are very prone to mechanical damage, which means that post-harvest interventions need to be kept to a minimum. However, some post-harvest treatments such as gaseous ozone (0.3-1 ppm) to prevent *Botrytis* rot can be used (Freshfel information, Appendix A). These treatments can also be applied during processing (see Section 4). In addition, other treatments have been tested on a more experimental basis and are further discussed in Section 12.2.

With a storage temperature of 3-5 °C the shelf life of many berries is short, not exceeding a week, especially for soft and fully mature ripe berries. Controlled Atmosphere (CA) storage (at 3 % O_2 and 10 % CO_2) combined with low temperature (0-1 °C) extends shelf life up to 7 weeks and is commonly used for blueberries but is now also applied to certain other berries (Freshfel information, Appendix A). The short post-harvest shelf life of berries encourages the use of decay-control techniques. Apart from low temperature, one of the most commonly used postharvest treatments to control fungal growth and reduce respiration of berries is modified atmosphere packaging (MAP) of 15-20 % CO_2 and 5 to 10 % O_2 (Mitcham et al., 2007) or 10-15 % CO_2 (Mitcham et al., 2004), depending on the type of berry. Carbon dioxide (CO_2) enriched atmospheres are used to reduce the incidence and severity of decay and therefore extend the postharvest life of berries (Li and Kader, 1989). MAP is commonly used during distribution for those berries intended to ship fresh for long distances, but commercialization of the final product is usually carried out under air. Packaging material is very diverse and depends on commercial considerations (from local to international distribution) and the choice of the producer. Materials for trays include wood, cardboard, or plastic, with or without plastic or polymeric film covers, providing different degrees of protection from humidity and post-harvest contamination. The choice of packaging material has been shown to influence consumer acceptability and shelf-life of blueberries (Almenar et al., 2010).

Fresh and frozen berries intended for sale are normally not subjected to physical interventions that will eliminate or substantially reduce the occurrence of *Salmonella* and Norovirus. Technologies currently available for use by the berry industry therefore fall short of being able to guarantee the absence of *Salmonella* or Norovirus in primary production.

2.3. Description of EU berries sector

This section is based on information provided by Freshfel up to 2012 (Freshfel information, Appendix A) with EUROSTAT data on production and FAOSTAT data on trade statistics up to 2012 based on voluntary reporting. The scale of production of berries in the EU is very variable between Member States without reliable indications of the proportions of different modes of cultivation or final mode of consumption (fresh, frozen or processed). Production of berries varies and includes home producers, small producers for local consumption, large producers, producers specializing in berries or producers growing berries as well as other crops and harvest from the wild. Appendix B shows some summary production and trade data for fresh and frozen berries provided by Freshfel. All the presented data, except for Table 10, refers to fresh berries.

Strawberries are the main type of berry produced in the EU (around 1 million metric tons a year) with the main producers being Spain (23.5 % of EU production), Poland (14.8 %), Germany (13.8 %), and Italy (13.4 %). Most production takes place in open fields although this varies between Member States. For example, in Poland most strawberry cultivation is in open fields and the berries are mainly intended for processing (64 % in Poland) whereas in Spain intensive protected cultivation is more often used and is mostly destined for the fresh market (82 % of production).

EU production of raspberries amounts to 182 000 metric tons a year, with 7 000 metric tons as EU imports. The main producer is Poland (65 % of EU production) followed by the UK (9 %).

Data on the imports of frozen strawberries and raspberries into the EU is provided in Table 10 (Appendix B). For strawberries, 134 320 metric tons were imported in 2012, of which 95 % came from Morocco (59 703 metric tons), China (46 705 metric tons), Egypt (15 840 metric tons) and Turkey (5 538 metric tons). For raspberries, of the 74 856 metric tons imported in 2012, 99 % came from Serbia (57 897 metric tons), Chile (11 382 metric tons), Bosnia Herzegovina (2 575 metric tons), and China (2 334 metric tons). There has been a considerable increase in import of soft frozen fruit into the EU for processing with 200 000 tonnes in the late 1980s to more than 500 000 tonnes in the 2000s, at an average annual growth rate of 6.0 %; in particular, with frozen strawberries mostly from China and Morocco and raspberries from Chile and Serbia (Commission Staff Working Document, 2006). Although product for processing is outside the scope of this Opinion, it is possible that frozen berries may be diverted from processing to inclusion in products that do not undergo steps suitable for the inactivation of pathogens.

The EU produced 41 561 metric tons of blueberries in 2011 with the main producers being France (23 % EU production), Poland (21 %) and Germany (16 %) (Table 18).

The EU production of currants represented 208 547 metric tons (4 447 metric tons EU imports), with Poland being the main producer (63 % of EU production), followed by France (8 %) (Table 11). Most currant production is processed, especially in the case of blackcurrants.

Other berries (including blackberries) represent a production of 166 020 metric tons in the EU, with Italy being the main producer (51 % of EU production), followed by Poland (30 %) (Table 23). Cranberries are the only berries which are predominantly imported (90 % of EU consumption).

3. Risk factors for microbiological contamination during agricultural production

Production practices, growth conditions and the location of the berries on the growing plant (soil surface, aerial part) in combination with intrinsic and extrinsic factors as well as harvesting and processing will affect the microbial status of berries at the time of consumption. Variability in the production systems and associated environments for berry production can lead to a wide range of unintentional or intentional events that may be potential sources of food safety hazards and these will vary considerably from one type of crop production to another and from one particular setting/context to another, even for the same crop. The following sections are intended to identify and characterize potential risk factors for contamination of berries in addition to those previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014) albeit that berries are more variable than leafy greens in terms of spacing and height of plants, longevity of the plant in the ground and the timescale over which berries are formed and harvested. In addition, berries are pulpy fruits with high moisture and sugar content and a soft skin, which makes them particularly susceptible to physical damage that accelerates their deterioration by increasing water loss and providing conditions to increase microbial contamination and spoilage during production, harvest, transport and storage. Strawberries and raspberries do not support growth of the enteric bacterial pathogens because of their internal high acidity (pH 3.1-3.6) (Siro et al., 2006). Furthermore, spoilage microorganisms that are present in refrigerated produce are psychrotrophic and therefore, have a competitive advantage over most pathogens (Ahvenainen, 1996). Dennis (1976) reported bacterial counts of 10^5-10^6/g on freshly harvested strawberries, raspberries and blackberries and a fungal flora which varied between different types of berry. Risk factors for physical damage to berries may occur during harvesting as well as by the action of various pests (rodents, insects, birds and wild mammals) and plant pathogens. This may lead to increased microbial spoilage.

Very few outbreak investigations or experimental studies have examined risk factors for contamination of berries by *Salmonella* and Norovirus during agricultural production. Data are available from outbreaks associated with berry consumption and other infectious agents: e.g. hepatitis A virus and frozen berries (Gillesberg Lassen et al., 2013; Rizzo et al., 2013), hepatitis A virus and raw blueberries (Calder et al., 2003), and *Cyclospora cayetanensis* and fresh raspberries (Herwaldt and Ackers, 1997). Risk factors presented below are also deduced from those presented for leafy greens in a previous Opinion (EFSA BIOHAZ Panel, 2014) and may not be supported by epidemiological or experimental evidence, unless specified in the relevant sections.

3.1. Environmental factors

Environmental factors refer to the specific conditions of the primary production area, climate and type of crop and were previously discussed for the production of leafy green vegetables (EFSA BIOHAZ Panel, 2014). These are likely to have an impact on microbial contamination routes, persistence of pathogens in growing fields, the use of fertilizers, sources quality and frequency of irrigation water and other water uses, pathogen prevalence and concentration and the overall safety of the berry production. Each production environment (including open field, enclosed or greenhouse production and wild areas) should be evaluated independently as each represents a unique combination of numerous characteristics that can influence the occurrence and persistence of pathogens in or near fields where berries are grown.

Some berries have frequent direct contact with soil during growth and/or harvesting. In addition, bird droppings and airborne contaminants (from e.g. birds nesting around the growth and packing areas, nearby livestock, poultry production, manure storage or treatment facilities, etc.) as well as proximity of wildlife may also pose a risk of contamination for berries, including when picking from the wild. The impact of environmental risk factors will depend on whether berries are produced in open fields, in protected cultures, in the soil or in soil-less systems. Although not associated with *Salmonella* contamination, a good illustration of potential risks was given by an outbreak of pathogenic *E. coli* associated with consumption of contaminated fresh strawberries caused by deer defecating in open production fields (Laidler et al., 2013).

3.1.1. Factors linked to the adherence, survival and internalisation of pathogens

There is limited or no information on *Salmonella* and Norovirus adherence and persistence in relation to berries. Evidence from outbreaks indicated that Norovirus can persist for a prolonged time period in frozen berries. Knudsen et al. (2001) showed that, using a cocktail of six *Salmonella enterica* serovars (Agona, Enteritidis, Gaminara, Michigan, Montevideo and Typhimurium at a total concentration of $10^{8\text{-}9}$ cfu) spot inoculated onto the surface of whole strawberries, after an initial decrease during drying the population did not decline further over a 48-h storage period. This was followed by 1- to 2-log reduction over a further 5 days. Similar rates of decline were reported for pathogenic *E. coli* in the same publication.

Deboosere et al. (2012) observed up to 1 % Norovirus GI and GII adhering to the surfaces of raspberries, and up to 0.1 % adhering to the surfaces of strawberries after artificial contamination by immersion in a buffer solution containing approximately 10^6 genome equivalents Norovirus for 18 h at 4^{o}C. From the graphical display of estimated percentages of adherent virus given in the paper, GI appeared more adherent than GII on both raspberries and strawberries, although whether the difference was significant was not reported.

There is no information on the potential for *Salmonella* or for Norovirus to internalise within berry fruit or plants.

3.1.2. Conditions in the field and adjacent land

The environmental conditions which result in airborne or waterborne contamination at the growing field as well as the use of adjacent land were identified as playing a vital role in the microbial safety of leafy greens (EFSA BIOHAZ Panel, 2014) and these risk factors are applicable to berries. Risk factors for contamination with pathogens include contact between berries and airborne contaminants as well as those arising from the soil, animal droppings, soil amendments (including natural fertilizers) or direct contact with irrigation water. Runoff and flooding present risks of contamination particularly where adjacent land use is associated with contamination from human or animal excreta. Materials used under plants during growing can reduce risks of berry contamination by minimizing contact with the soil, e.g. by the use of a mulch or biodegradable materials (e.g. straw). During harvest, contamination of containers and berries can be minimised by using clean and sanitary plastic or biodegradable materials (e.g. paper basket liners) on a single use basis to prevent cross-contamination.

Soil-less, protected cultures of strawberries, which are frequently grown above ground level, are less likely to be exposed to contamination with pathogens from the adjacent land in both outdoor and protected cultivation than other production systems.

3.1.3. Climatic conditions

The effects of climatic conditions on the contamination sources and pathways of pathogens onto leafy greens during the pre-harvest phase were previously outlined (EFSA BIOHAZ Panel, 2014), and risk factors identified for leafy greens are equally applicable to berries. Heavy rains may increase the exposure of berries to pathogens if soil contaminated with pathogens splashes onto fruit surfaces, as well as causing contamination through flooding where floodwater comes into direct contact with berries. The risk of splashing from the soil is presumably reduced for berries grown high above the ground, such as from bushes or soil-less strawberry production. Wet berries are very susceptible to microbiological spoilage, which can lead to over-ripe berries with leaking juice. Fungicides may be used to control spoilage and, depending on the quality of the water used for the fungicide, may be a potential source of contamination for pathogens. Because of increased handling, spoiled and damaged berries may be more susceptible to contamination by pathogens, compared to intact product.

3.1.4. Contact with animal reservoirs

Domestic animals (e.g. cattle, sheep, chickens, dogs, cats, and horses) as well as wild animals (e.g. frogs, lizards, snakes, rodents, foxes, deer, badgers, wild boar and birds) can contaminate leafy green crops with their faeces if they pass through growing areas (EFSA BIOHAZ Panel, 2014). The risk factors previously identified for leafy greens are also applicable to berries, as shown by an outbreak of *E. coli* O157:H7, which was caused by the contamination of strawberries with deer faeces (Laidler et al., 2013). While domestic animals should be separated from growing operations for berries, it can be more difficult to control access by wild animals. Wild and domestic animals and birds (as well as humans) represent risk factors for contamination of berries with pathogens when they are present in the production environment and are a potential source of direct contamination of the crop, soil, surface water sources and other (particularly water) inputs. Risks may vary with different berry types. For example soil contamination with faeces is a particular risk for berries likely to have direct soil contact (e.g. strawberries) that have frequent direct contact with the ground during growth and/or harvesting. Bird droppings and airborne contaminants (birds nesting around the packing area, nearby livestock, poultry production or manure storage or treatment facilities, etc.) may also pose a risk of contamination.

Domestic and wild animals and birds should be excluded as far as possible from berry production areas using appropriate biological, cultivation, and physical and chemical pest control methods. This may be challenging with berries since they will attract animals and birds seeking a source of food. Preventing wild life gaining access to and causing damage of berries is one of the reasons for using protected cultures (Freshfel information, Appendix A). Although most berries are cultivated, those that are gathered from the wild are at particular risk of microbiological contamination from wild animals and birds.

3.2. Organic amendments (manure, slurries, composts, wastewater treatment sludge and sewage)

The use of untreated solid or liquid manure may be a risk factor for contamination of berries with pathogens including *Salmonella*. Information on the persistence of foodborne pathogens in soil and manure (including *Salmonella*) has been highlighted previously for leafy greens (EFSA BIOHAZ Panel, 2014). This is an important consideration in berry production as contamination of berries by pathogens could arise from manure used during cultivation. For organic soil-grown strawberries in SW France, it is generally recommended that there is a delay of at least 3-4 months between manure application and planting, with planting in spring and harvest in summer. This means that there is at least a year between manure application and harvest in this example (Chambre d'Agriculture de Lorraine, 2005). In another example, using ‘tray-plants’ of strawberries, planting occurs in December and harvest starts in March, thereby providing at least 6 months between manure application and harvest (Chambre d'Agriculture du Lot et Garonne, 2007). For perennial berry plants such as raspberries, manure is best used to fertilize the soil before planting, but during production of the plant, manure can be applied between rows in winter after pruning, providing there is at least 6 months between manure application and harvest (Chemonics International, 2006; Chambre d'Agriculture de Corrèze, 2007). In the above examples, application of fresh manure is not recommended as it can damage the berry plants and properly composted manure is preferable. If composting is carried out inappropriately (e.g. infrequent turning, slow heating, adding fresh manure, manure deep-stacking, cross-contamination between manure and compost) it may allow the survival of pathogens (Jiang and Shepherd, 2009). As outlined previously for leafy greens (EFSA BIOHAZ Panel, 2014), adequately composted manure (e.g. following Regulation (EU) No 142/2011[12]) should not represent a risk factor for contamination of crops with *Salmonella* and human pathogenic viruses including Norovirus). Data is not available to indicate if there is an increased risk of contamination with pathogens for organic grown berries.

The risk of sewage or wastewater contaminating vegetables with human foodborne pathogens, including Norovirus and *Salmonella*, has been reviewed (Bryan, 1977) and the risks are similar for berries as were outlined for leafy greens (EFSA BIOHAZ Panel, 2014). Norovirus is excreted in high numbers in faeces by infected humans (EFSA Panel on Biological Hazards (BIOHAZ), 2012), and the virus is likely to be present in wastewater, sewage and wastewater treatment plant effluent, in particular during periods of the year with high incidence of disease in the human population.

3.3. Water use during production (irrigation, pesticides and fertilizers, washing)

Only clean water should be used for berry production and, as with leafy greens (EFSA BIOHAZ Panel, 2014), water from contaminated sources represents a major risk factor for contamination with pathogens. Risks can be minimised by growers identifying the sources of water used on the farm (mains water, re-used, irrigation water, reclaimed wastewater, discharge water from aquaculture, well, open canal, reservoir, rivers, lakes, farm ponds, etc.). Risks posed by water should be minimized by assessing the microbial quality (e.g. detected levels of faecal indicators) of the sources of water used on the farm. This should include documented checks detailing the potential for microbial contamination from all possible human and/or animal faecal sources of contamination (e.g. from animals, human habitation, leaks from in field sanitary facilities, sewage treatment, manure and composting operations) and the water's suitability for its intended use. In the case of identified contamination sources, corrective actions should be taken to minimize the risk of contamination arising from the use of water on the farm. The effectiveness of corrective actions should be verified. Identifying and implementing corrective actions is a means of preventing or minimizing contamination of water used for primary production (e.g. settling or holding ponds) that are used for subsequent irrigation and/or harvesting but which may attract animals or birds and increase the microbial risks associated with the use of such water for irrigation. Possible corrective actions may include fencing to prevent large animal access, proper maintenance of wells, filtering water, not disturbing the sediment when drawing water, building settling or holding ponds, and use of water treatment facilities. Analytical testing may be necessary for assessment after a change in irrigation water source, flooding or a heavy rainfall, when water is at a higher risk of contamination.

There is a risk of pre-harvest contamination of berry fruit with Norovirus if the fruit is spray-irrigated, or pesticides applied in faecally contaminated water. The presence of three Norovirus genotypes in samples of strawberries linked to a large outbreak of gastroenteritis in Germany in 2012 (Mäde et al., 2013) raises the possibility that the fruit had been exposed to sewage contamination during pre-harvest. Maunula et al. (2013) detected Norovirus GII in 2/56 samples of irrigation water used in a strawberry fruit production site, at an average estimated concentration of 1.1×10^3 genome

[12] Commission Regulation (EU) No 142/2011 of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive. OJ L 54, 26.2.2011, p.1-254.

equivalents/l[13]. Contact with contaminated irrigation water could expose berry fruit to Norovirus, particularly if the water is delivered by spray irrigation, e.g. by overhead sprinklers. Norovirus also may be capable of survival in water used for pesticide application (Verhaelen et al., 2013b), and spraying pesticides using faecally contaminated water could result in Norovirus-contaminated berry fruit.

3.4. Equipment

Risks associated with contamination and cross-contamination from equipment and handling were previously identified for leafy greens (EFSA BIOHAZ Panel, 2014). These risks can occur at any point in the farm-to-plate continuum and are equally applicable to berry production, and cross-contamination of food contact surfaces by workers handling contaminated berries is also possible. In some countries, when many small producers are involved, central collection points are used prior to transportation to freezing processors.

Salmonella survives better on cut strawberries than on intact fruits (Knudsen et al., 2001), fruit damage is likely to be a risk factor for the contamination and persistence of pathogens during production and storage of berries. Therefore, poor handling of berries both in the field and at packing stations is detrimental to both fruit quality and safety. Damage can occur to berries as a result of sharp edges or poorly designed storage containers. Since increased spoilage and quality deterioration will occur as a result of fruit damage, there is likely to be increased manual handling by pickers and packers to sort into categories and remove substandard fruit. Stals et al. (2013) demonstrated that Norovirus GII4 could be transferred from gloves to a stainless steel surface and then to foodstuffs, and vice versa. Risks can be reduced by field packing berries into consumer ready containers where they will not be washed until final use (e.g. strawberries). This minimizes the possibility of damage and microbial contamination through additional handling steps. Growers should ensure that clean pallets and containers (disinfected where necessary, particularly if not single use) are used and take measures to ensure that the containers do not come into contact with soil, water and manure during field packing operations. In soil-less culture, the equipment used to grow berries must be kept clean to prevent risks of contamination with human pathogens. Soil-less culture of berries requires the substrate and associated equipment to be disinfected to prevent infection by plant pathogens (EFSA, 2014). This will also presumably contribute to reducing the risk of contamination by human pathogens.

3.5. Worker health and hygiene, worker training

People working with leafy greens eaten raw as salads can transfer microorganisms of significant public health concern to plants by direct contact (EFSA BIOHAZ Panel, 2014) and this risk is also important for berries, particularly as they are often consumed whole and do not have outer parts which are removed. Poor hygienic practices by agricultural workers in the field (including leakage from portable toilets to fields and in-field defecation) has also been identified as potential source of contamination (Suslow et al., 2003) and these poor practices as well as deliberate contamination with faecal material will also significantly increase the risk of contaminating berries. Good hygienic practices during pre-harvest, harvest and post-harvest activities are essential. Since ready-to-eat berries, especially strawberries and raspberries are seldom, if at all, harvested mechanically, and are therefore handled extensively during harvest, personal hygiene including attention to clothing and gloves is critical when manual harvesting. The health and hygiene of fruit pickers are critical factors

[13] In this study, a most probable number approach was followed using end-point detection of RTPCR signal in dilutions of nucleic acid extracted from the sample, and the data were expressed as 'PCR-detectable units' (PCRU). However, in this Opinion any such data will be expressed as 'genome equivalents' on the supposition that the lowest PCRU may represent amplification of one target RNA molecule, and to facilitate a harmonised comparison of findings of different studies. It should be noted however that due to the lack of culturable Norovirus (and consequently well-established reference materials), detection and quantification limits may differ depending upon the exact experimental conditions used in the cited works.

The term 'genome copies' has been used in some publications to describe data obtained using a calibrated quantitative RT-PCR as a detection assay. However it is possible that RNA fragments containing the primer sequences can be detected and therefore 'genome equivalents' is used in this Opinion.

influencing Norovirus (and other pathogen) contamination and failure to adhere to hand hygiene is one of the major risk factors for contamination. The level of excretion of Norovirus by infected food handlers can be very high (EFSA Panel on Biological Hazards (BIOHAZ), 2012), and poor-compliance with good hygienic practices by infected handlers is likely to result in hand contamination whether they are symptomatic or asymptomatic. Maunula et al. (2013) found some berry pickers' hands to be contaminated with enteric viruses (human adenovirus). Contamination of handler's hands will lead to contamination of handled berries. Sharps et al. (2012) reported that 60, 58 and 4 % of human Norovirus on gloved fingertips could be transferred to blueberries, grapes and raspberries respectively. Cross-contamination via food handlers' gloves is also a risk factor. Verhaelen et al. (2013a) found that approximately 11 % of murine Norovirus artificially inoculated onto raspberries could be transferred to the fingertips of nitrile gloves after touching the produce for 5 sec, and 0.1 – 0.5 % of murine Norovirus on a glove fingertip could be transferred to the surface of a berry by touching.

Risks of foodborne pathogen contamination can occur due to cross-contamination with microorganisms associated with harvesting methods and can be via soil or extraneous debris on the fruit during and after harvesting. An analysis of outbreaks linked to fresh produce in the US identified that fruits (not berries) that had been dropped on the ground or were in contact with the soil represented a factor that could increase the risk of contamination of intact fruits with bacterial pathogens (Sivapalasingam et al., 2004). Poor sorting and selection of berries is a risk factor for contamination, and in order to prevent cross-contaminating healthy berries during harvest, harvest workers should not handle diseased, damaged or fallen fruit in the field. Failure to segregate and remove culled fruit from the field is a risk factor for contamination of healthy fruit, which will further attract pests and encourage spoilage.

3.6. Conclusions

The risk factors for the contamination of berry fruits with *Salmonella* are poorly documented in the literature, with limited available data, but are likely to include the following, based on what is known for other pathogens or other fresh produce:

- Environmental factors, in particular proximity to animal rearing operations and climatic conditions that increase the transfer of pathogens from their reservoirs to berries;
- Contact with animal reservoirs (domestic or wild life) gaining access to berry fields;
- Use of untreated or insufficiently treated manure or compost;
- Use of contaminated agricultural water either for irrigation or for application of agricultural chemicals such as fungicides;
- Contamination and cross-contamination by harvesters, food handlers and equipment at harvest or post-harvest.

The risk factors for the contamination of berry fruits with Norovirus are also poorly documented in the literature, with limited available data, but are likely to include the following, based on what is known for other pathogens or other fresh produce:

- Environmental factors, in particular climatic conditions (e.g. heavy rainfall) that increase the transfer of Norovirus from sewage or sewage effluents to irrigation water sources or fields of berries;
- Use of sewage-contaminated agricultural water either for irrigation or for application of agricultural chemicals such as fungicides.

- Contamination and cross-contamination by harvesters, food handlers and equipment at harvest or post-harvest.

There is no information on the potential for *Salmonella* or for Norovirus to internalise within berry fruit or plants.

For both *Salmonella* and Norovirus, processes at primary production which wet the berries represent the highest risk of contamination with both pathogens, and these include spray application of agricultural chemicals such as fungicides and, if it is applied, the use of overhead irrigation.

4. Description of processing methods for berries

After harvest, berries are sorted, packaged and stored. Berries may be subjected to minimal processing such as cleaning, cutting, washing and mashing as well as freezing. Production can be highly seasonal, with premium product entering the fresh market but the same manufacturers may switch to frozen product based on price, demand or when there is an excess of fresh product. Minimally processed perishable berry products exist, but they currently represent a minor part of the market and include juices prepared using minimal or no heat treatment, or through high hydrostatic pressure treatment (fruit juices or fruit-based drinks). These products may be prepared from fresh or frozen berries.

Processed berry products that are shelf-stable, some of which have undergone a heat treatment including cooking, drying, jams, preserves, heat treated fruit juices, are outside the scope of this Opinion. Most of these treatments are likely to inactivate Noroviruses and pathogenic bacteria such as *Salmonella*.

Processing of fresh produce, including fruits and berries, has been described in a previous Opinion (EFSA Panel on Biological Hazards (BIOHAZ), 2013) and will not be described here in detail. Fresh berries are often directly picked into punnets and sold in that state, or they may be repackaged at the processing plant. Berries are generally not washed (although there are some exceptions) but may receive a fungicidal treatment (see below). As with leafy greens (EFSA BIOHAZ Panel, 2014), the quality of the water, if used, for washing berries is a key consideration. Where berries are washed this will have some effect on reducing the microbiological flora (including pathogens) but it may also result in cross-contamination if the microbial quality of the process water is not controlled using a disinfectant treatment. Thus, the main goal of using disinfection agents will be to avoid cross-contamination between different batches of berries. Washing raspberries and strawberries was shown to result in approximately 1 log_{10} cfu/g reduction in a mixture of five serovars of *Salmonella enterica* (Agona, Baildon, Gaminara, Michigan, and Montevideo) (Bialka and Demirci, 2007b). Similar results from washing alone were reported by Lukasik et al. (2003) for *Salmonella enterica* serovar Montevideo inoculated onto strawberries. A slight increase in the effect of washing on reducing *Salmonella* contamination of strawberries was reported after the addition of sanitizing agents into the washing process (Raiden et al., 2003). As stated for leafy greens (EFSA BIOHAZ Panel, 2014), chlorine-derived compounds are the sanitizers most frequently used during washing in commercial facilities.

Optimal storage is between 3 and 5 ^{o}C with a shelf-life of about 1 week, although for certain berries this is much longer, for example, blueberries have a shelf-life of 2 to 3 months and red currants 5 to 6 months (Freshfel information, Appendix A).

4.1.1. Mashing, freezing, unpasteurised juicing

Freezing is an important processing method for berries (e.g. 95 % of the raspberries produced in Serbia, one of the main raspberry producers in the world and the main exporter to EU, are frozen (Djurkovic, 2012). Before being frozen, berries are loaded onto conveyor belts and manually graded. Freezing can be done according to different techniques (FAO, 2005). This can be as 'individually quick frozen fruits (IQF)' for the highest quality, or bulk frozen as 'crumble' which are in turn often used as input to make purées or juices and the purées further serve as an ingredient for other berry flavoured/supplemented food products (such as yoghurts, smoothies, drinks, ice creams, etc). Crumble may be a more risky product as damaged fruit from multiple production runs are combined and traceability during production and during processing can be very poor. Some berries are washed with water of potable quality (with possible addition of chlorine in the water) before freezing (e.g. strawberries and blueberries), but the most fragile types of berry (e.g. raspberries, blackberries) are not washed (Freshfel information, Appendix A). The washing step of berries, if applied, is intended to remove dirt and dust rather than having the purpose of accomplishing a microbial reduction. The manual removal of organic matter (e.g. stalks, calyx and other inedible parts) is also important as frozen berries with a lot of organic matter may be rejected later by recipients and this will involve greater handling prior to freezing. However, it is important for the scope of this Opinion to indicate that, unlike certain other types of fresh produce, berries are not blanched prior to freezing (EFSA Panel on Biological Hazards (BIOHAZ), 2013) although in the production of purées, berries are usually subjected to a mild heat treatment (e.g. 30 sec at 70 °C) which will accomplish some microbial reduction. However, IQF berries do not undergo any treatment that would eliminate or substantially reduce pathogenic bacteria or viruses if these are present. Concerning the origin of the frozen products, the highest quality (e.g. IQF) are more likely to have been picked by hand, whereas lower quality product may be mechanically harvested. For strawberries, the calyx is usually removed by hand before freezing, adding an additional handling step (Freshfel information). Sucrose or citrate may be added to some frozen products, particularly if a cutting step is included as with some strawberries (FAO, 2005).

Freezing establishments can be in separate locations from the growers, and berries from multiple small-scale growers may be consolidated into larger frozen batches of fruit. In addition, secondary consolidation of smaller batches of frozen berries together with mixing of berry species and varieties from different manufacturers (including different countries of origin) occurs while the fruits are frozen. The shelf life of frozen product can be up to 24 months or more.

Salmonella is able to survive freezing (Jay, 2004), and the bacterium has been shown to survive on frozen whole strawberries (Knudsen et al., 2001) as well as in juices and purées of strawberries (Duan and Zhao, 2009; Huang et al., 2013). For example, the survival of *Salmonella* during freezing of strawberry purée was demonstrated by Huang et al. (2013). Fresh strawberry purée was artificially contaminated with high (~6 log cfu/g) and low (~3 log cfu/g) levels of *Salmonella* spp. and stored at −18 °C for 12 weeks. *Salmonella* (a mixture of serovars: Saintpaul, Newport, Montevideo, Stanley) declined in frozen fresh strawberry purée at an average rate of 3 to 3.5 $\log_{10}$ over one month storage at -18 °C, with a faster decline of 2 $\log_{10}$ in the first 10 days (Huang et al., 2013). The bacterium was recovered from purée contaminated at both high and low levels after 4 weeks and from the higher contamination level after 12 weeks (Huang et al., 2013). A much more rapid decline was reported by Duan and Zhao (2009) for *Salmonella enterica* serovar Enteritidis in frozen strawberry juice: 6 $\log_{10}$ and 7-8 $\log_{10}$ reductions after respectively 1 and 2 days storage followed by thawing. Although *Salmonella* declines during freezing of whole berries and berry products, it is not possible to use freezing to assist the definition of a critical control point to ensure the absence of this pathogen. *Salmonella*-contaminated frozen berries are likely to be infectious if consumed after a short storage period. There are limited data describing the survival of *Salmonella* on whole frozen berries, and the addition of sucrose in frozen berry products may improve survival of *Salmonella*, as shown for *E. coli* O157 (Knudsen et al., 2001).

The presence of Norovirus in frozen raspberries has been linked to outbreaks of gastroenteritis in Finland (Sarvikivi et al., 2012) and in frozen strawberries associated with a large outbreak in Germany (Mäde et al., 2013). The fruits implicated in these outbreaks had been frozen, which demonstrates the capacity of these viruses to survive and remain infectious after undergoing a freezing process. Outbreaks of hepatitis A infection have also been linked with frozen berry fruit (Gillesberg Lassen et al., 2013; Rizzo et al., 2013). Freezing is unlikely to have a major effect on the infectivity of Norovirus. Richards et al. (2012) found that the capsid integrity and the genome copy number of human Norovirus GII.4 remained stable after 120 days storage at -80 ºC, and also after 14 freeze-thaw cycles at the same temperature. Butot et al. (2009) examined the effect of freeze-drying on human

Norovirus GI and GII on berry fruits (blackberries, blueberries, raspberries and strawberries). They measured the effect of freezing on the number of genome copies detectable before and after the process, which involved freezing berries at -20 °C for up to 48 h and then using a combination of vacuum and heating to 55 °C. They found reductions in Norovirus genome copies of between 0.63 and 2.67 logs although the impact on infectivity of the virus is not known. It is therefore probable that lowering the temperature of berry fruits will not reduce the potential for Norovirus to remain infectious. The effect of mashing and juicing on Norovirus infectivity has not been studied.

High hydrostatic pressure is increasingly being used to stabilize non thermally treated fruit juices and obtain products with superior sensory quality (Nguyen-The, 2012). In strawberry purée, a reduction of at least 5 log_{10} of *Salmonella enterica* (a mixture of 4 serovars Montevideo, Newport, St-Paul and Stanley) was obtained for pressures equal or higher than 300 MPa applied for 20 min at 21 °C (Huang et al., 2013). When used to decontaminate strawberry purée before freezing, the same reduction was obtained after a few days storage at -1 °C for lower pressures, between 200 and 300 MPa (Huang et al., 2013). According to this study, high hydrostatic pressure should reduce the risk of *Salmonella* in processed strawberries, to a similar extent as for thermal treatments usually applied to fruit juices. However, the impact of high hydrostatic pressures on *Salmonella* depends greatly on the *Salmonella* serovars and on the fruit substrate (Nguyen-The, 2012). Using a receptor-binding assay to provide an indication of virus inactivation, Li et al. (2013) treated blueberries artificially contaminated with Norovirus GI.1 with high hydrostatic pressure. Both blueberry samples which had been dried, and which were immersed in water, were tested. After treatment with HHP at 600 MPa 2 min at 21°C, a receptor-binding reduction of >3 log was observed in virus on water-immersed blueberries, whereas the binding reduction was only 0.9 log in Norovirus on dried blueberries.

5. Risk factors for microbiological contamination during processing treatments

After harvest, microbiological risk factors for berries are those that allow survival of pathogens acquired during cultivation and harvest. Cross-contamination from water, plant or machinery as well as via food handlers may also occur. The most relevant risk factors during processing are environmental factors, water sources (if used for washing or for other treatments), equipment, worker health and hygiene.

5.1. Influence of berries composition on the risk in raw and processed products

Berries have a high water content (85 % to 92 % depending on species), pH range between 2.7 (cranberries) and up to 4.5 (some blackberries) with some variation within the same berry species (e.g. pH range between 3.2 and 4.1 for strawberries) (Knudsen et al., 2001), and significant amounts of nutrients (Lund and Snowdon, 2000). The high sugar levels and low pH are conducive to growth of yeasts and moulds where spoilage occurs. The low pH conditions are not favourable to *Salmonella* growth, but may permit some survival. *Salmonella* (various serotypes) declined when inoculated on the surface of intact strawberries (Knudsen et al., 2001; Siro et al., 2006), and raspberries (Siro et al., 2006). However, the surface environment of intact berries is different to that of cut fruits in terms of humidity and pH, depending on the degree of leakage from the inner tissues of the fruit, the pH and available nutrients. Knudsen et al. (2001), observed survival without decline of various serotypes of *Salmonella* on the surface of cut strawberries over the whole shelf-life of 7 days at both 4 °C and 2 °C.

Naturally occurring phenolic compounds from juices of various berries including cranberries, lingonberries, raspberries, blueberries, strawberry, cloudberries, bilberries, blackcurrants and sea buckthorn berries, extracted and added to various growth media, inhibited growth of *Salmonella* (Puupponen-Pimiä et al., 2001; Ryan et al., 2001; Puupponen-Pimiä et al., 2005; Kylli et al., 2011; Park et al., 2011), possibly by destabilization of the bacterial outer membrane (Alakomi et al., 2007). For example, in strawberry juice (pH 3.7) stored at -23 °C before thawing to 7 °C, *Salmonella enterica* serovar Enteritidis declined by 3 to 5 log_{10} in 5 days (Duan and Zhao, 2009). Also, a mixture of 5 *Salmonella enterica* serovars (Enteritidis, Gaminara, Hartford, Muenchen and Rubislaw in both stationary-phase and acid-adapted bacterial cells) showed at least a 5-log reduction in numbers after a 6 or 24 h incubation in cranberry juice (Enache and Chen, 2007) as well as on whole cranberries

(Nogueira et al., 2003; Magariños et al., 2008; Cesoniene et al., 2009; Kylli et al., 2011). The importance of these antimicrobial effects is unclear given the minimal processing which berries are subjected to.

Berry juices are not likely to be a favourable substrate for *Salmonella* survival, but one *Salmonella* Panama outbreak described in a previous EFSA Opinion (EFSA Panel on Biological Hazards (BIOHAZ), 2013) was caused by fresh raspberry juice. The inhibitory activity of berry juices or berry juice components against *Salmonella* reported in several studies is therefore not sufficient to ensure safety of unpasteurized juice. A short delay between preparation, contamination of the juice and its consumption (see Section 6) may permit the survival of *Salmonella* which can then cause illness if consumed.

5.2. Environmental factors

Environmental factors refer to the specific conditions of the processing area, which may potentially have an impact on the safety of the berries. The risk factors concerning the processing environment are likely to be the same as or similar to those described for leafy greens (EFSA BIOHAZ Panel, 2014), although they are not documented in specific studies. Avoiding access to the storage and processing environment by animals, birds, insects and rodents is particularly important as they could carry pathogens and present a risk of contaminating berries or the environment. Preventing transport of dirt (soil, plant debris, dust etc) into the processing plant, and avoiding cross-contamination e.g. between processed product and wastes or from contaminated product, is also important.

5.3. Water sources (washing and other uses)

Most berries intended for direct consumption are generally not washed by the producer or processor after harvest and therefore the risks from wash-water identified for leafy greens (EFSA BIOHAZ Panel, 2014) are less relevant for most berries. However, for those berries that are washed, water could be a vehicle of contamination as described for leafy greens (EFSA BIOHAZ Panel, 2014). Other uses of water (e.g. for refreshing, cooling, fungicide application, ice or other uses) may also be potential sources of contamination.

5.4. Equipment

Risks from contamination via process equipment were previously discussed for leafy greens (EFSA BIOHAZ Panel, 2014). However as outlined in the previous section, berry damage can occur from improper, careless and poor handling during packing, for example from sharp edged or poorly designed storage containers and is likely to lead to increased spoilage as well as greater handling (see Section 3.4). Adherence of *Salmonella* on processing equipment may become a source of contamination for berries. A *Salmonella* outbreak caused by contaminated fruit juice in the US was attributed to a lack of processing equipment cleaning (Cook et al., 1998).

5.5. Worker health and hygiene, worker training

The risk from all workers including food handlers are similar for those described for leafy greens (EFSA BIOHAZ Panel, 2014) as well as for any other sectors processing ready-to-eat foods. Cross-contamination of surfaces by workers handling contaminated produce is possible. Stals et al. (2013) demonstrated that Norovirus GII.4 could be transferred from gloves to a stainless steel surface and from there to foodstuffs, and vice versa. In particular, berries are subjected to extensive handling before processing, in particular for whole or cut frozen fruits, which must often be graded and trimmed by hand (e.g. removal of calyx or cutting into sections for strawberries). The risk of contamination with Norovirus from workers excreting the virus is particularly important as described in the above section for primary production and harvest. In addition, freezing of berries should be carried out as soon as possible after harvest, and where freezing equipment is close to production areas, there is a risk that workers may transport soil and dirt from the field inside the plant.

Thus, lack of compliance of workers with Good Manufacturing Practices (GMPs) and Good Hygiene Practices (GHPs) and failure to adequately implement food safety management systems including HACCP will present microbiological risks in berry processing. These systems include adequate training as well as both hand washing and toilet facilities, which are further considered in later sections (see Section 12).

5.6. Conclusions

The internal contents and juices of berries generally have a low pH and can contain antimicrobial phenolic compounds. During minimal processing, contamination and cross-contamination via equipment, water (if washing is applied) and particularly via food handlers are the main risk factors for berries for both *Salmonella* and Norovirus.

Data from outbreaks associated with strawberry and raspberry consumption indicates that Norovirus is able to persist on the surface of fresh and frozen berries. *Salmonella* will also show some persistence on the surface of whole, cut and frozen strawberries and raspberries but will decline over time. There is limited or no data on the persistence of these pathogens on the surfaces of other species of berry.

For *Salmonella*, the risk of cross-contamination during washing is reduced if disinfectants are properly used within the washing tank. The effectiveness of disinfectants against Norovirus is not fully defined due to the lack of an infectivity assay.

6. Description of the distribution, retail and catering including domestic and commercial environments for berries

A high proportion of berries consumed in the EU are imported from non-EU countries, mostly as frozen berries. Most fresh berries have a short shelf life and must be distributed and consumed rapidly. Some may be imported from non-EU countries (e.g. Morocco, Freshfel information, Appendix A). Storage, transport and retailing of berries will be carried out under refrigeration, in particular for berries shipped over long distances. However some may be transported at ambient temperature (e.g. for products sold locally). MAP or controlled atmosphere are commonly used for berries shipped over a long distance. Berries may be packaged in trays exposed to air, or under various types of polymeric films, or in boxes.

Distribution practices for fresh berries can be diverse, however they usually involve several stages of transport and storage, with the possibility of packaging, re-packaging and handling. Transport and distribution can be done at chilled or ambient temperature, in a variety of packaging formats and units, depending on the type of product, the region and the season. Distribution of berries is done via various retail outlets ranging from large supermarkets, to small shops or public markets, for both packaged and loose products. Berries are also sold as a loose product as well as products in salad bars at both retail and in catering, sometimes allowing for self-selection and service by the consumer. Washing of product may take place in a similar manner to that outlined in primary processing, but is more likely to be in sinks with running potable water used for general food handling. Some use of water to refresh product may also take place. As stated previously, fresh berries require optimal storage of between 3 and 5^{o}C with a shelf life of about 1 week, although for certain berries this is much longer: blueberries for 2 to 3 months and red currants for 5 to 6 months in particular if stored near to 0 °C and in controlled atmosphere (Freshfel information, Appendix A).

Frozen berries can be produced in EU countries but are also imported from non-EU countries, and can be transported over long distances.

Fresh, as well as frozen, berries can be prepared as whole or cut fruit. These can be consumed as the sole ingredient or added to other products (e.g. fruit salads or ‘frutti di bosco’) both commercially and in domestic environments. They can also be used for production of unpasteurised juices and ‘smoothies’ (again sometimes mixed with other fruits and vegetables) usually for immediate consumption or with very short shelf lives. Fresh or frozen berries can be added together as purées or compotes. Strawberry compote made with (insufficiently cooked) frozen berries was the food type associated with the large Norovirus outbreak in Germany (BfR, 2012). Overall, it can be inferred from the existing literature data that noroviruses can tolerate a low pH value and that at a temperature range above 70 °C they lose infectivity depending on the holding time applied. Heating strawberry compote to core temperatures of above 90 °C and/or long holding times in the temperature range above 70 °C seems to be a suitable way to completely deactivate the virus. The precise time/temperature combination above which Norovirus infectivity is eliminated is unknown. In the German incident, kitchens not associated with an outbreak almost exclusively served the strawberries after boiling, but the exact core temperatures that were reached during the heating processes are unknown (BfR, 2012).

Fresh and frozen berries are frequently used as ingredients of other processed products, such as cakes, pastries, desserts, many of which are prepared by the caterer or in the bakery, often without further treatment likely to kill *Salmonella* or inactivate Norovirus. These products include composite products such as confectionery, yoghurt, ice cream etc. In such preparations, berries may be incorporated together with other ingredients which could promote growth of *Salmonella* if present on berries, whereas the bacterium would have only survived or declined on the berry alone (see section above on the influence of berries composition).

7. Risk factors for microbiological contamination during distribution, retail and catering including domestic and commercial environments

Risk factors during distribution, retail and catering for berries are likely to be the same or similar to those for leafy greens (EFSA BIOHAZ Panel, 2014), although they are not generally supported by published studies. The primary risk factors are contamination from the environment (e.g. hygiene of premises and storage rooms), cross-contamination through direct or indirect contact with contaminated water or equipment or handling by infected persons.

A particular difference between berries and leafy greens is the use of frozen berries as an ingredient in many products and preparations. The origin of frozen berries (particularly when mixed) can be very diverse which can make traceability challenging in the event of a problem. The risk for caterers of using frozen berries, imported from third countries and not produced and processed according to EU hygiene standards, must be considered.

7.1. Water sources (washing)

As previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014), water that has been contaminated with bacteria and viruses, and is then used in food preparation, can cause contamination of berries. This represents a similar contamination or cross-contamination risk to that which can occur during processing (see Section 5.2). It has been shown that viruses (including Norovirus) can be transferred from contaminated liquid to the surfaces of berries (Rodriguez-Lazaro et al., 2012). There is no direct experimental evidence for transfer of bacterial foodborne pathogens to berries by this route, although it has the potential to occur.

7.2. Equipment

There is the potential for Norovirus contamination from various food products to spread via cross-contamination through contact with food processing or preparation surfaces as previously discussed (EFSA BIOHAZ Panel, 2014). For example, this could occur through cutting of a contaminated item followed by using the same utensil to cut uncontaminated items without adequate cleaning between each steps.

Due to the wide diversity of foodstuffs potentially prepared and handled in catering establishments, cross-contamination of berries from foodstuffs more frequently contaminated with *Salmonella* or other pathogens is a risk factor. The same risk of cross-contamination may exist at retail for berries, although this has not been documented, probably because there is generally adequate segregation between berries and other types of foods.

7.3. Worker health and hygiene, worker training

Contamination of leafy greens with both *Salmonella* and Norovirus through contact with the hands of infected persons during preparation was previously discussed (EFSA BIOHAZ Panel, 2014), and similar risks occur with respect to the contamination of berries. Poor hand hygiene (e.g. not washing thoroughly) following use of toilet facilities prior to handling of foodstuffs is an important and universal risk factor for contamination of food.

7.4. Storage temperature

Norovirus does not multiply in foods. Storage temperature influences the risk only to the extent of its persistence on the surface of contaminated berries. However since it is not possible to perform infectivity assays, there is no information on the relative persistence of Norovirus on berries at different storage temperatures. *Salmonella* is not able to grow on fresh strawberries (Knudsen et al., 2001) and the influence of storage temperature on its survival is not known. There is no specific information on the behaviour of *Salmonella* on other fresh berries.

7.5. Conclusions

At distribution, retail and catering and in domestic and commercial environments, cross-contamination of items, in particular via direct or indirect contact between contaminated food and berries together with poor hygiene from food handlers are the main risk factor for *Salmonella*. These cross-contamination risks include the salad bar environment.

At distribution, retail and catering and in domestic and commercial environments, the Norovirus-infected food handler is the main risk factor for contamination. This can be direct via poor hand hygiene or indirect via food contact surfaces that have been subjected to cross-contamination. These contamination and cross-contamination risks include the salad bar environment.

The use of contaminated water for washing of berries is a risk factor for both *Salmonella* and Norovirus contamination.

A particular feature of berries is their widespread use as a frozen ingredient of many and diverse products and preparations. Mixing batches of frozen fruit (including mixtures of different berry species) can present difficulties in traceability.

8. Analytical methods for the detection and enumeration of *Salmonella* in berries - Standardisation of methods for detection and enumeration of *Salmonella* in berries

As previously outlined (EFSA BIOHAZ Panel, 2014), methods for detection of *Salmonella* spp. in FoNAO are well developed, and analytical reference methods are standardised and widely adopted across laboratories testing food, including that for Official Control: EN/ISO standard method 6579[14] is prescribed in Regulation 2073/2005[15] when analysing pre-cut ready-to-eat fruit and vegetables in the scope of the verification of compliance with the currently established food safety microbiological criterion for *Salmonella* spp.. Alternative methods based on modifications of the ISO method using alternative enrichment media or isolation media (chromogenic media) or using immunoassays and real time PCR are also available for rapid detection of *Salmonella*, and many of these methods have been ISO 16140 validated showing performance characteristics equivalent to the EN/ISO standard method 6579 (EFSA BIOHAZ Panel, 2014).

[14] EN/ISO 6579:2002. Microbiology of food and animal feeding stuffs - Horizontal method for the detection of *Salmonella* spp. International Organization for Standardization, Geneva, Switzerland.

[15] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. OJ L 338, 22.12.2005, p. 1-26.

9. Data on occurrence and levels of *Salmonella* in berries

There is no routine or regular monitoring of berry fruits for the presence of *Salmonella* in EU Member States and the very limited prevalence data on the rates of contamination of berries by *Salmonella* in the peer-reviewed literature only relates to fresh strawberries. There is limited data relating to the testing of strawberries or strawberry juices, however no information pertaining to contamination of other types of berries is available (Table 1). It is not possible to include prevalence data on contamination of berries by *Salmonella* within Zoonoses monitoring data (according to the Directive 2003/99/EC[16]) since these data are aggregated within broad food categories, e.g. the single category of vegetables and fruits.

[16] Directive 2003/99/EC of the European Parliament and of the Council of 17 November 2003 on the monitoring of zoonoses and zoonotic agents, amending Council Decision 90/424/EEC and repealing Council Directive 92/117/EEC. OJ L 325, 12.12.2003, p. 31-40.

Table 1: Occurrence of *Salmonella* in berries

Sampling place	Commodity	Country	Detection method	Number of samples analysed	Number of positive samples	% of positive samples	95 % CI[(a)]	Sample size	Reference
Production	Fresh strawberries	South Korea	Direct subculture of a homogenate onto Rambach Agar	36	0 [(b)]	0	[0,6.7]	10 g	(Yoon et al., 2010)
Retail markets	Fresh strawberries (domestic (n=94), imported (n = 77), unknown (n=2))	Norway	Pre-enrichment using NMKL 71, screened by immunoassay (Bioline) and confirmed by culture NMKL 71	173	0	0	[0,1.4]	25 g	(Johannessen et al., 2002)
Retail farmers' markets	Fresh strawberries	Canada	Health Canada MFLP-29	31	0	0	[0,7.7]	25 g	(Bohaychuk et al., 2009)
Retail	Strawberry juice	Greece	American Public Health Association Compendium of methods for the Microbiological Examination of Foods 2001	3	0	0	[0,53.6]	50 ml	(Vantarakis et al., 2011)
Import	Fresh strawberries	USA from various countries [(c)]	NS	143	1	0.7	[0.1,3.2]	16 oz	(U.S. FDA, 2001)
Farm	Berries [(d)]	USA	FDA BAM	194	0	0	[0,1.3]	25 g	(Mukherjee et al., 2006)

NS = not stated

(a): The credible interval was calculated using a Bayesian approach and taking as prior beta (1/2,1/2) (Miconnet et al., 2005)

(b): *Salmonella* detected on strawberry leaves from a single greenhouse at 1.7 log cfu/leaf, as well as from harvest bins and workers gloves.

(c): Argentina, Belgium, Canada, Mexico, New Zealand

(d): Fresh strawberries, raspberries and blueberries

10. Analytical methods for the detection and enumeration of Norovirus in berries - Standardisation of methods for detection and enumeration of Norovirus in berries

Information on the standardisation of methods for detection of Norovirus in foods can be found in Section 4.3.2 of the Scientific Opinion of the EFSA BIOHAZ (EFSA Panel on Biological Hazards (BIOHAZ), 2011b).

There are two ISO/CEN methods[17], which are currently available for Norovirus detection and quantification respectively on berries. These methods have now the status of a Technical Specification (TS) and, based upon validation data, will need to be to reviewed three years after initial publication before becoming a full International Standard (ISO, online). The methods are technically complex, and their performance strictly according to their technical specifications can only be carried out in specialised and well-resourced laboratories with skilled personnel. In particular, the production of the nucleic acid controls is challenging, and the availability of reliable quality control materials and external quality assessment (EQA) schemes will be necessary before there can be complete confidence in the concordance of results between laboratories. These ISO/CEN methods are currently technical specifications and have the opportunity to be further refined with regard to sampling, sample preparation, limit of detection and interpretation of results.

11. Data on occurrence of Norovirus in berries

Between 2007 and 2011, 27 Norovirus outbreaks associated with raspberries and one outbreak associated with strawberries were reported in the EU (EFSA Panel on Biological Hazards (BIOHAZ), 2013). However, over the same period only one *Salmonella* outbreak was reported which was associated with fresh raspberry juice. Due to the complexity of the Norovirus detection methods and the need for further research and guidelines on interpretation of detecting Norovirus genomic copies, few studies have examined the presence of Norovirus on berries. However, most of the limited available data applies to strawberries or raspberries and techniques for the detection of this virus have not been applied to other berries produced or consumed in the EU. The recognition of Norovirus (as well as Hepatitis A virus) as a foodborne pathogen transmitted through berry consumption has only recently emerged, and this has led to the adoption of Norovirus RT-qPCR-based methods for food analysis particularly at National Reference Laboratories.

There has been no routine or regular monitoring of berry fruits for the presence of Norovirus in most of the EU Member States and there is very limited prevalence data on the rates of contamination of berries (not involved in foodborne outbreaks) by Norovirus in the peer-reviewed literature. In January 2013, following a large outbreak of Norovirus gastroenteritis in Germany in 2012 in which consumption of imported Chinese frozen strawberries was implicated, the European Commission mandated the analysis of 5 % of all batches of frozen strawberries from China arriving at European ports (Commission Implementing Regulation (EU) No 323/2014[18]). During 2013 there were 1367 consignments which were imported to the EU. Of these there were 98 physical checks each of which included testing for Norovirus in five 25 g samples. There were two non-compliances out of these 98 checks (2.0 %, 95 % C.I: [0.4,6.4][19]) resulting from the detection of this virus in at least one of the five individual samples (Appendix C, Table 24).

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[17] ISO/TS 15216-1: 2013. Microbiology of food and animal feed - Horizontal method for determination of hepatitis A virus and norovirus in food using real-time RT-PCR - Part 1: Method for quantification. International Organization for Standardization, Geneva, Switzerland.
ISO/TS 15216-2: 2013. Microbiology of food and animal feed - Horizontal method for determination of hepatitis A virus and norovirus in food using real-time RT-PCR - Part 2: Method for qualitative detection. International Organization for Standardization, Geneva, Switzerland.

[18] Commission Implementing Regulation (EU) No 323/2014 of 28 March 2014 amending Annexes I and II to Regulation (EC) No 669/2009 implementing Regulation (EC) No 882/2004 of the European Parliament and of the Council as regards the increased level of official controls on imports of certain feed and food of non-animal origin Text with EEA relevance. OJ L 95, 29.03.2014, p.12-23.

[19] The credible interval was calculated using a Bayesian approach and taking as prior beta (1/2,1/2) (Miconnet et al., 2005)

There have been few research surveys conducted on Norovirus contamination of berries and they have been limited to strawberries and raspberries (Table 2). In addition it is difficult to harmonise the data from reported studies due to differences in the sensitivities of the detection methodologies employed (Baert et al., 2011). Some raspberry samples taken during outbreak investigations have tested positive for the presence of Norovirus (Maunula et al., 2009b; Sarvikivi et al., 2012).

As part of an investigation into an outbreak of gastroenteritis, which occurred in Sweden in 2001 (Le Guyader et al., 2004), a sample of frozen raspberries, which had been used in catering, was analysed in three replicate tests, and found to contain multiple strains of Norovirus. A survey conducted in Belgium from April to May 2009, Stals et al. (2011) found 4 samples of raspberries imported from Poland/Serbia and 6 samples of strawberries imported from Spain, positive for Norovirus.

Sarvikivi et al. (2012), investigating an outbreak of Norovirus gastroenteritis in Finland in 2009, found Norovirus in 2 samples of imported Polish frozen raspberries to be positive for Norovirus; both batches contained GII.4, the same genotype as implicated in the outbreak. Maunula et al. (2009a) found Norovirus GI in three samples of imported Polish frozen raspberries taken in the scope of the investigation of three gastroenteritis outbreaks in Finland; the same genotype was detected in patients' stool samples. The samples all came from the same batch of fruit, but when 2 samples were taken from the same batch of remaining stock at the wholesaler no virus could be detected. This may have indicated that contamination of the batch was low or unevenly distributed, or that the particular berries which caused the outbreak had been contaminated by a food handler at the outbreak setting, although after the batch was withdrawn the outbreak stopped, which favours the former explanation. Maunula et al. (2013) analysing for viral contamination of the strawberries and raspberries supply chain (including at sites in Poland and Serbia) did not find Norovirus in the berries at point of sale (168 samples). Data obtained from samples collected during outbreak investigation may not reflect the overall prevalence of Norovirus in berries. Investigating the Norovirus gastroenteritis outbreak in Germany in 2012 linked to consumption of frozen imported strawberries, Mäde et al. (2013) found 7 out of 11 samples of frozen strawberries taken from catering facilities to contain Norovirus. Three samples contained both Norovirus GI and GII strains; no information is available on the genotype(s) from the affected patients.

Table 2: Occurrence of Norovirus in berry fruits

Sampling place	Commodity	Sampling country	Number of samples analysed	Number of samples where Norovirus detected	% of positive samples	95 % CI[(a)]	Numbers in positive samples	Reference
Processing company	Raspberries [(b)]	Belgium	10	4	40.0	[15.3,69.6]	2.45 – 3.7 log genome equivalents per 10 g	(Stals et al., 2011)
Processing company	Strawberries [(c)]	Belgium	20	6	30.0	[13.6,51.7]	2.29 – 4.1 log genome equivalents per 10 g	(Stals et al., 2011)
Food companies	Raspberries (n = 142) and strawberries (n = 8)	France	150	10	6.7	[3.5,11.5]	2.4 – 5.8 log genome equivalents g^{-1}	(Baert et al., 2011)
Retail	Fresh raspberries	4 European countries	60	0	0	[0,4.1]	NA	(Maunula et al., 2013)
Retail	Frozen raspberries	4 European countries	39	0	0	[0,6.2]	NA	(Maunula et al., 2013)
Retail	Fresh strawberries	4 European countries	21	0	0	[0,11.1]	NA	(Maunula et al., 2013)
Catering	Frozen raspberries *	Finland	14	2	14.3	[3.1,38.5]	ND	(Sarvikivi et al., 2012)
Catering	Frozen raspberries *	Finland	3	3	100	[46.4,100]	ND	(Maunula et al., 2009b)
Wholesaler	Frozen raspberries *	Finland	2	0	0	[0,66.7]	ND	(Maunula et al., 2009b)
Catering	Frozen raspberries *	Sweden	1	1	100	[14.7,100]	ND	(Le Guyader et al., 2004)
Catering	Frozen strawberries	Germany	11	7	63.6	[34.8,86.3]	ND	(Mäde et al., 2013)

ND = not detected
NA = not applicable
* Samples taken as part of outbreak investigation.
(a): The credible interval was calculated using a Bayesian approach and taking as prior beta (1/2,1/2) (Miconnet et al., 2005)
(b): frozen, unpublished data
(c): fresh, unpublished data

The data derived from the different studies indicated in Table 2 may not be comparable because of differences in sampling, methods and interpretation of RT-PCR results. In some of these studies Norovirus was detected in food samples collected in the absence of any known association with outbreaks (Baert et al., 2011; Stals et al., 2011). Consequently, a potential risk for infection cannot be excluded but the actual risk from RT-PCR Norovirus-positive produce is still unknown, as the infectivity of detected virus cannot currently be determined. There is a need to thoroughly evaluate the public health risk of Norovirus (genomic copies) contamination derived from pro-active screening studies in foods/environmental samples that are not associated with reported outbreaks or illness (Baert et al., 2011). However, human Norovirus is not naturally occurring in berries, and its presence whether infectious or not indicates direct or indirect contamination from human origin (faecal, vomit) and thereby that a failure in good hygiene practice has occurred at some point along the supply chain.

There is consequently no or limited prevalence data on the rates of contamination of berries by Norovirus in the peer-reviewed literature, which currently only addresses strawberries and raspberries (Table 2). So far it has not been possible to include prevalence data on contamination of berries by Norovirus within Zoonoses monitoring data (according to the Directive 2003/99/EC[20]) since these data are aggregated within broad food categories, e.g. the single category of vegetables and fruits.

12. Mitigation options to reduce the risk for humans posed by *Salmonella* or Norovirus in berries

12.1. Introduction

Many of the mitigation options previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014) are generic and equally applicable to other foods of non-animal origin, including berries. However there are some differences, which are inherent to berries. In general berries, and particularly strawberries and raspberries, are a substantially different commodity when compared to leafy greens with respect to: the production cycle, some of the processes applied to them (particularly freezing), their intrinsic characteristics (low pH) and epidemiological evidence associating their consumption with foodborne outbreaks. Berries are usually grown on bushes or herbaceous plants above the ground, and consequently soil contamination is reduced as compared with leafy greens. Berries are pulpy fruit with a high moisture content and a soft skin, which makes them particularly susceptible to physical damage, pest infestation and microbial spoilage. However, because of the high acidity (pH 2.7 up to pH 4.5) of the internal tissues they are unlikely to support the survival of *Salmonella* over extended periods. Enteric bacteria may occur on the surface of the berries under certain circumstances particularly if there has been recent direct or indirect exposure to animal or human faecal contamination however these are likely to decline. Evidence for this decline is only available for strawberries and raspberries. Evidence from outbreaks indicates that Norovirus tolerates low pH environments and will persist on both fresh and frozen berries. The long shelf life of frozen berries (several months to years) may enable better traceability of contaminated batches than for fresh berries, however in practice traceability has proved problematic for frozen berries too (ECDC and EFSA, 2014).

12.2. General mitigation options

Appropriate implementation of food safety management systems including Good Agricultural Practices (GAP), Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) should be the primary objective of operators producing berries. These food safety management systems should be implemented along the farm to fork continuum and are applicable to the control of a range of microbiological hazards. Although some intervention strategies or control measures can be defined to prevent, limit the spread or sometimes reduce the level of contamination in berries, the main focus for

[20] Directive 2003/99/EC of the European Parliament and of the Council of 17 November 2003 on the monitoring of zoonoses and zoonotic agents, amending Council Decision 90/424/EEC and repealing Council Directive 92/117/EEC. OJ L 325, 12.12.2003, p. 31-40.

food safety management should be on preventive measures, as it is difficult or not possible to define critical control points (CCPs) that either eliminate the microbial hazard or significantly reduce it. Codes of practice and guidelines should encourage the use of appropriate good agricultural and hygiene practices at farm level. Food safety management based on GMP and HACCP principles should be applied by processors, distributors, retailers and caterers involved in production of ready-to-eat berries. In addition, the responsibilities of food business operators producing or harvesting plant products require them to take adequate control measures as outlined in Regulation (EC) No. 852/2004. Where practicable, a comprehensive food safety control plan should be developed. This should include a written description for each hazard identified when assessing environmental hygiene at primary production and the steps that will be implemented to address them (EFSA BIOHAZ Panel, 2014). Production areas should be evaluated for hazards that may compromise hygiene and food safety; the evaluation should particularly identify potential sources of faecal contamination. If the evaluation concludes that contamination in a specific area is at levels that may compromise the safety of crops, intervention strategies should be applied to restrict growers from using this land for primary production of fresh or frozen products until the hazards have been addressed. Alternatively, product from higher risk areas could be sent for heat processing. Heating of frozen berries was recommended as an emergency public health measure to consumers in Ireland ('Frozen imported berries should be boiled for one minute before consumption') as a response to the outbreak of hepatitis A in 2013 (FSAI, 2013) as well as in Denmark (DVFA, 2014) and this strategy would be equally applicable for use by suppliers or manufacturers (DVFA, 2012).

Attention should be paid to the application of the above-mentioned mitigation options during production and processing in all countries of origin and traceability should be ensured. There should be complete traceability through primary production, processing, distribution, retail, and catering to consumption of all berries or berry products. Despite the legal requirements for traceability, this may be problematic to achieve where consolidation and mixing of batches of frozen berries is carried out and where these are used as an ingredient in different foods and food types.

12.2.1. Environment

As outlined for leafy greens (EFSA BIOHAZ Panel, 2014), primary production should not be carried out in areas where the known or suspected presence of pathogens could potentially be transferred to horticultural crops intended for human consumption without a validated process kill step (CAC, 1969, 2003). Preventive measures are not always easy to implement as farmers may not control adjacent land activities or the land history does not include knowledge of the extent or level of pathogens in the soil or the time necessary to reduce these to acceptable levels (Suslow et al., 2003; James, 2006; Gil et al., 2013).

Some berries come into direct contact with soil during growth and/or harvesting (e.g. strawberries). Bird droppings and airborne contaminants (e.g. from birds nesting around the packing area, nearby livestock, poultry areas or manure storage or treatment facilities, etc.) may also pose a risk of contamination to berries. Growers should use production practices (e.g. site selection, wind breaks) to minimize exposure of berries to airborne contaminants and limit contact of berries with the soil, animal droppings, soil amendments (including natural fertilizers) or direct contact with irrigation water. Contact with the soil can be reduced by the use of material used under growing berry plants to minimize contact (e.g. using mulch or biodegradable materials such as straw) as well as during harvest (e.g. plastic or biodegradable materials such as leaves or paper liners of biodegradable baskets). During berry growth, plastic surfaces, which can come into contact with berries, should be clean and sanitary. If biodegradable materials and/or mulch are used, they should be applied only once and not reused in order to prevent cross-contamination. Growers should implement safe handling, transport and storage practices and immediately cool berries after harvesting. Pre-cooling (i.e., rapid removal of field heat) of berries within the first 2 hours after harvesting is important in maintaining freshness and quality. Therefore berries should be cooled and stored as soon as possible under temperature-controlled conditions. Cooling is therefore a potential source of contamination and growers should use potable quality water for ice and hydrocoolers if used. However, since refrigerators and cold rooms are frequently used for berry storage, every effort should be made to prevent cross-contamination during handling and storage in these environments.

Berries that have undergone cleaning and/or chemical treatment should be separated, either physically or by time, from raw material and environmental contaminants. Cross-contamination should be prevented between raw and washed berries intended for freezing from sources such as wash and rinse water, equipment, utensils and vehicles. For berries that are intended to be consumed raw as well as to be frozen, sorting and selection should be implemented to avoid using fruits that have visible signs of decay or damage as these may have increased handling and increase the risk of microbial contamination.

Premises and rooms should be designed to separate areas for incoming berries from the field (areas for incoming soiled) from those used for subsequent handling (outgoing sorted berries). This can be accomplished in a number of ways, including linear product flow. Where feasible, raw material handling areas should be separated from processing/packing areas. Within each of these areas, cleaning operations should be conducted separately to avoid cross-contamination between equipment and utensils used in each operation. For products that are not immediately wrapped or packed (i.e. where berries might be exposed to contaminants from the environment), the rooms where final products are packaged and stored should be designed and maintained to be as dry as possible.

Berry packing and/or processing establishments may be seasonal, and used for only a few months per year. Consequently facilities may be dormant for many months, and this leaves them susceptible to pest infestations. Measures to minimize pest infestations should be put in place. The design should allow thorough cleaning and disinfection of all food contact surfaces and equipment including after periods when equipment has not been used such as the start of seasonal harvest.

12.2.2. Manure and sewage sludge

As outlined for leafy greens (EFSA BIOHAZ Panel, 2014), appropriate production, storage, management and use of manure and sewage sludge are important to reduce residual pathogen populations for all primary production (including berry production).

12.2.3. Water

12.2.3.1. Water in primary production

Selection of appropriate irrigation sources and avoiding, if possible, uncontrolled water sources such as rivers and lakes was previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014), and these considerations are equally applicable to berry production. Among the potential interventions, both water treatment and efficient drainage systems that take up excess overflows may be needed to prevent the additional dissemination of contaminated water. Since *E. coli* is an indicator microorganism for faecal contamination in irrigation water (as well as other uses of water such as that for application of pesticides), growers should arrange for periodic testing to be carried out to inform preventive measures. Such considerations should also be applied to the extent possible when harvesting from the wild to reduce the risk of pathogen contamination from animals and birds, as well as control of run-off. The latter may be very difficult, especially in areas allowing public access. Berries that are intended for direct consumption are generally not washed after harvest. However for berries that are washed, potable quality water should be used. It is recommended that the quality of the water used in packing establishments be controlled and monitored, i.e. using tests for indicator organisms and/or foodborne pathogens.

12.2.3.2. Process water

Mitigation strategies aiming to reduce risks of microbial contamination and cross-contamination for all water used during processing and only potable quality water should be used. This should include wash-water where used, as well as that used for other purposes (including ice).

12.2.4. Equipment

The importance of clean equipment as well as cleaning as a preventive measure to avoid contamination associated with growing and harvesting was previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014) and the same considerations should be applied for berry production and processing. Priority attention should be given to hygiene of containers used for field packing of berries which will not be washed by the harvester or processor prior their sale to the consumer. This will help minimize the possibility of microbial contamination through additional handling steps. Growers should ensure that clean pallets and containers (disinfected where necessary if not single use) are used and ensure that the containers do not come into contact with soil or manure during field packing operations.

12.2.5. Workers

The importance of standard enforceable policies and provision of training in sanitation for all employees working in primary production, processing, retail and catering was emphasised for leafy greens (EFSA BIOHAZ Panel, 2014). Compliance with hygiene requirements, in particular hand hygiene, is an absolute necessity for food handlers at all stages of the berry production and the supply chain to reduce the risks of both *Salmonella* and Norovirus contamination. Only workers who have been trained in hygienic handling should be assigned to pick, pack or process berries. It is important to minimize post-harvest handling of berries to maximise product shelf life and avoid the introduction of pathogens or other contaminants. It is also important to recognize and document field contamination indicators (e.g. broken fences, animal droppings, high incidence of insects) and take appropriate actions to mitigate associated risks. In addition, the importance of correct berry handling techniques should be emphasised to minimize or prevent damage to the fruit and associated microbial contamination. All persons involved in the handling of berries should receive hygiene training appropriate to their tasks and receive periodic assessment while performing their duties to ensure tasks are being completed with due regard to good hygiene and hygienic practices.

12.2.6. Final product

Consumers should be advised to avoid the purchase of trays or cases with damaged or rotten berries. Although neither *Salmonella* nor Norovirus will grow on these products, for quality reasons consumers should store berries in a cool environment preferably refrigerated.

Consumers should be advised on how to handle, prepare, and store berries safely to avoid cross-contamination with foodborne pathogens from various sources (e.g. hands, sinks, cutting boards, utensils, raw meat etc). They should also be given guidance on correct hand washing methods, and the need to wash fresh berries with potable water before consumption or freezing for consumption at a later date.

12.2.7. Conclusions

Appropriate implementation of food safety management systems including Good Agricultural Practices (GAP), Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) should be the primary objective of operators producing berries. These food safety management systems should be implemented along the farm to fork continuum and are applicable to the control of a range of microbiological hazards.

Attention should be paid to the quality of the water source for irrigation, agricultural chemicals (e.g. fungicides) and in particular to the avoidance of the use of water contaminated by sewage.

The existing requirements in CODEX documents or EU Hygiene Regulation for growers and producers producing or harvesting berries are very general in nature and leave room for interpretation e.g. use potable quality water, or clean water, whenever necessary to ensure that foodstuffs are not contaminated.

Apart from avoiding the use of sewage-contaminated water at all stages of the supply chain, the main mitigation options for reducing the risk of Norovirus contamination on berry fruits are adherence to hand hygiene by food handlers at all stages of the supply chain (see Section 12).

In primary production compliance with existing prerequisite programs such as Good Agricultural Practices (GAP) and with recommended Codes of Practices and guidance such as the relevant Codex guidelines, will assist *Salmonella* and Norovirus risk mitigation strategies. During processing Good Manufacturing Practices (GMP) and food safety management systems (including HACCP) will also assist *Salmonella* and Norovirus risk mitigation strategies.

Food safety management based on GMP and HACCP principles should be applied by processors, distributors, retailers and caterers involved in production of ready-to-eat berries.

The evaluation of water quality, water treatment technologies or other risk mitigation options (e.g. selection of appropriate agents for cleaning and disinfection) for Norovirus is limited by the current lack of suitable methods for *in vitro* determination of Norovirus infectivity and current Norovirus RT-qPCR-based detection and monitoring methods are unable to discriminate between infectious and non-infectious virus particles.

A high proportion of berries consumed in the EU are imported from non EU countries, mostly as frozen berries, and attention should be paid to the application of these mitigation options during production and processing in the countries of origin.

Clear information (including labelling) should be provided to consumers on appropriate handling of berries which includes specific directions for product storage, preparation, intended use, and shelf life indicators.

12.3. Specific mitigation options to reduce the risk of *Salmonella* contamination

As *Salmonella* has reservoirs in domestic as well as wild animals, birds and humans, the main mitigation options for reducing the risk of contamination of berries are to prevent direct contact with faeces as well as indirect contact through slurries, sewage, sewage sludge, and contaminated soil, water, equipment or food contact surfaces.

Most berries are fragile fruits, which are often not treated or only minimally treated post-harvest. However, in some cases, berries are subjected to post-harvest treatment (e.g. with gaseous ozone) particularly for the prevention of fungal spoilage (Freshfel information, Appendix A). Some berries intended for freezing are washed in water or chlorinated water (Freshfel information, Appendix A).

Generally berries are not washed, but for those that are, they can be immersed in a washing tank to remove dirt, soil and pesticides. As stated previously for leafy greens (EFSA BIOHAZ Panel, 2014) washing alone will have some effect in reducing the microbiological (including pathogen) biota whilst also creating potential opportunities for cross-contamination to occur, and this is equally applicable to berries. Therefore, the microbial quality of the process water could be maintained using a disinfection treatment, the main goal of which will be to avoid cross-contamination. For artificially contaminated raspberries and strawberries, washed with water alone resulted in reductions of approximately 1 log cfu/g of a mixture of five serovars of *Salmonella enterica* (serovars Agona, Baildon, Gaminara, Michigan and Montevideo; (Bialka and Demirci, 2007b). Similar results of washing with water were reported by Lukasik et al. (2003) for *Salmonella enterica* serovar Montevideo inoculated onto strawberries. A slight increase in the effect of washing with water on reducing *Salmonella* contamination of strawberries was reported following the addition of sanitizing agents into the washing process (Raiden et al., 2003).

The efficacy of different physical and chemical treatments for the reduction of *Salmonella* spp. is outlined later in this section. However, this information is often derived from experimental studies with low strength of evidence, and is difficult to extrapolate to processing conditions (e.g. artificial contamination with high doses, extended contact times, and using of potable quality water with minimal organic matter). The different experimental set up of these studies also makes the comparison between different studies difficult.

Lukasik et al. (2003) reported the effect of different treatments against *Salmonella enterica* serovar Montevideo at 10^7/ml inoculated onto strawberries. Reductions of almost 2 log units (>98 %) in numbers of *Salmonella* were obtained with sodium hypochlorite (50 to 300 ppm of free chlorine), 'stabilized chlorine dioxide' (200 ppm), peroxyacetic acid (100 ppm), and acidified sodium chlorite (100 or 200 ppm) (Lukasik et al., 2003). Hydrogen peroxide (0.5 %) and Cetylpyridinium chloride (0.1 %) were less effective than free chlorine and hydrogen peroxide caused discoloration (Lukasik et al., 2003). On strawberries, Hung et al. (2010) obtained reductions of *E. coli* O157 between 0.9 and 1.8 $\log_{10}$, depending on contact times, with solutions containing from 23 to 55 mg/l active chlorine. Aqueous solutions with a similar range of concentration of active chlorine gave a much higher reduction of the same bacteria on blueberries: 3.3 to 4.8 $\log_{10}$ (Pangloli and Hung, 2013). This may indicate differences in the efficacy of sanitizers between different types of berries, with a higher efficacy on e.g. blueberries than on strawberries.

The efficacy of chlorine dioxide as a disinfectant on berries has been tested in several studies.

- On whole blueberries, the effect of up to 15 mg/l of aqueous chlorine dioxide on reducing *Salmonella enterica* serovar Typhimurium contamination was investigated (Wu and Kim, 2007). The most effective contact times were up to 20 minutes, which resulted in a reduction of more than 3 log cfu/g. This treatment also reduced natural yeasts and moulds (Lukasik et al., 2003). In a further study, fresh blueberries were inoculated with a cocktail of 10^6 cfu/g of three *Salmonella enterica* serovars (Enteritidis, Heidelberg and Typhimurium) and exposed to gaseous chlorine dioxide (4 mg/litre, 0.16 mg/g) for 12 h in a sealed 20-litre container (99.9 % relative humidity) at 22°C (Popa et al., 2007). This treatment resulted in an approximate 4 log reduction in the *Salmonella* levels and also had the effect of reducing yeasts and moulds spoilage.

- On strawberries spot-inoculated with a mixture of 3 *Salmonella enterica* serovars, namely Basildon, Javiana and Montevideo, a high-concentration short-time chlorine dioxide gas treatment (10 mg/l for 180 seconds) achieved a reduction of almost 5 log cfu/cm^2 (Trinetta et al., 2013). In another study on strawberries inoculated with 5 serovars of *Salmonella enterica* (serovars Agona, Gaminara, Michigan, Montevideo and Poona), gaseous chlorine dioxide (100 mg in total applied during 1h) gave a more than 4.7 $\log_{10}$ reduction when *Salmonella* was inoculated on the berry surface, but only 1 $\log_{10}$ when it was 'puncture inoculated'. Sanitizers may be less efficient when used on damaged berries (Yuk et al., 2006).

Sy et al. (2005) studied the efficacy of gaseous chlorine dioxide for both its efficacy in reducing five serovars of *Salmonella enterica* (serovars Agona, Baildon, Montevideo, Gaminara and Michigan) (as well as yeasts, and moulds) and its impact on quality after treatment and during shelf life of blueberries, strawberries and raspberries. Treatment with 8.0 mg/litre of chlorine dioxide reduced the population of *Salmonella* on blueberries by 2.4 to 3.7 log cfu/g. The treatment was more effective when the inoculum was placed on the skin compared with when it was placed on the stem scar tissue. Populations of *Salmonella* on strawberries treated with 8.0 mg/ litre of chlorine dioxide were reduced by 3.8 to 4.4 log cfu/g; and a reduction of 1.5 log cfu/g raspberries was achieved.

Gaseous and aqueous ozone were evaluated for the purpose of decontaminating blueberries artificially contaminated with 5 serovars of *Salmonella enterica* (serovars Agona, Baildon, Gaminara, Michigan and Montevideo) (Bialka and Demirci, 2007a). Blueberries were exposed to 4 different gaseous ozone treatments: continuous ozone exposure, pressurized ozone exposure, and 2 combined treatments. Maximum reductions of *Salmonella* after 64-min pressurized or 64-min continuous exposure were 3.0 and 2.2 $\log_{10}$ cfu/g, respectively. Aqueous ozone experiments were conducted at 20 °C and 4 °C and no *Salmonella* was detected after 64 min of ozone exposure at 2 °C.

The addition of ozone to water for washing raspberries and strawberries was investigated by Bialka and Demirci (2007b) using fruit inoculated with five serovars of *Salmonella enterica* (Agona, Baildon, Gaminara, Michigan and Montevideo). Fruits were treated with aqueous ozone concentrations of 1.7 to 8.9 mg/l at 20 °C for 2 to 64 min, with an aqueous ozone concentration of 21 mg/l at 4 °C for 64 min: maximum *Salmonella* reduction on raspberries was 4.5 log cfu/g at 4 °C, whereas reduction on strawberries was 3.3 log cfu/g at 20 °C after 64 min. Gaseous ozone gave maximal reductions of 2.6 and 3.6 log_{10} respectively (Bialka and Demirci, 2007c). The authors used very long treatment times (up to 64 min for gaseous ozone with pressurized ozone at 83 kPa). No impact on berry quality was noted immediately after treatment but the impact on quality during subsequent storage was not reported.

Finally, there have been limited studies reporting the effect of physical treatments on *Salmonella* on fresh berries:

- Pulsed UV-light was evaluated at 3 different distances from the light source. Maximum reductions of 4.3 log_{10} cfu/g were observed at 8 cm from the light source after 60 s of treatment for *Salmonella* (Bialka and Demirci, 2008).

- Ultraviolet light (UV 254 nm) and ultrasound treatment of cut strawberries inoculated with 10^{6-7}/g *Salmonella enterica* serovar Enteritidis was investigated (Birmpa et al., 2013): UV and ultrasound treatment reduced the *Salmonella* by up to 1.4 and 3 log cfu/g respectively.

- The effects of nitrogen gas plasma treatment on approximately 10^6 cfu *Salmonella enterica* serovar Typhimurium inoculated onto strawberry surfaces was evaluated (Fernández et al., 2013): a 15 min treatment resulted in a 1.76 log-reduction of viability.

- High hydrostatic pressure treatment of 450 MPa for 2 min at 21 °C was able to eliminate *Salmonella* in strawberry purée prior to freezing (Huang et al., 2013).

In a previous Opinion EFSA assessed the efficacy of irradiation to reduce the number of foodborne pathogens in a range of foods, including fresh fruits (EFSA Panel on Biological Hazards (BIOHAZ), 2011a). D_{10} values for *Salmonella* spp. reported in this Opinion were around 0.40-0.80 kGy. The dose recommended in EU by (SCF, 1986) for fresh fruits was 2 kGy and should permit in theory between 5 and 2 log_{10} reductions of *Salmonella*. However, 2 kGy may cause deterioration of some berries.

In conclusion for fresh berries, chemical sanitizers, applied either as gas or aqueous solutions, and physical treatments mediate reduction of surface contamination of *Salmonella*. However the extent of this reduction depends on the type of berry, the site of contamination on the berry, and may be limited by the impact of the decontamination treatment on berry quality. The evidence presented is of low strength since it has neither been assessed outside experimental laboratory-based simulations nor during realistic shelf lives for berries. As stated for leafy greens (EFSA BIOHAZ Panel, 2014), although reductions in the surface contamination of *Salmonella* spp. could be expected, total inactivation is not possible with the available technologies because microorganisms are not accessible for the sanitizing treatments.

12.4. Specific mitigation options to reduce the risk of Norovirus contamination

Information on existing preventive measures for Norovirus contamination in place according to current EU legislation and control options for leafy greens can be found in Section 6.2 of the Scientific Opinion of the EFSA BIOHAZ Panel (EFSA Panel on Biological Hazards (BIOHAZ), 2011b), in the Codex Committee on Food Hygiene guidelines for control of virus contamination of food (CAC, 2012), and in guidance sheets produced by the FP7 project 'Integrated monitoring and control of foodborne viruses in European food supply chains' (available at http://www.eurovital.org/).

The Codex Committee on Food Hygiene guidelines for control of virus contamination of food (CAC, 2012) recommend that potential sources of viral contamination of the environment should be identified prior to production activities, and that primary food production should not be carried out in areas where the presence of viruses may lead to the viral contamination of food, e.g. in close proximity to a sewage treatment plant where there might be discharges of sewage water in the surface water, as even sewage treated by systems such as filtration can contain high levels of Norovirus (Nenonen et al., 2008).

The only reservoir for Norovirus is humans, therefore avoiding the use of sewage-contaminated water at all stages of the supply chain is an important mitigation option for reducing the risk of Norovirus contamination on berry fruits. Norovirus may be found in supply waters used in primary production, e.g. ground water (Cheong et al., 2009; Borchardt et al., 2012) and river water (Wyn-Jones et al., 2011; Maunula et al., 2013) which they can contaminate via the ingress of sewage, e.g. through outflow from a sewage treatment plant, or failure of a sewage system. Norovirus GII has been detected in irrigation water used in berry fruit production (Maunula et al., 2013). Fresh water in the environment can favour the survival of enteric viruses (Rzezutka and Cook, 2004), and it is highly likely that Norovirus will survive in an infectious state in river and groundwater from introduction via a sewage pollution event to application of the water to berry fruits during irrigation, washing or pesticide application (Verhaelen et al., 2013b). Untreated water used in primary production and / or processing is therefore a significant vehicle for virus contamination of berry fruits. The Codex Committee on Food Hygiene guidelines for control of virus contamination of food (CAC, 2012) recommend that efforts should be made to use only clean or potable water during production and processing. At production, an assessment should be performed of the microbial quality of the sources of water used, including an assessment of possible sources of human faecal contamination sources of the water (sanitary survey). Corrective actions should be taken if sources of contamination are identified. Possible corrective actions include disinfection e.g. by chlorine. The effectiveness of chlorine against Norovirus is not fully defined due to the lack of an infectivity assay, although studies observing the effect of chlorination on detectable viral RNA (Shin and Sobsey, 2008) indicate that chlorine concentrations used to treat drinking water are likely to be effective.

Equipment such as knives used in harvesting or trimming, conveyor belts or utensils used for processing, may act as vehicles for cross-contamination of produce. For example, a study using murine Norovirus as a model demonstrated that knives and graters processing contaminated fresh produce items including cucumbers and tomatoes can become contaminated by the virus and cross-contaminate subsequently processed items (Wang et al., 2013). Regulation EC No 852/2004 requires that equipment which comes into contact with food should be cleaned effectively, and where necessary disinfected. The efficacy of currently available surface disinfection treatments against Norovirus is not fully understood, and EFSA has recommended that efforts should be focussed on avoiding viral contamination (EFSA Panel on Biological Hazards (BIOHAZ), 2011b).

Persons handling food during harvesting, processing and catering are potential sources of Norovirus contamination of foods. Viruses can be transferred from the hands onto food items or food preparation surfaces, particularly under moist conditions (Bidawid et al., 2000). It has been stated (EFSA Panel on Biological Hazards (BIOHAZ), 2011b; CAC, 2012) that persons with symptoms of gastroenteritis should be excluded from working in food production until the symptoms have subsided, e.g. for 48 hours. However, as pre- and post-symptomatic shedding can occur (Atmar et al., 2008) this exclusion procedure will not entirely prevent the possibility of food contamination with Norovirus. Compliance with hand hygiene practices such as effective washing and drying is an absolute necessity for all food supply chain employees, and should be emphasised in local codes of practice and training manuals.

Information on effects of treatments used in food processing on noroviruses can be found in Sections 4.2. and 4.2.1. of the Scientific Opinion of the EFSA BIOHAZ Panel (EFSA Panel on Biological Hazards (BIOHAZ), 2011b). The effect of food processes such as heating on noroviruses has not been directly ascertained, due to the lack of an effective cell culture-based infectivity assay. Studies using surrogates (Baert, 2013) indicate that Norovirus infectivity could be reduced by heating at pasteurisation temperatures and above. In studies conducted using substrates other than berries, Norovirus surrogates were no more resistant to high hydrostatic pressures than *Salmonella* (Nguyen-The, 2012). There is no information on inactivation of Norovirus on berries by irradiation. Caution should however always be taken in the direct extrapolation of surrogate-derived information to Norovirus (Richards, 2012). Some Member States have recommended that imported berries be heated before consumption. Outbreaks attributed to consumption of frozen berries indicate that Norovirus is resistant to freezing.

13. *E. coli* as a microbiological indicator in berries

Monitoring of indicator organisms is routinely used by the industry, environmental agencies and public health organizations to verify effective implementation of Good Agricultural Practices (GAP) and Good Manufacturing Practices (GMP) for a wide range of foods and food manufacturing processes (Efstratiou et al., 2009; Wilkes et al., 2009; Ferguson et al., 2012). However it should be emphasised that testing should never be relied upon as a food safety management strategy, but rather should verify the effectiveness of existing risk management strategies (Good Agricultural Practices (GAP), Good Hygiene Practices (GHP), Good Manufacturing Practices (GMP) and HACCP). As previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014), when testing pre-cut ready-to-eat fruit and vegetables in the scope of the verification of compliance with the currently established processing hygiene microbiological criterion for *E. coli*, EN/ISO standard methods 16649-1[21] or 16649-2[22] are generally available and are prescribed in Regulation 2073/2005[23].

14. Data on occurrence of *E. coli* in berries

There are limited studies that have enumerated *E. coli* on berries. Data available from published studies is presented in Table 3. It is of note that all studies examined strawberries, except for one study which included other types of berries (blueberries, raspberries). None of these studies were undertaken in the EU.

Since there is a lack of data on the prevalence and levels of *E. coli* in berries, it is not currently possible to establish relationships between production and processing practices and numbers of *E. coli*. However, as previously discussed for leafy greens (EFSA BIOHAZ Panel, 2014), *E. coli* is commonly present in faecal material and has general use as a hygiene indicator. Consequently, because *E. coli* is present in high numbers in faecal material (*e.g*. fresh manure) and likely to decline in the soil and on the surfaces of berries during primary production, it can be considered as an indicator of a recent exposure to risk factors for *Salmonella*. However, there is currently insufficient available data to assess the effectiveness of *E. coli* to verify compliance to Good Agricultural Practices (GAP), Good Hygiene Practices (GHP), Good Manufacturing Practices (GMP) and food safety managements systems (including HACCP) in the production of berries.

E. coli is not suitable as an indicator for Norovirus contamination in shellfish (Lees, 2000): however there is insufficient information to establish if this is also true in other food types including berries.

[21] EN/ISO 16649-1:2001. Microbiology of food and animal feeding stuffs - Horizontal method for the enumeration of betaglucuronidase-positive *Escherichia coli* - Part 1: Colony-count technique at 44 degrees C using membranes and 5-bromo-4-chloro-3-indolyl beta-D-glucuronide. International Organization for Standardization, Geneva, Switzerland.

[22] EN/ISO 16649-2:2001. Microbiology of food and animal feeding stuffs - Horizontal method for the enumeration of betaglucuronidase-positive *Escherichia coli* - Part 2: Colony-count technique at 44 degrees C using 5-bromo-4-chloro-3-indolyl beta-D-glucuronide. International Organization for Standardization, Geneva, Switzerland.

[23] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. OJ L 338, 22.12.2005, p. 1-26.

Table 3: Occurrence of *E. coli* in berries

Sampling place	Commodity	Country	Detection method	Number of samples analysed	Number of positive samples	% of positive samples	95 % CI[(a)]	Detection limit	*E. coli* levels	Reference
Production	Fresh strawberries	US	Enrichment in laurylsulfate tryptose brilliant, then green bile broth, followed by Eosin methylene blue agar	11	0	0	[0,20]	MPN	NR	(Mukherjee et al., 2004)
Production	Fresh strawberries	South Korea	Eosin methylene blue agar	36	0	0	[0,6.7]	1 log cfu/g	NR	(Yoon et al., 2010)
At production	Berries (strawberries, blueberries, raspberries)	US	Enrichment in laurylsulfate tryptose brilliant, then green bile broth, followed by Eosin methylene blue agar	194	1	0.5	[0.1,2.4]	MPN	1.9 log MPN/g	(Mukherjee et al., 2006)
Retail farmers' markets	Fresh strawberries	Canada	Health Canada MFHPB-19 MPN	31	0	0	[0,7.7]	MPN	NR	(Bohaychuk et al., 2009)

NR = not reported
(a): The credible interval was calculated using a Bayesian approach and taking as prior beta (1/2,1/2) (Miconnet et al., 2005)

15. Microbiological criteria for berries

15.1. Introduction to microbiological criteria

EU Food hygiene legislation (Regulation (EC) No 852/2004)[24] lays down minimum hygiene requirements; Official Controls are in place to check food business operators' compliance and food business operators should establish and operate food safety programs and procedures based on HACCP principles. Regulation (EC) No 2073/2005[25] on microbiological criteria (MC) for foodstuffs is an implementing measure of the food hygiene legislation applicable since January 2006. It is important to emphasize that the safety of food is predominantly ensured by a preventive approach, such as implementation of GAP, GMP, GHP and application of procedures based on HACCP principles, while microbiological criteria can be used for validation and verification of these procedures. This is also the main principle underlying current legislation. In the European Union legislation, in relation to berries, microbiological criteria have been established for *Listeria monocytogenes* in all ready-to-eat foods, and for generic *E. coli* and *Salmonella* in ready-to-eat pre-cut fruit and vegetables and unpasteurised fruit and vegetable juices (see Sections 15.2.2. and 15.2.3.). These criteria also apply to frozen pre-cut fruit including pre-cut berries. There are no specific microbiological criteria for fresh or whole frozen berries.

Considerations on the establishment of Microbiological Criteria should be made on the basis of public health goals which are intended to inspire actions to improve the future public health status and reduce the disease burden (EFSA, 2007). From 2007-2011, one *Salmonella* outbreak was reported which was associated with fresh raspberry juice. For Norovirus in berries the situation is different and outbreaks associated with Norovirus in frozen raspberries and strawberries are an emerging public health risk: between 2007 and 2011, there were 27 Norovirus outbreaks associated with raspberries (19 outbreaks implicated frozen raspberries, but no additional information has been reported for the remaining 8 outbreaks) and one outbreak associated with strawberries was reported in the EU (EFSA Panel on Biological Hazards (BIOHAZ), 2013). In addition a further Norovirus outbreak in Finland (9 cases) associated with berries was reported in 2011 (Zoonoses database), 103 cases of hepatitis A were reported in 2012-13 in Denmark, Finland, Norway and Sweden associated with frozen strawberries (Nordic Outbreak Investigation Team, 2013) and a large outbreak of 10,952 Norovirus cases were reported in Germany in 2012 associated with consumption of imported frozen strawberries in 2012 (BfR, 2012). Furthermore there is a large (1,315 cases) multistate outbreak of hepatitis A associated with frozen berry consumption in 2013-14 (ECDC and EFSA, 2014). It is not known if in these outbreaks contamination by Norovirus occurred at minimal processing or if it occurred during primary production. However, on considerations of public health risk, prevention of Norovirus contamination of raspberries and strawberries throughout production and minimal processing, particularly those intended for freezing, should be of high priority for processors.

There are very limited studies on the prevalence of *Salmonella* in berries (only 2 studies available in the EU). Norovirus however has been detected in berries in samples, albeit on a limited scale, collected both from within outbreaks as well as in the absence of known association with human Norovirus infection. It is not possible to assess the representativeness of these data and there is no information on the adequacy of the implementation of GAP and/or other food safety systems (including HACCP) associated with the presence of Norovirus in the studies presented in Table 2.

15.2. Hygiene Criteria for berries at primary production

The current legal framework does not include microbiological criteria applicable at the primary production stage. It is part of the growers' responsibility to validate and verify Good Agricultural Practices (GAP) and Good Hygiene Practices (GHP) for berry production. For this purpose a criterion, designated as a Hygiene Criterion could be used. *E. coli* was identified as suitable for a Hygiene

[24] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 30.4.2004, p. 1-54.

[25] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. OJ L 338, 22.12.2005, p. 1-26.

Criterion at primary production of leafy greens (EFSA BIOHAZ Panel, 2014). Compared to leafy greens, common production practices for berries make introduction, survival and subsequent detection of *E. coli* and *Salmonella* less likely. For instance, protected and soil-less culture which represents the majority of ready-to-eat strawberry production units in some EU areas (as outlined in Section 2) offers less opportunities for faecal contamination of the berries than, for example, open field production with overhead irrigation using contaminated surface water. In addition, *E. coli* and *Salmonella* have been shown to decline on berries as discussed in Section 3.1.1. In addition, there are very limited studies available on the presence and levels of enteric bacteria such as *E. coli* on berries and therefore it is currently not possible to assess the suitability of an EU-wide *E. coli* Hygiene Criterion at primary production for berries. However, using *E. coli* as an indicator of recent human or animal faecal contamination is likely to be useful for verification of GAP and GHP in individual production sites (e.g. to assess clean water used for irrigation and other water uses such as for the application of pesticides and fertilizers, and screening food handlers' hands), for example during prerequisite compliance audits, where epidemiological studies indicated a higher risk of infection or at the discretion of the food business operator. Consequently if water is contaminated with *E. coli* there is a higher risk for the presence of Norovirus and *Salmonella* and hence berries will also have a higher risk of contamination by Norovirus and *Salmonella*.

On considerations of public health risk, prevention of Norovirus contamination of raspberries and strawberries, particularly those intended for freezing should be of high priority for primary producers. The risk of Norovirus contamination may be different across different production systems, locations and berry types. However Norovirus occurrence indicates direct or indirect contamination from human faeces or vomit.

Other enteric viruses, e.g. human adenovirus (Hundesa et al., 2006) have been suggested as indicators of human faecal contamination and therefore of potential risk of Norovirus contamination. Adenovirus may be more prevalent than Norovirus in the berries supply chain (Maunula et al., 2013), although this information is limited and the analytical methods may not be easier to implement compared to those for Norovirus.

More data are required before the suitability of an enteric viral indicator can be validated. In the absence of reliable indicators for Norovirus contamination of berries and despite the limitations of current Norovirus detection methods, detection of Norovirus genomic copies in raspberries and strawberries may be useful for verification of GAP and GHP when applied to berries, for water used for irrigation (as well as for other water uses such as for the application of pesticides and fertilizers), and to screen food handlers' hands in individual production sites, for example during prerequisite compliance audits, where epidemiological studies indicated a higher risk of infection or at the discretion of the food business operator. It is, however, currently not possible to assess the suitability of an EU-wide Norovirus Hygiene Criterion at primary production for raspberries and strawberries, but this should be considered for the future.

15.3. Process Hygiene Criteria for berries

As defined in the legislation, a Process Hygiene Criterion is a criterion indicating the acceptable functioning of a production process. In Regulation (EC) No 852/2004)[26] processing is defined as any actions that substantially alter the initial product, including heating, smoking, curing, maturing, drying, marinating, extraction, extrusion or a combination of those processes. In this section, only minimally processed berries are considered, defined as those subjected to one or more of cleaning, cutting and washing procedures as well as freezing. Process Hygiene Criteria are only applicable to food business operators and not to primary producers although results during processing may provide useful information to validate and verify Good Agricultural Practices (GAP) and Good Hygiene Practices (GHP) at primary production. Furthermore, Process Hygiene Criteria communicate the expected outcome of a process as end-manufacturing or end-product criteria. Process Hygiene Criteria do not

[26] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 30.4.2004, p. 1-54.

distinguish between more or less hygienic production processes but implicitly consider all production processes with equal final contamination values as equally hygienic.

A Process Hygiene Criterion should be seen in connection with all the preventive measures in place (including verification of HACCP) and an appropriate testing frequency should be applied. Based on the obtained data, if specified levels of a Process Hygiene Criterion such as *E. coli* are exceeded, processors should take corrective actions based on the main mitigation options previously described in the Section 12 of this Opinion. These mitigation options should focus on the appropriate implementation of Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) with special attention to 1) the control of the microbial quality of the raw material, 2) treatment and quality maintenance of washing water (if applied) to reduce the build-up of microorganisms, 3) cleaning of contaminated equipment, and 4) strict control of worker hygiene.

There are currently process hygiene microbiological criteria for *E. coli* in samples collected during the manufacturing process (n = 5; c = 2; m = 100 cfu/g and M = 1,000 cfu/g) for ready-to-eat pre-cut fruit and vegetables as well as unpasteurised fruit and vegetable juices (Regulation (EC) No 2073/2005). In the scope of this Opinion this microbiological criterion only applies to RTE pre-cut berries and unpasteurised berry juices. However, there is no information available on the prevalence and levels of *E. coli* in these types of products and therefore the suitability of this criterion cannot be assessed. Currently, there are no Process Hygiene Criteria covering whole frozen berries and for these products there are also no available data on occurrence of *E. coli* or *Salmonella.* It is therefore not possible to assess the suitability of an EU-wide *E. coli* Process Hygiene Criterion for whole frozen berries. However, using *E. coli* as an indicator for verification of GMP and food safety management systems (including HACCP) might be useful for frozen berries in individual processing premises e.g. during food safety management audits, where epidemiological studies indicated a higher risk of infection or at the discretion of the food business operator.

In consideration of public health risk, prevention of Norovirus contamination and cross-contamination of raspberries and strawberries throughout production and minimal processing, particularly those intended for freezing should be of high priority for processors. Notwithstanding the limitations of current Norovirus detection methods, detection of Norovirus genomic copies in raspberries and strawberries is considered to be a useful parameter to be used for verification of GMP and HACCP when applied to berries at processing premises. If Norovirus is detected in the finished products at the end of the production line then further investigation should be undertaken and where necessary corrective actions should be taken. These actions may include reassessing suppliers, improvement of personal hygiene, plant hygiene etc. (Section 12).

Microbiological criteria for Norovirus in berries are useful for validation and verification of food safety management systems, including HACCP-based processes and procedures, and can be used to communicate to food business operators and other stakeholders what is acceptable or unacceptable viral load for berries to be placed on the market. Although noroviruses can be detected in berries, prevalence studies are limited, and quantitative data on viral load are scarce, thus it is currently not possible to provide a risk base for establishing a Process Hygiene Criterion for these foods. However, on the basis of the emerging public health risk, the collection of appropriate data and subsequent development of a Norovirus Process Hygiene Criterion for frozen raspberries and strawberries should be considered as a priority.

15.4. Food Safety Criteria for berries

As previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014), the EU Food Safety Criteria defined in EU legislation are for the microbiological acceptability of food products. These criteria apply to products at the end of production or placed on the market. If the criteria are not met the product/batch is expected to be withdrawn from the market. The following conclusions concerning Food Safety Criteria were previously stated (EFSA, 2007):

(a) An advantage of establishing Food Safety Criteria for pathogenic microorganisms is that harmonised standards on the acceptability of food are provided for both authorities and industry within the EU and for products imported from third countries.

(b) Food Safety Criteria will impact the entire food chain, as they are set for products placed on the market. Risk of recalls and the economic loss as well as loss of consumer confidence will be a strong motivation to meet the criteria. Therefore Food Safety Criteria are assumed to have an effect on food safety and public health where there is an actual or perceived risk. However, it is not possible to evaluate the extent of public health protection provided by a specific Food Safety Criterion.

(c) Microbiological testing alone may convey a false sense of security due to the statistical limitation of sampling plans, particularly in the cases where the hazard presents an unacceptable risk at low concentrations and/or low and variable prevalence.

(d) Food safety is a result of several factors. Microbiological criteria should not be considered without other aspects of EU Food legislation, in particular HACCP principles and official controls to audit food business operators' compliance.

In order to establish Food Safety Criteria, it is a prerequisite that methods to properly detect the hazard are available at a reasonable cost. Inherent in this is that hazards must be accurately defined, or the result may be that food batches are erroneously considered unsafe. Regulation (EC) No 2073/2005[27] on microbiological criteria does not prescribe any sampling/testing frequencies except for minced meat, mechanically separated meat and meat preparations. While this leaves flexibility to tailor the intensity of testing according to the risk, it also leaves the possibility of inconsistency in testing and control (EFSA, 2007).

There are Food Safety Microbiological Criteria for the absence of *Salmonella* in 25 g samples (n=5; c=0) of ready-to-eat pre-cut fruit and vegetables as well as unpasteurised fruit and vegetable juices for products placed on the market during their shelf life (Regulation (EC) No 2073/2005). However on the basis of public health risk, there is currently insufficient evidence to justify the establishment of a Food Safety Criterion for *Salmonella* for fresh and minimally processed berries (including frozen berries).

There is no EU Food Safety Criterion for Norovirus in berries. However, there is a recent European Regulation (323/2014)[28] which mandates an increased level of official control by testing for Norovirus in imported frozen strawberries from China. The laboratories performing the testing are reporting results as presence or absence in 25 g (see Section 11). For frozen raspberries and strawberries there is epidemiological evidence from outbreaks to identify this food as associated with emerging public health risks. However, the prevalence studies on Norovirus in frozen berries are limited. In addition, quantitative data are scarce; thus it is currently not possible to provide a risk base for establishing a Food Safety Criterion for these foods. Furthermore, the methodology used for detection and quantification of Norovirus in berries requires improvement regarding the limit of detection and quantitative accuracy. Also, real time RT-PCR does not discriminate between infectious and non-infectious Norovirus (Knight et al., 2013) and therefore presents a greater level of uncertainties than for most bacteria since it may overestimate or underestimate the risk. However on the basis of the emerging public health risk, the collection of appropriate data and subsequent risk-based development of a Norovirus Food Safety Criterion for frozen raspberries and strawberries should be considered as a priority. For fresh or frozen berries other than raspberries and strawberries there is no epidemiological

[27] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. OJ L 338, 22.12.2005, p. 1-26.

[28] Commission Implementing Regulation (EU) No 323/2014 of 28 March 2014 amending Annexes I and II to Regulation (EC) No 669/2009 implementing Regulation (EC) No 882/2004 of the European Parliament and of the Council as regards the increased level of official controls on imports of certain feed and food of non-animal origin Text with EEA relevance. OJ L 95, 29.03.2014, p.12-23.

evidence or prevalence data to support the establishment of a Food Safety Criterion on the basis of public health risk, but this may need to be re-evaluated if additional information becomes available.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

- Berries, for the scope of this Opinion, are defined according to commercial production and consumption as small, spherical or ovoid, fleshy and juicy fruits.
- This food commodity is often consumed as a perishable product receiving no or only minimal processing. Berries are also consumed as highly processed products such as components of jams, preserves, heat treated fruit juices or purées and dried fruits which can be shelf-stable, having undergone heating or drying: such products are outside the scope of this Opinion.
- Despite the wide variety of plant species grown for berry production, the most important types for the fresh market in the EU are strawberries, raspberries, blackberries and blueberries.
- Berries can be produced by small herbaceous plants (e.g. strawberry), bushes (e.g. blackberry, blackcurrant, blueberry, gooseberry, raspberry) or small trees (e.g. mulberry, elderberry).
- Berries are produced using various systems, depending on the type of berry, the intended use (e.g. fresh market or for processing including freezing), the geographical origin and the economic choices of the growers. Plants can be grown in soil or soil-less cultures in protected environments or in open fields.
- Berries are harvested during the fruiting season. Those consumed fresh, are usually manually harvested and, to avoid mechanical damage, can be directly picked and placed in their final packaging for sale to caterers or consumers. Berries for freezing can be either manually or mechanically harvested.
- The internal contents and juices of berries have generally a low pH and can contain antimicrobial phenolic compounds.
- After harvest, berries are sorted, packaged and stored. Berries may be subjected to minimal processing such as cleaning, cutting, mashing and washing as well as freezing.
- Fresh and frozen berries intended for sale are normally not subjected to physical interventions that will eliminate or substantially reduce the occurrence of *Salmonella* and Norovirus.
- There is some information on the risk factors and mitigation options for *Salmonella* and Norovirus contamination of strawberries and raspberries, but there is little or no information for other berries.
- A particular feature of berries is their widespread use as a frozen ingredient in many diverse food products and preparations.
- Mixing batches of frozen fruit, including mixtures of different berry species, can present difficulties in traceability.

Answers to the terms of Reference

TOR 3. To identify the main risk factors for the specific food/pathogen combinations identified under ToR 2, including agricultural production systems, origin and further processing.

- The risk factors for the contamination of berry fruits at primary production with *Salmonella* are poorly documented in the literature, with limited available data, but are likely to include the following, based on what is known for other pathogens or other types of fresh produce:

  - Environmental factors, in particular proximity to animal rearing operations and climatic conditions that increase the transfer of pathogens from animal reservoirs to berries;
  - Contact with animal reservoirs (domestic or wild life) gaining access to berry fields;
  - Use of untreated or insufficiently treated manure or compost;
  - Use of contaminated agricultural water either for irrigation or for application of agricultural chemicals such as fungicides and
  - Contamination and cross-contamination by harvesters, food handlers and equipment at harvest or post-harvest.

- The risk factors for the contamination of berry fruits at primary production with Norovirus are also poorly documented in the literature, with limited available data, but are likely to include the following, based on what is known for other pathogens or other types of fresh produce:
  - Environmental factors, in particular climatic conditions (e.g. heavy rainfall) that increase the transfer of Norovirus from sewage or sewage effluents to irrigation water sources or fields of berries;
  - Use of sewage-contaminated agricultural water, either for irrigation or for application of agricultural chemicals such as fungicides and
  - Contamination and cross-contamination by harvesters, food handlers and equipment at harvest or post-harvest.

- There is no information on the potential for *Salmonella* or for Norovirus to internalise within berry fruit or plants.

- For both *Salmonella* and Norovirus, processes at primary production which wet the berries represent the highest risk of contamination with both pathogens, and these include spray application of agricultural chemicals such as fungicides and, if it is applied, the use of overhead irrigation.

- *Salmonella* and Norovirus may show some persistence on the surface of berries. Decline has been reported for *Salmonella* on fresh and frozen strawberries. Evidence from outbreaks indicates that Norovirus can persist for a prolonged time period in frozen raspberries and strawberries.

- During minimal processing, contamination and cross-contamination via equipment, water (if washing is applied) and particularly via food handlers are the main risk factors for berries for both *Salmonella* and Norovirus. For *Salmonella*, this risk of cross-contamination during washing is reduced if disinfectants are properly used within the washing tank. The effectiveness of disinfectants against Norovirus is not fully defined due to the lack of an infectivity assay.

TOR 4. To recommend possible specific mitigating options and to assess their effectiveness and efficiency to reduce the risk for humans posed by food/pathogen combinations identified under ToR 2.

- Appropriate implementation of food safety management systems including Good Agricultural Practices (GAP), Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) should be the primary objective of operators producing berries. These food safety management systems should be implemented along the farm to fork continuum and are applicable to the control of a range of microbiological hazards.

- Attention should be paid to the selection of the water sources for irrigation, agricultural chemicals (e.g. fungicides) and in particular to the avoidance of the use or the ingress of water contaminated by sewage.

- Production areas should be evaluated for hazards that may compromise hygiene and food safety, particularly to identify potential sources of faecal contamination. If the evaluation concludes that contamination in a specific area is at levels that may compromise the safety of crops, intervention strategies should be applied to restrict growers from using this land for berry production until the hazards have been addressed.

- Each production environment (including open field, enclosed or greenhouse production, and wild areas) should be evaluated independently for hazards as each represents a unique combination of numerous characteristics that can influence occurrence and persistence of pathogens in or near fields for growing berries.

- Among the potential interventions, both water treatment and efficient drainage systems that take up excess overflows may be needed to prevent the additional dissemination of contaminated water. Since *E. coli* is an indicator microorganism for faecal contamination in irrigation water, growers should arrange for periodic testing to be carried out to inform preventive measures.

- A high proportion of berries consumed in the EU are imported from non EU countries, mostly as frozen berries, and attention should be paid to the application of these mitigation options during production and processing in the countries of origin.

- Food safety management based on GMP and HACCP principles should applied by processors, distributors, retailers and caterers involved in production of ready-to-eat berries.

- Mitigation strategies aiming to reduce risks of microbial contamination for all water used during processing and only potable quality water should be used. This should include wash-water where used, as well as that used for other purposes (including ice).

- All persons involved in the handling of berries should receive hygiene training appropriate to their tasks and receive periodic assessment while performing their duties to ensure tasks are being completed with due regard to good hygiene and hygienic practices.

- As *Salmonella* has reservoirs in domestic as well as wild animals, birds and humans, the main mitigation options for reducing the risk of contamination of berries are to prevent direct contact with faeces as well as indirect contact through slurries, sewage, sewage sludge, and contaminated soil, water, equipment or food contact surfaces.

- Although *Salmonella* declines during freezing of whole berries and berry products, it is not possible to use freezing as a critical control point to ensure the absence of this pathogen.

- The only reservoir for Norovirus is humans, therefore avoiding the use of sewage-contaminated water at all stages of the supply chain is an important mitigation option for reducing the risk of Norovirus contamination on berry fruits.

- Compliance with hygiene requirements, in particular hand hygiene, is an absolute necessity for food handlers at all stages of the berry production and the supply chain to reduce the risks of both *Salmonella* and Norovirus contamination.

TOR 5. To recommend, if considered relevant, microbiological criteria for the identified specific food/pathogen combinations throughout the production chain.

- From 2007-2011, one *Salmonella* outbreak was reported which was associated with fresh raspberry juice.

- For Norovirus in berries the situation is different and outbreaks associated with Norovirus in frozen raspberries and strawberries are an emerging public health risk: between 2007 and 2011, there were 27 Norovirus outbreaks associated with raspberries (19 outbreaks implicated frozen raspberries, but no additional information has been reported for the remaining 8 outbreaks) and one outbreak associated with strawberries was reported in the EU. In addition a further Norovirus outbreak in Finland (9 cases) associated with berries was reported in 2011, 103 cases of hepatitis A were reported in 2012-13 in Denmark, Finland, Norway and Sweden associated with frozen strawberries and a large outbreak of 10,952 Norovirus cases were reported in Germany in 2012 associated with consumption of imported frozen strawberries in 2012. It is not known if in these outbreaks contamination by Norovirus occurred at minimal processing or if it occurred during primary production.

- Therefore, on considerations of public health risk, prevention of Norovirus contamination of raspberries and strawberries throughout production and minimal processing, particularly those intended for freezing, should be of high priority for processors.

- There is no routine or regular monitoring of berry fruits for the presence of *Salmonella* in EU Member States and there is only very limited prevalence data on *Salmonella* contamination of berries in the peer-reviewed literature, which only relates to fresh strawberries. There is limited data relating to the testing of strawberries or strawberry juices, however no information pertaining to contamination of other types of berries is available.

- There has been no routine or regular monitoring of berry fruits for the presence of Norovirus in most of the EU Member States and there is very limited prevalence data on Norovirus contamination of berries (not involved in foodborne outbreaks) in the peer-reviewed literature.

- There are limited studies that have enumerated *E. coli* on berries. All studies examined strawberries, except for one study which included other types of berries (blueberries, raspberries). None of these studies were undertaken in the EU.

- The current legal framework does not include microbiological criteria applicable at the primary production stage (Hygiene Criteria).

- It is currently not possible to assess the suitability of an EU-wide *E. coli* Hygiene Criterion at primary production for berries. However, using *E. coli* as an indicator of recent human or animal faecal contamination is likely to be useful for verification of GAP and GHP when applied to berries in individual production sites (e.g. to assess clean water used for irrigation and other water uses such as for the application of pesticides and fertilizers, and screening food handlers' hands) for example during prerequisite compliance audits, where epidemiological studies indicated a higher risk of infection or at the discretion of the food business operator.

- In the absence of reliable indicators for Norovirus contamination of berries and despite the limitations of current Norovirus detection methods, detection of Norovirus genomic copies in raspberries and strawberries may be useful for verification of GAP and GHP when applied to berries, for water used for irrigation (as well as for other water uses such as for the application of pesticides and fertilizers), and to screen food handlers' hands in individual production sites, for example during prerequisite compliance audits, where epidemiological studies indicated a higher risk of infection or at the discretion of the food business operator.

- It is, however, currently not possible to assess the suitability of an EU-wide Norovirus Hygiene Criterion at primary production for raspberries and strawberries, but this should be considered for the future, as well as for other berry fruits if additional public health risks are identified.

- Currently there are no Process Hygiene criteria covering whole frozen berries and for these products there are no available data on occurrence of *E. coli* or *Salmonella.* It is therefore not possible to assess the suitability of an EU-wide *E. coli* Process Hygiene Criterion for whole frozen berries. However, using *E. coli* as an indicator for verification of GMP and food safety management systems (including HACCP) might be useful for frozen berries in individual processing premises e.g. during food safety management audits, where epidemiological studies indicated a higher risk of infection or at the discretion of the food business operator.

- Microbiological criteria for Norovirus in berries are useful for validation and verification of food safety management systems, including HACCP-based processes and procedures, and can be used to communicate to food business operators and other stakeholders what is acceptable or unacceptable viral load for berries to be placed on the market. Although noroviruses can be detected in berries, prevalence studies are limited, and quantitative data on viral load are scarce, thus it is currently not possible to provide a risk base for establishing a Process Hygiene Criterion for these foods.

- However, on the basis of the emerging public health risk, the collection of appropriate data and subsequent development of a Norovirus Process Hygiene Criterion for frozen raspberries and strawberries should be considered as a priority.

- On the basis of public health risk, there is currently insufficient evidence to justify the establishment of a Food Safety Criterion for *Salmonella* for fresh and minimally processed berries (including frozen berries).

- For frozen raspberries and strawberries there is epidemiological evidence from outbreaks to identify this food as associated with emerging public health risks. However, the prevalence studies on Norovirus in frozen berries are limited. In addition, quantitative data are scarce; thus it is currently not possible to provide a risk base for establishing a Food Safety Criterion for these foods.

- Real time RT-PCR does not discriminate between infectious and non-infectious Norovirus and therefore presents a greater level of uncertainties than for most bacteria since it may overestimate or underestimate the risk.

- For fresh or frozen berries other than raspberries and strawberries there is no epidemiological evidence or prevalence data to support the establishment of a Food Safety Criterion on the basis of public health risk, but this may need to be re-evaluated if additional information becomes available.

RECOMMENDATIONS

- More detailed categorization of food of non-animal origin should be introduced to allow disaggregation of the currently reported data collected via EFSA’s Zoonoses database on prevalence and enumeration of foodborne pathogens.

- ISO technical specifications for Norovirus detection and quantification on berries should be further refined with regard to sampling, sample preparation, limit of detection, quantitative accuracy and interpretation of results. Such developments will allow the collection of data to support the development of Process Hygiene and Food Safety Criteria for berries.

- There is a need for targeted surveys on the occurrence of Norovirus in different types of berries both at primary production, after minimal processing (including freezing) and at the point of sale. Where possible, these surveys should use methods which provide an indication of virus infectivity, together with studies to identify the level of hazard control and efficacy of application of food safety managements, including HACCP, that has been achieved at different stages of production systems.

- There should be evaluation of procedures such as sanitary surveys, training, observational audits and other methods to verify agricultural and hygiene practices (including food handlers' hand hygiene) for berries at primary production. Evaluation of systems for monitoring of water used in primary production should be prioritised.

- Further data should be collected to evaluate the suitability of bacterial or viral indicators for Norovirus and other relevant microbiological hazards in berries and in berry production and processing environments.

- Research should be undertaken with the aim of developing infectivity assays for Norovirus.

- Research should be also undertaken with the aim of determining whether Norovirus can internalise within berries during crop production during natural exposure.

- There is a need for more research on decontamination treatments effective against all relevant microbiological hazards for ready-to-eat berries particularly those intended to be frozen.

- Collection of appropriate data and subsequent risk-based development of a Process Hygiene Criterion or Food Safety Criterion to support improved control of Norovirus in frozen raspberries and strawberries should be considered as a priority.

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APPENDICES

Appendix A. List of questions to be addressed by the European Fresh Produce Association (Freshfel) and information received from Freshfel on 22 July and 5 November 2013

1. How do you categorise berries according to different:
   - production systems,
   - processing (excluding thermal treatment or any equivalent (e.g. blanching as well as shelf-stable juices) and
   - presentation at retail?

   All questions below aim at characterizing the berries sector in the EU.

PRODUCTION SECTOR

2. Provide an overview of this sector listing the most commonly produced botanical varieties of berries in the EU?
3. Which are the top 10 types of berries produced in EU?
4. Which are the top 10 types of berries sold in EU?
5. Which countries are the major producers in the EU?
6. Which are the main third countries providing the EU with berries?
7. Which is the share of the market covered by imported production versus intra-EU production of berries?
8. What is the share of producers of berries which are not members of Freshfel in the EU?

   Which volume of production do these producers represent?
9. Are there any figures in the EU to characterize the proportion of the production of berries from "home/small scale" producers when compared to "large-scale" production?
10. Provide available figures on (i) production, (ii) producers, (iii) trade, (iv) certification and (v) distribution (type of outlets) of the berries.

AGRICULTURAL PRODUCTION SYSTEMS

11. Are there any producer's survey results which could help to describe how berries are produced in the EU?
12. Characterise the profile of workers in the production of berries (e.g. training, casual workers, foreign workers etc).
13. Please indicate percentages of production of berries (i) in fields, (ii) in greenhouses (iii) soil-less (hydroponics) or (iv) in soil?
14. Are there any additional production systems in place in the EU (as well as for imported products)?
15. Which berries can be produced as hydroponic crop?
16. Indicate the major irrigation systems and water sources in the agricultural production of berries.

Is the water quality controlled (microbiologically)? If so and if available, provide, data on microbiological quality of the water used in the agricultural production of berries.

PROCESSING OF BERRIES

17. Which are the most common processing practices for berries in the EU?
18. Which agricultural practices and processing steps - can be executed (i) only manually, (ii) both manually or mechanically or (iii) preferentially mechanically?

    What are the percentages of manual versus mechanical practices?
19. Indicate the major water sources in the processing of berries.

    Is the water quality controlled (microbiologically)? If so and if available, provide data on microbiological quality of the water used in the processing of berries.
20. How important is the share of production in the EU for different berries categories proposed in the scope of the answer to question 1?

    Which proportion of berries are (i) sold directly (without further processing) or (ii) undergoing processing (pre-cutting, mixing, packaging, freezing and drying)?

DISTRIBUTION AND RETAIL

21. Which are the procedures and conditions for transport and distribution of berries in the EU?

    Are there any specific cooling practices in place for berries at harvest or post-harvest storage (or long distance transport)?
22. Are there any specific control measures in place in the EU to maintain the cold chain during storage and distribution of berries?

    Are there any specific control measures in place to maintain long term storage?
23. Which proportion of berries may be sold without temperature control during distribution in the EU?
24. Describe how traceability of berries is addressed for the different agricultural production systems and processing options?

SYSTEMS IN PLACE TO ENSURE SAFETY OF PRODUCTS

25. Are there any European guidelines/codes available from Freshfel or other associations of producers on practices (including pre-cutting, mixing, packaging freezing and drying) to ensure food safety in the production of berries?
26. In your view, what are the strengths and weaknesses of the current GAPs, GMPs and standards to ensure microbiological quality of berries?
27. In your view, which are the major weak points from the microbiological point of view in the agricultural production systems as well as in the processing of berries?
28. Do the producers of pre-cut/mixed/pre-packaged/frozen/dry berries in the EU need to be registered as food processing establishments?
29. What are the hygienic requisites that these processing establishments need to comply with?

    How is compliance with these hygienic requisites verified?

30. Are there any central repositories of data on non-compliance with the GAPs, GMPs, standards as well as on the analysis of these data?
31. Are there many companies producing berries which are applying the “test to release” for microbiological parameters? If so, are companies using presence/absence tests? In case enumeration testing is used, which are the threshold levels (cfu/g) used for interpretation of the analysis results?
32. Are the producers, producer associations or any other stakeholders (e.g. retail) also doing regular testing/monitoring of berries?
33. Which are the sampling plans used in the scope of this testing/monitoring of berries?
34. Is there any additional testing/monitoring in place for imported berries?
35. Does Freshfel have any available data in the EU on levels of detection and enumeration of *Salmonella* and Norovirus in berries?
36. Which methods for detection and enumeration of *Salmonella* and Norovirus in berries are being used in the food chain in the EU?
37. Which are the differences on the hygienic requisites for the production of organic berries when compared to conventional production?

    How is compliance with these hygienic requisites verified?
38. What are the hygienic requisites in place for imported berries?

    How is compliance with these hygienic requisites verified?
39. Which chemical and/or physical decontamination methods are being used in the EU for the treatment of soil, substrates, manure or compost?
40. Which chemical and/or physical decontamination methods are being used in the EU for the treatment of water (reservoirs, irrigation systems, processing water)?
41. Describe the practices in use in the EU for chemical and/or physical decontamination of berries? Which are the main methods in place in the EU?
42. Which chemical and/or physical decontamination methods are allowed in the EU among Member States?
43. Does Freshfel provide specific recommendations on methods used to reduce contamination of berries by *Salmonella* and Norovirus?

Information received from European Fresh Produce Association (Freshfel) on 22 July and 5 November 2013

4 November 2013

Background information berry category

Opinion EFSA-Q-2012-00179

Definitions (questions 1-2)

(1)Categorisation

A. Production

Several production systems are used depending on the specifications of the final product which need to be achieved.

- Drip irrigation / sprinkler irrigation
- Hydroponic / substrates / soil
- Open air / protected (polytunnels, ...)

B. Processing

Fresh

- Washed (e.g. strawberry, blackberry, blueberry)
- Unwashed

Processed (see also question 17)

- Washed / unwashed
- Static / Individually Quick Frozen

C. Retail presentation

Fresh

- Open cardboard or plastic punnets
- Closed plastic punnets (heat sealed or clip-lids)

Processed

- Cardboard boxes or bags
- Individual berry types or mixes

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(2) Varieties

The following botanical varieties are commonly produced (see also UNECE Standard FFV-57 concerning the marketing and commercial quality control of berry fruits):

- Strawberries (Fragaria L.)
- Raspberries (Rubus idaeus L.)
- Blueberries (Vaccinium corymbosum L., Vaccinium formosum Andrews, Vaccinium angustifolium Aiton, Vaccinium virgatum Aiton)
- Blackberries (Rubus sect. Rubus)
- Currants (Ribes rubrum L., Ribes nigrum L.)
- Cranberries (Vaccinium macrocarpon Aiton)
- Loganberries (Rubus loganobaccus L. H. Bailey)
- Gooseberries (Ribes uva-crispa L.)
- Bilberries (Vaccinium myrtillus L.)
- Cowberries, lingonberries (Vaccinium vitis-idaea L.)
- Wild cranberries (Vaccinium oxycoccos L.)
- Cloudberries (Rubus chamaemorus L.)
- Hybrids of these species

EU market (questions 3-10, 20)

(10) Detailed statistics have been prepared for the main segments constituting the berry category. The data provided relate to the production in the EU, imports from 3rd countries and intra-EU import flows for each product. Production data have been obtained from FAOSTAT, whereas trade data have been obtained from EUROSTAT. It should be noted that these data do not distinct product flows going to the fresh market from product flows going to processing. Furthermore these data do normally not include wild berries.

(5-7) Fresh berries on the EU market are pre-dominantly produced in the EU and the share of imports from 3rd countries is limited (1-5%). One notable exception is the cranberry segment of which 90% is imported from 3rd countries. Unlike other fruit and vegetable categories, the berry category is not specifically concentrated in certain regions. The increased use of protected production systems along with the highly perishable nature of berries result in a diverse supply base. The production of berries for processing is however concentrated in Eastern Europe, especially Poland.

(3-4) The most important berry segments for the fresh market are strawberries, raspberries, blackberries and blueberries. As the share of imports from 3rd countries is limited, this overview generally corresponds with the importance of the product categories in sales.

(20) There are no specific data available on the various market outlets for each of the berry segments. Cranberries and blackcurrants cannot be consumed fresh and are always processed in some form. Some data is available for strawberry processing, which is dominated by Poland processing 64% of its crop, followed by Spain with 18%, other producing countries vary between 2 an 8%.

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(9) With regard to the differentiation between commercial production and home or small-scale production, there are no reliable figures available. Whereas home or small-scale production of vegetables is by and large considered as marginal in Western Europe, it is more prevalent in certain Eastern European countries. The economic crisis and certain trends (local produce, authenticity) may however have contributed to an increased popularity of the segment.

Agricultural production systems (questions 11-16)

(11) The berry category comprises a wide range of products which in turn can be grown in several production systems which are continuously being optimised through research and innovation (see also categorisation – production systems). There are no survey results describing how berries are produced in the EU.

(13-15) Berries destined for processing are all grown in fields. In countries with intensive systems (e.g. BeNeLux, UK) the majority of strawberries are grown on substrate in plastic tunnels, while less intensive systems make use of ridged beds covered with mulch. Raspberries and other berries are principally grown in soil under plastic tunnels. More and more growers are moving to substrate systems (peat, coco peat) for the production of berries given many soil decontaminants (e.g. Methyl Bromide) may no longer be used. If soil is used it is almost 100% covered with a plastic or fabric mulch. Strawberries and raspberries can be produced as hydroponic crops, but this remains an exception.

(16) The major irrigation systems used in agricultural production are drip irrigation and sprinkler irrigation. The main water sources include surface waters (river, lake), reservoirs supplied by well water or rain water, and well water (drinking water in case of hydroponics). In the case of products destined for the fresh market, the water quality is mostly controlled just once per year. In general E. Coli, Salmonella, Streptococcus faecalis, and total coliforms are the parameters being analysed.

(12) The field staff in the production of berries mainly consists of seasonal workers from various countries depending on the production countries (e.g. North Africa in the case of Italy or Spain). In the packinghouse, there's a mix between national and foreign workers. The workers are trained with regard to the prevention of food safety incidents, which is generally a prerequisite

Processing berries (questions 17-19)

(17) The most common processing practices include:

- Cleaning, performed either:
    - with washing (chlorination): for example strawberries and blueberries
    - without washing: for example blackberries and raspberries. Both products are fragile and will collapse if washed, particularly after the calyx is removed.

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- Freezing to – 18°C, either:
  - Static: products are placed in a tray, on a pallet, in the cold store, and are frozen over night.
  - IQF (Individually Quick Frozen): products are added to a perforated belt which enters a freezing tunnel, where freezing air is blown through the belt to freeze the berries in a matter of minutes.
- Intermediate storage: frozen berries are stored at -18°C in food-grade liners inside boxes (typically 10kg – 15kg) or bags (typically 15kg –25kg), until requested by the customer
- Inspection and repacking into customer packaging

(18) Agricultural practices depend on the country of production and field conditions (flat or hills). In EU countries such as Poland or Serbia berries are usually produced by small farms (mainly manually harvested). Where decalyxing is required (in particular strawberries) this is performed manually (in the field or at the factory) as well as washing, the remainder of the process is mechanical.

(19) The main water sources used in the processing practices are drinking water and potable well water. The water is tested according the applicable microbiological standards for potable water.

Distribution & retail

(21) Berries are generally cooled using forced air systems a short time after harvest. After removing the field heat, fruit is transferred and held in standard regular atmosphere coolers. The optimal temperature ranges from 3 to 5 °C. Most berries have a shelf life of 1 week, certain berries may however be stored longer if needed (blueberries 2-3 months, red currants 5-6 months). Work is constantly being done to try and improve and increase shelf life.

Systems in place to ensure safety of products

(41) Berries are generally not washed, but receive a post-harvest fungicide treatment (e.g. ozone) to prevent the development of Botritis.

Other questions on distribution & retail and systems in place to ensure safety of products are of horizontal nature and apply to all fresh produce categories. The responses to these questions are available in a separate document.

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Enjoy Fresh
Fruits & Vegetables

19 July 2013

Background information distribution & food safety practices

Distribution & retail (questions 21-24)

(21) No particular transport and distribution conditions apply for leafy greens destined for fresh market (i.e. transport under ambient temperature), for quality reasons many operators will nevertheless try to ensure the cold chain, particular for long haul transport (<10°C). In the case of fresh-cut, transport and distribution need to take place under regulated temperature. The practices vary per country and are fixed in national legislation (BE, DE, NL: <7°C, FR: 1-4°C, IT: <6°C, SE: 2-5°C). In general operators will apply lower temperatures to optimise quality and shelf life. Some species (e.g. herbs),however, do not support such lower temperatures.

(22) The control of the cold chain will be under the responsibility of the manufacturer until the delivery, whereby the temperature will be checked during loading and unloading of the truck as well as being registered during transport. From delivery until the purchase by the consumer, the control of the cold chain will be under the responsibility of the retailer. In the case of long term storage (e.g. cabbage, carrots, onions), cabbage and carrots are stored in cold stores whereby temperature and moisture are set. Onions are stored similarly to potatoes in ventilated cold stores whereby sprout suppressants are used.

(23) All vegetables for the fresh market may be sold under ambient temperature. In general most vegetables will however be sold under regulated temperature to maintain quality and ensure longer shelf life. Fresh-cut produce may only be sold under regulated temperature (see also question 21).

(24) Traceability: see presentation

Food safety systems (questions 25-42)

(25-26) Guidelines for good hygiene practices in fresh produce are available at national level, with separate guidance for primary production, distribution & trade as well as processing (fresh-cut). All guidance documents are generic and apply to both fruit and vegetables, although they include specific provisions for certain product categories where needed.

EU guidelines are not available, private certification systems (e.g. GlobalGAP, QS, IFS, BRC, ...) however provide a broader scope.

The main strength of these schemes consists in the identification of hazards and establishment of preventive measures from field to distribution. A weakness in the guidelines on primary production is the lack of attention to microbiological and emerging risks. These are however gradually being addressed.

(27) Major weak points in agricultural production system include the irrigation with surface

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water, contamination by pests or animals and contact with the soil for certain salad types. The principal weak point for fresh-cut produce is a possible major rupture of the cold chain after delivery.

(28) EU Hygiene rules (Reg. 852/2004) require the registration as food processing establishment of any company producing fresh-cut produce. The hygienic requirements these companies need to comply with are provided in Annex II which are further clarified in national good hygiene practices guidelines or private certification schemes. Control of these requirements take place through control plans, internal and external audits as well as official inspections.

(29) There is no central repository of non-compliances at EU or national level. Generally companies analyse non-compliances in order to improve their practices. Some national industry associations pool microbiological test results on fresh produce as well as chlorine data to enable collective improvement actions or monitor the state of play regarding pathogens for which no microbiological criteria have been established.

(30) Positive release schemes are not used in the fresh-cut segment given the short shelf life of fresh-cut produce and the time needed for microbiological analysis.

(31) Producers and producer associations do carry out regular testing, a microbiological control plan is defined by each party involved in primary production. A retail level a random control plan is implemented.

(32) Sampling plans for microbiological testing/monitoring are defined in the legislation and are set by each food business operator on the basis of a risk analysis.

(33 and 37-38) Imported produce is treated similarly to EU produce and is not subject to additional testing or specific other hygiene requirements.

(34) Freshfel does not have centralised data available regarding the detection of Salmonella and Norovirus on leafy greens, or Salmonella, Yersinia, Shigella and Norovirus on bulb and stem vegetables and carrots.

The French fresh-cut industry association (SFPAE) collected data for Salmonella on leafy greens, from 2010 to 2012 more than 1.000 samples per year (all negative). The association is also carrying out further research regarding norovirus (results expected in 2014).

Belgium, Germany and the Netherlands have set-up a monitoring scheme for various fruit and vegetables which will be implemented in the coming months.

(35) Detection methods being used:

- Salmonella: NEN-EN-ISO 6579:2002, BRD 07/11-12/05, Rapid Salmo AES 10/4-05/04
- Norovirus: no validated method to date (research French association SFPAE)
- Shigella: NEN-EN-ISO 21567:2004
- Yersinia: NEN-EN-ISO 10273:2003

Commercial kits are sporadically used, generally companies prefer accredited methods in order to avoid discussions in case of complaints.
Commonly vegetables in the fresh-cut segment are tested on Salmonella, E. Coli and Listeria; other pathogens may be tested for on specific request of customers.

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(36) There is no difference in hygienic requirements for the production of organic versus conventional leafy greens.

(39) Decontamination methods used in primary production:

- Soil treatment: Metam-sodium, Dazomet, 1,3-Dichloropropone, steam, solarisation
- Manure treatment: composting

These treatments are primarily meant to combat pests (nematicide) and disease, and limit weed competition (herbicide). Assurance schemes generally recommend to maximise the time between manure application and harvest. GlobalGAP recommends untreated organic fertiliser should not be used from 60 days previous to the harvest season.

(40) Water treatment methods:

- Water reservoir: mostly no treatment, where allowed oxidative or copper compounds as well as chlorine
- Irrigation system: chlorydric acid
- Processing water
    - Chemical: chlorine solutions; ozone; peracetic acid
    - Physical: UV-light, ultrasound

(41) Decontamination methods of produce:

- Chemical: not available
- Physical: grading (optical and visual), recovery of foreign bodies by difference in density in the cleaning trays, leaching during the cleaning process, rinsing with drinking water

(42) Freshfel does not provide specific recommendations on methods used to reduce contamination by pathogens on fresh produce.

Key differences EU vs US fresh produce practices

- Preventive approach (GAP, GHP) EU versus curative approach US => disinfection in the field and of finished product
- Production concentrated in South West => transportation time =>longer shelf life (14-18 days vs 7-11 days in EU)
- Processing facilities near the production sites in US vs processing facilities nearby the consumer market in EU
- Transport under regulated temperature in EU vs transport with crushed ice (source of contamination) in US
- Presence of large cattle farms with flood washing systems nearby rivers which are used for irrigation in US
- Scale of operators is much larger in US vs EU
- Larger market penetration of fresh-cut produce in US vs EU

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Appendix B. Berries production statistics tables (EUROSTAT, FAOSTAT) (provided by Freshfel on 5 November 2013)

Table 4: Strawberry production in metric tons (Source: FAOSTAT for 2007/2011; EUROSTAT for 2012)

Producing Country	2007	2008	2009	2010	2011	2012	Share in 2011
Spain	269 139	281 240	266 772	275 355	262 730	374 500	23.5 %
Poland	174 578	200 723	198 907	153 410	166 159	NR	14.8 %
Germany	158 658	150 854	158 563	156 911	154 418	155 800	13.8 %
Italy	160 558	155 583	163 044	153 875	150 000	NR	13.4 %
United Kingdom	92 100	104 900	109 900	102 900	106 890	96 000	9.6 %
France	46 900	44 142	49 142	50 358	50 813	53 100	4.5 %
Netherlands	43 000	42 200	43 000	42 700	47 000	50 000	4.2 %
Extra-EU	40 461	43 294	42 997	36 526	41 155	38 735	3.7 %
Belgium	41 000	37 400	33 000	35 000	37 500	NR	3.4 %
Romania	16 496	21 233	21 969	21 434	18 909	15 800	1.7 %
Austria	14 612	19 363	17 108	16 426	14 239	9 900	1.3 %
Sweden	11 800	11 700	11 700	11 500	12 893	16 300	1.2 %
Finland	9 697	11 151	11 578	10 286	12 764	14 200	1.1 %
Greece	9 419	9 000	11 000	9 986	9 337	42 900	0.8 %
Denmark	6 000	6 200	5 931	5 390	7 090	7 900	0.6 %
Bulgaria	5 964	8 599	8 599	5 727	7 027	4 800	0.6 %
Hungary	4 616	6 684	6 597	3 844	3 595	4 100	0.3 %
Lithuania	5 063	5 105	4 990	2 634	3 124	3 500	0.3 %
Portugal	2 600	2 620	2 650	2 790	2 667	14 400	0.2 %
Czech Republic	11 993	12 543	2 580	2 654	2 172	1 800	0.2 %
Slovenia	1 762	1 872	2 054	1 790	1 993	NR	0.2 %
Ireland	1 400	1 514	1 603	1 461	1 572	NR	0.1 %
Cyprus	1 867	1 715	1 642	1 788	1 503	1 400	0.1 %
Estonia	1 500	1 512	1 790	1 275	1 292	1 100	0.1 %
Slovakia	587	691	1 209	1 418	846	700	0.1 %
Latvia	1 446	1 984	657	607	783	900	0.1 %
Malta	393	504	480	690	762	900	0.1 %
Luxembourg	35	13	19	17	19	NR	0.0 %
Total	**1 133 644**	**1 184 339**	**1 179 481**	**1 108 752**	**1 119 252**	**908 735**	**100.0 %**

NR: Not reported at the time of production of the table.

Table 5: Strawberry imports from intra-EU in metric tons (Source: EUROSTAT)

Importing Country	2007	2008	2009	2010	2011	2012	Share 2012
Germany	82 194	86 622	105 755	100 597	99 298	105 041	23.5 %
France	94 746	91 688	93 469	83 959	78 640	94 463	21.2 %
Italy	31 806	36 796	33 132	36 518	36 039	41 012	9.2 %
United Kingdom	58 472	37 153	31 932	30 473	36 214	37 955	8.5 %
Belgium	25 693	24 585	23 166	22 213	23 754	30 665	6.9 %
Austria	17 240	17 248	19 545	17 227	19 323	29 442	6.6 %
Netherlands	24 713	17 997	20 648	28 785	27 518	24 559	5.5 %
Portugal	11 250	10 112	20 473	11 040	13 026	16 405	3.7 %
Poland	2 643	3 400	3 262	4 894	7 063	12 371	2.8 %
Czech Republic	7 556	6 972	8 456	7 039	9 050	10 526	2.4 %
Denmark	8 531	8 695	11 418	8 532	7 649	8 192	1.8 %
Sweden	4 465	4 688	5 698	5 448	6 572	7 484	1.7 %
Lithuania	2 035	3 886	1 816	2 323	2 609	6 375	1.4 %
Spain	2 008	1 661	1 585	3 403	2 502	3 830	0.9 %
Bulgaria	529	357	1 228	1 316	1 900	3 032	0.7 %
Slovakia	1 422	4 091	7 387	3 527	1 322	2 276	0.5 %
Hungary	1 698	1 616	1 082	1 638	2 290	2 133	0.5 %
Slovenia	1 489	1 815	1 584	1 743	1 856	1 994	0.4 %
Luxembourg	1 412	1 442	1 427	1 536	1 514	1 681	0.4 %
Finland	1 087	971	1 380	1 283	1 611	1 668	0.4 %
Ireland	2 677	2 600	3 524	1 461	1 109	1 492	0.3 %
Estonia	1 475	913	1 037	1 213	1 157	1 126	0.3 %
Romania	644	499	705	570	426	1 008	0.2 %
Latvia	966	1 080	608	1 247	420	868	0.2 %
Greece	798	516	770	742	1 087	491	0.1 %
Cyprus	67	171	143	83	140	111	0.0 %
Malta	13	60	58	54	59	85	0.0 %
Total	**387 627**	**367 633**	**401 286**	**378 864**	**384 149**	**446 285**	**100.0 %**

Table 6: Strawberry imports from extra-EU in metric tons (Source: FAOSTAT for 2007/2011; EUROSTAT for 2012)

Exporting Country	2007	2008	2009	2010	2011	2012	Share 2012
Morocco	20 638	23 253	19 407	16 502	24 228	22 632	58.4 %
Egypt	6 737	6 761	13 244	9 218	5 866	6 800	17.6 %
Turkey	4 880	7 704	7 081	7 575	5 531	5 197	13.4 %
United States	4 648	3 723	2 204	1 998	3 412	2 411	6.2 %
Peru	320	226	211	145	336	313	0.8 %
Palestina (OPT)[a]	203	0	0	73	456	311	0.8 %
Russia	0	0	1	0	11	202	0.5 %
Croatia	7	38	90	131	153	169	0.4 %
Israel	2 026	948	447	490	602	160	0.4 %
Jordan	146	68	99	20	90	154	0.4 %
Other	857	616	213	375	470	393	1.0 %
Total	**40 461**	**43 337**	**42 997**	**36 526**	**41 155**	**38 740**	**100.0 %**

(a) OPT: Occupied Palestinian Territory

Table 7: Raspberry production in metric tons (Source: FAOSTAT for 2007/2011; EUROSTAT for 2012)

Producing Country	2007	2008	2009	2010	2011	2012	Share in 2011
Poland	56 391	81 552	81 778	92 864	117 995	0	64.8 %
United Kingdom	14 800	15 500	15 300	17 000	16 761	14 000	9.2 %
Spain	10 000	12 000	11 165	9 226	9 552	12 900	5.2 %
Extra-EU	9 767	6 741	6 757	5 394	9 362	6 492	5.1 %
Bulgaria	3 711	3 540	3 510	6 109	7 650	4 900	4.2 %
Germany	6 191	5 334	5 068	5 212	4 778	4 700	2.6 %
France	5 716	6 219	4 342	3 590	3 722	0	2.0 %
Hungary	6 166	6 304	4 967	3 184	2 267	1 500	1.2 %
Italy	1 647	1 700	1 956	1 990	2 000	0	1.1 %
Lithuania	1 531	1 691	1 794	1 499	1 615	1 900	0.9 %
Portugal	700	900	1 500	1 579	1 509	3 100	0.8 %
Austria	1 321	1 139	1 112	1 168	1 209	800	0.7 %
Belgium	700	700	500	1 155	850	0	0.5 %
Netherlands	621	526	666	582	716	0	0.4 %
Finland	436	534	567	529	696	700	0.4 %
Sweden	300	400	430	400	465	0	0.3 %
Latvia	109	143	228	180	353	100	0.2 %
Ireland	156	167	188	187	210	0	0.1 %
Estonia	210	256	213	282	160	100	0.1 %
Denmark	66	65	65	95	73	100	0.0 %
Greece	77	72	74	67	63	0	0.0 %
Czech Republic	23	50	42	50	61	0	0.0 %
Romania	2 200	17	48	31	47	0	0.0 %
Slovakia	19	14	6	2	4	0	0.0 %
Luxembourg	NR	NR	NR	1	1	0	0.0 %
Slovenia	0	0	0	0	0	0	0.0 %
Total	**122 858**	**145 564**	**142 276**	**152 376**	**182 119**	**51 292**	**100.0 %**

NR: Not reported at the time of production of the table.

Table 8: Raspberry imports from intra-EU in metric tons (Source: EUROSTAT)

Importing Country	2007	2008	2009	2010	2011	2012	Share in 2012
Germany	13 862	18 801	15 867	13 390	15 308	14 284	31.0 %
United Kingdom	7 014	8 189	8 109	6 005	6 995	7 310	15.9 %
France	4 946	6 250	6 351	5 664	6 940	6 534	14.2 %
Netherlands	10 949	9 722	11 163	13 349	8 281	6 049	13.1 %
Austria	7 022	10 844	6 222	5 766	4 588	4 642	10.1 %
Belgium	3 632	3 364	3 398	2 538	3 269	2 065	4.5 %
Italy	3 066	5 057	3 100	1 887	2 228	1 555	3.4 %
Lithuania	45	150	174	248	411	670	1.5 %
Spain	147	502	1 132	825	711	648	1.4 %
Sweden	194	252	303	355	424	571	1.2 %
Denmark	310	472	573	889	569	519	1.1 %
Ireland	235	406	362	399	375	309	0.7 %
Finland	72	49	55	101	141	185	0.4 %
Luxembourg	100	93	113	127	135	148	0.3 %
Slovakia	166	38	162	73	76	145	0.3 %
Czech Republic	59	85	161	186	171	123	0.3 %
Portugal	33	175	66	143	110	76	0.2 %
Romania	7	7	4	8	21	69	0.1 %
Poland	11	49	34	78	95	66	0.1 %
Hungary	0	28	0	23	39	51	0.1 %
Latvia	27	12	9	6	21	22	0.0 %
Slovenia	6	35	47	25	14	22	0.0 %
Malta	0	0	0	1	2	17	0.0 %
Estonia	157	69	28	31	44	15	0.0 %
Greece	21	36	5	7	5	14	0.0 %
Bulgaria	31	183	233	0	0	2	0.0 %
Cyprus	2	1	8	0	1	1	0.0 %
Total	**52 113**	**64 868**	**57 677**	**52 125**	**50 971**	**46 113**	**100.0 %**

Table 9: Raspberry imports from extra-EU in metric tons (Source: EUROSTAT)

Exporting Country	2007	2008	2009	2010	2011	2012	Share in 2012
Morocco	638	753	1 206	1 456	1 989	2 361	36.4 %
Mexico	659	477	470	977	968	1 520	23.4 %
United States	1 181	606	548	655	741	1 150	17.7 %
South Africa	210	261	373	445	655	805	12.4 %
Serbia	6 886	4 563	4 070	1 650	3 883	389	6.0 %
Tanzania	47	58	51	74	87	105	1.6 %
Bosnia and Herzegovina	3	1	2	47	21	77	1.2 %
Norway	2	8	9	22	31	46	0.7 %
Chile	113	14	17	37	12	21	0.3 %
Others	30	1	11	32	975	20	0.3 %
Total	**9 767**	**6 741**	**6 757**	**5 394**	**9 362**	**6 492**	**100.0 %**

Table 10: Frozen strawberry and raspberry imports from extra-EU in metric tons (Source: EUROSTAT)

	Frozen strawberries					Frozen raspberries				
EU imports from	**2005**	**2009**	**2010**	**2011**	**2012**	**2005**	**2009**	**2010**	**2011**	**2012**
Morocco	30 436	39 241	32 339	42 737	59 703	2	567	241	298	251
China	43 096	45 664	54 527	67 687	46 705	279	1 713	3 636	2 701	2 334
Egypt	238	4 180	5 747	9 687	15 840	NR	NR	0	NR	NR
Turkey	5 927	4 793	6 638	6 982	5 538	74	183	105	119	151
Peru	24	1 106	1 092	2 891	3 050	NR	NR	NR	NR	NR
Chile	543	1 043	1 859	1 772	1 269	13 523	12 913	19 485	21 628	11 382
Serbia	242	1 155	1 939	1 992	744	28 754	54 225	57 036	67 734	57 897
Mexico	NR	428	143	116	326	NR	NR	NR	20	6
Norway	186	299	376	285	302	96	130	155	161	122
Tunisia	225	109	498	562	281	NR	NR	NR	NR	NR
Argentina	130	468	156	114	127	52	14	NR	NR	NR
Canada	120	NR	NR	NR	124	23	NR	NR	NR	49
United States	185	417	44	45	123	45	106	153	2	49
Ukraine	239	213	360	205	79	141	4	17	2	10
FYROM[(a)]	NR	72	78	141	66	82	1	4	14	20
Switzerland	NR	0	NR	24	15	19	38	9	4	11
Bosnia and Herzegovina	13	254	55	57	8	1 429	1 678	2 143	2 633	2 575
Other	78	85	48	78	21	1	101	68	2	0
Total	**81 681**	**99 526**	**105 901**	**135 374**	**134 320**	**44 518**	**71 673**	**83 052**	**95 317**	**74 856**

NR: Not reported at the time of production of the table.
(a) FYROM: Former Yugoslav Republic of Macedonia

Table 11: Currant production in metric tons (Source: FAOSTAT for 2007/2011; EUROSTAT for 2012 and data from Lithuania)

Producing Country	2007	2008	2009	2010	2011	2012	Share in 2011
Poland	138 568	196 587	196 453	196 658	169 634	195 300	63.1 %
France	9 485	7 678	11 074	21 110	20 720	NR	7.7 %
Austria	19 934	19 767	19 375	19 375	19 960	2 900	7.4 %
Denmark	10 000	9 721	10 400	13 309	13 372	NR	5.0 %
United Kingdom	12 500	13 700	15 800	17 300	12 060	NR	4.5 %
Germany	8 808	10 587	11 847	11 927	9 587	NR	3.6 %
Extra-EU	13 910	20 975	22 328	19 803	8 304	4 447	3.1 %
Netherlands	3 200	2 711	3 435	3 000	3 693	NR	1.4 %
Lithuania	3 800	4 500	5 500	4 000	0	3 600	0.0 %
Hungary	5 191	6 435	7 267	3 853	2 987	NR	1.1 %
Finland	1 936	1 238	2 099	1 438	2 181	NR	0.8 %
Belgium	1 600	1 700	1 900	2 096	1 687	NR	0.6 %
Czech Republic	3 200	3 177	2 506	2 017	1 672	2 300	0.6 %
Estonia	483	734	912	536	780	NR	0.3 %
Italy	700	800	760	716	700	NR	0.3 %
Spain	173	250	350	450	450	NR	0.2 %
Latvia	2 102	484	358	350	427	NR	0.2 %
Sweden	450	465	464	500	400	NR	0.1 %
Slovakia	176	247	305	265	214	NR	0.1 %
Ireland	140	136	157	148	158	NR	0.1 %
Romania	29	11	18	19	30	NR	0.0 %
Greece	20	19	22	17	16	NR	0.0 %
Slovenia	5	6	5	5	5	NR	0.0 %
Bulgaria	NR	NR	NR	0	0	NR	0.0 %
Total	**236 410**	**301 928**	**313 335**	**318 892**	**269 037**	**208 547**	**100.0 %**

NR: Not reported at the time of production of the table.

Table 12: Currant imports from intra-EU in metric tons (Source: EUROSTAT)

Importing Country	2007	2008	2009	2010	2011	2012	Share in 2012
United Kingdom	11 056	9 934	10 289	10 813	12 700	10 630	48.6 %
Netherlands	6 729	4 702	4 789	5 008	6 611	6 535	29.9 %
Germany	1 149	1 153	1 043	1 131	1 086	1 094	5.0 %
Portugal	95	359	216	472	1 173	830	3.8 %
France	374	664	635	911	867	517	2.4 %
Ireland	56	112	246	175	241	416	1.9 %
Poland	770	726	613	492	593	307	1.4 %
Romania	98	112	34	12	7	294	1.3 %
Czech Republic	89	128	179	206	218	238	1.1 %
Denmark	127	53	151	193	167	213	1.0 %
Hungary	357	548	527	279	192	197	0.9 %
Italy	122	149	105	133	103	130	0.6 %
Belgium	220	123	30	40	28	100	0.5 %
Spain	232	203	227	200	167	69	0.3 %
Slovakia	128	81	49	41	26	54	0.2 %
Bulgaria	0	13	30	4	42	52	0.2 %
Austria	49	63	57	45	50	48	0.2 %
Estonia	6	3	4	4	2	32	0.1 %
Sweden	134	29	24	30	17	29	0.1 %
Finland	27	38	22	19	29	26	0.1 %
Lithuania	33	10	0	12	21	18	0.1 %
Cyprus	86	80	58	45	50	17	0.1 %
Slovenia	9	10	30	12	8	11	0.0 %
Latvia	7	4	2	21	21	9	0.0 %
Luxembourg	5	16	12	8	8	7	0.0 %
Greece	13	42	0	23	19	2	0.0 %
Malta	4	12	7	2	2	2	0.0 %
Total	**21 975**	**19 366**	**19 375**	**20 329**	**24 444**	**21 876**	**100.0 %**

Table 13: Currant imports from extra-EU in metric tons (Source: EUROSTAT)

Exporting Country	2007	2008	2009	2010	2011	2012	Share 2012
Iran	8 958	5 338	1 232	4 719	2 610	1 617	36.4 %
India	0	1	337	55	770	786	17.7 %
South Africa	204	749	1 011	1 098	745	730	16.4 %
United States	395	6 383	4 892	4 508	887	563	12.7 %
Chile	1 506	2 545	2 848	2 035	818	294	6.6 %
China	1 884	3 391	4 970	4 266	1 995	261	5.9 %
Afghanistan	7	0	0	345	85	116	2.6 %
Uzbekistan	168	477	20	267	59	40	0.9 %
United Arab Emirates	0	55	0	0	0	19	0.4 %
Turkey	179	1 581	5 820	327	209	19	0.4 %
Other	609	457	1 198	2 182	127	1	0.0 %
Total	**13 910**	**20 975**	**22 328**	**19 803**	**8 304**	**4 447**	**100.0 %**

Table 14: Blackcurrant production in metric tons (Source: EUROSTAT)

Producing Country	2007	2008	2009	2010	2011	2012	Share in 2010
Poland	101 000	151 200	145 800	151 500	0	0	75.5 %
United Kingdom	11 400	0	0	17 300	12 000	10 000	8.6 %
Denmark	0	0	0	11 100	10 100	10 200	5.5 %
France	7 500	7 700	0	7 400	9 400	0	3.7 %
Lithuania	3 000	3 900	4 900	3 600	3 300	3 100	1.8 %
Netherlands	0	0	0	3 000	3 000	0	1.5 %
Czech Republic	800	900	0	2 000	1 700	2 500	1.0 %
Austria	7 100	6 700	6 400	1 400	1 300	1 200	0.7 %
Hungary	1 900	2 400	2 500	1 300	1 600	1 700	0.6 %
Finland	1 600	1 000	1 700	1 000	1 700	1 300	0.5 %
Italy	0	0	0	700	0	0	0.3 %
Latvia	1 100	400	300	300	400	500	0.1 %
Extra-EU	28	294	22	19	60	2	0.0 %
Sweden	0	300	0	0	300	0	0.0 %
Bulgaria	0	0	0	0	0	100	0.0 %
Estonia	0	0	0	0	0	200	0.0 %
Germany	0	0	0	0	0	6 300	0.0 %
Portugal	0	0	0	0	0	100	0.0 %
Slovakia	100	200	200	0	0	200	0.0 %
Total	**135 528**	**174 994**	**161 822**	**200 619**	**44 860**	**37 402**	**100.0 %**

Table 15: Blackcurrant imports from intra-EU in metric tons (Source: EUROSTAT)

Importing Country	2007	2008	2009	2010	2011	2012	Share in 2012
Germany	3 056	4 544	6 559	6 370	6 241	9 278	63.2 %
Italy	1 203	1 680	1 762	1 780	1 785	1 945	13.2 %
United Kingdom	138	95	575	300	7	1 799	12.2 %
Austria	755	1 236	132	1 199	932	590	4.0 %
Hungary	1	0	0	0	25	487	3.3 %
Netherlands	216	18	489	660	568	335	2.3 %
Belgium	242	0	150	199	292	119	0.8 %
France	29	170	79	45	58	74	0.5 %
Denmark	5	33	49	36	50	21	0.1 %
Latvia	144	300	387	401	49	9	0.1 %
Spain	3	0	1	2	2	8	0.1 %
Romania	0	0	0	7	6	8	0.1 %
Portugal	3	3	1	2	19	7	0.0 %
Lithuania	6	139	1	10	23	3	0.0 %
Estonia	573	0	0	0	74	3	0.0 %
Cyprus	3	1	11	1	0	2	0.0 %
Luxembourg	2	1	5	5	5	1	0.0 %
Finland	0	0	1	1	1	1	0.0 %
Poland	0	238	592	0	75	1	0.0 %
Czech Republic	18	6	4	0	0	1	0.0 %
Bulgaria	0	4	1	307	12	0	0.0 %
Greece	0	0	0	4	6	0	0.0 %
Ireland	1	0	3	3	3	0	0.0 %
Malta	2	2	0	0	0	0	0.0 %
Sweden	6	0	2	1	0	0	0.0 %
Slovenia	0	1	1	1	1	0	0.0 %
Slovakia	19	8	1	8	12	0	0.0 %
Total	**6 425**	**8 480**	**10 804**	**11 341**	**10 246**	**14 691**	**100.0 %**

Table 16: Redcurrant production in metric tons (Source: EUROSTAT)

Producing Country	2007	2008	2009	2010	2011	2012	Share in 2012
Poland	37 600	45 400	50 600	44 300	45 400	45 900	94.7 %
Czech Republic	2 400	2 700	3 600	0	2 800	1 800	3.7 %
Lithuania	800	500	600	400	0	500	1.0 %
Extra-EU	77	185	197	156	228	244	0.5 %
Austria	12 900	13 000	13 000	0	0	0	0.0 %
Belgium	1 600	1 700	1 900	0	0	0	0.0 %
Cyprus	0	0	0	0	0	0	0.0 %
Denmark	0	0	0	2 200	3 300	0	0.0 %
Finland	300	200	400	400	0	0	0.0 %
France	1 900	1 800	0	0	0	0	0.0 %
Hungary	3 200	4 000	4 800	2 500	0	0	0.0 %
Italy	0	0	0	0	0	0	0.0 %
Latvia	1 000	100	0	0	0	0	0.0 %
Slovakia	100	100	0	0	0	0	0.0 %
Total	**61 877**	**69 685**	**75 097**	**49 956**	**51 728**	**48 444**	**100.0 %**

Table 17: Redcurrant imports from intra-EU in metric tons (Source: EUROSTAT)

Importing Country	2007	2008	2009	2010	2011	2012	Share in 2012
Germany	1 567	1 941	1 734	1 001	2 360	1 809	52.4 %
France	551	444	441	424	466	377	10.9 %
Belgium	434	193	336	310	367	357	10.3 %
Lithuania	5	115	44	110	297	213	6.2 %
United Kingdom	280	234	152	180	216	145	4.2 %
Bulgaria	7	0	36	231	72	135	3.9 %
Italy	98	63	193	136	100	120	3.5 %
Austria	327	769	1 127	543	524	75	2.2 %
Spain	39	113	218	89	41	46	1.3 %
Sweden	57	52	55	52	47	30	0.9 %
Ireland	80	6	2	6	11	22	0.6 %
Netherlands	186	38	2	34	62	20	0.6 %
Luxembourg	12	16	19	13	15	20	0.6 %
Romania	3	6	1	10	9	19	0.6 %
Denmark	4	14	19	9	7	16	0.5 %
Slovakia	1	1	2	1	63	8	0.2 %
Poland	168	492	131	2	33	7	0.2 %
Czech Republic	30	6	6	4	7	7	0.2 %
Latvia	3	5	1	1	4	7	0.2 %
Greece	2	9	70	80	6	5	0.2 %
Finland	3	31	17	4	4	4	0.1 %
Portugal	22	10	13	10	16	4	0.1 %
Slovenia	0	2	1	1	10	2	0.1 %
Estonia	1	12	7	0	2	2	0.1 %
Hungary	1	1	0	5	7	1	0.0 %
Malta	0	0	0	2	2	1	0.0 %
Cyprus	0	0	6	0	0	0	0.0 %
Total	**3 880**	**4 570**	**4 631**	**3 260**	**4 746**	**3 449**	**100.0 %**

Table 18: Blueberry production in metric tons (Source: FAOSTAT) [(a)]

Producing Country	2007	2008	2009	2010	2011	Share in 2011
France	19 000	20 000	19 890	11 001	9 379	22.6 %
Poland	5 226	7 857	11 023	9 195	8 595	20.7 %
Germany	5 818	4 116	9 940	8 305	6 608	15.9 %
Netherlands	4 956	4 199	5 322	4 648	5 722	13.8 %
Sweden	2 500	2 584	2 576	2 800	2 600	6.3 %
Lithuania	4 392	4 400	1 794	1 800	2 513	6.0 %
Romania	2 000	2 220	2 349	2 201	2 402	5.8 %
Spain	968	1 038	1 100	1 700	1 700	4.1 %
Italy	1 440	1 435	1 526	1 405	1 441	3.5 %
Portugal	200	220	250	263	251	0.6 %
Latvia	900	300	300	500	200	0.5 %
Bulgaria	100	100	92	90	96	0.2 %
Denmark	NR	NR	NR	47	54	0.1 %
Total	**47 500**	**48 469**	**56 162**	**43 955**	**41 561**	**100.0 %**

NR: Not reported at the time of production of the table.
(a): No import information from non-EU countries was available upon retrieval of these tables

Table 19: Blueberry imports from intra-EU in metric tons (Source: FAOSTAT)

Importing Country	2007	2008	2009	2010	Share in 2010
Germany	1 773	2 372	3 872	4 815	24.1 %
Austria	1 286	2 124	2 581	2 265	11.3 %
Netherlands	318	772	676	2 059	10.3 %
United Kingdom	2 587	1 158	901	2 007	10.1 %
France	331	1 098	1 519	1 484	7.4 %
Italy	579	907	835	1 300	6.5 %
Estonia	1 732	1 128	3 248	1 158	5.8 %
Poland	2 278	741	1 108	1 138	5.7 %
Denmark	255	182	615	790	4.0 %
Latvia	39	50	387	535	2.7 %
Finland	967	980	1 200	518	2.6 %
Belgium	130	367	185	448	2.2 %
Spain	63	76	130	438	2.2 %
Lithuania	2 758	342	1 133	424	2.1 %
Sweden	693	119	130	213	1.1 %
Czech Republic	97	200	133	156	0.8 %
Slovenia	23	57	149	100	0.5 %
Ireland	48	3	0	35	0.2 %
Luxembourg	10	11	12	29	0.1 %
Slovakia	3	5	18	25	0.1 %
Bulgaria	0	0	0	15	0.1 %
Romania	19	7	3	3	0.0 %
Portugal	4	5	3	2	0.0 %
Greece	0	0	0	0	0.0 %
Malta	0	1	0	0	0.0 %
Total	**15 993**	**12 705**	**18 838**	**19 957**	**100.0 %**

Table 20: Cranberry production in metric tons (Source: FAOSTAT)

Producing Country	2007	2008	2009	2010	2011	Share in 2010
Extra-EU	10 538	14 388	14 991	17 310	NR	89.8 %
Latvia	1 900	1 665	1 525	1 434	1 530	7.4 %
Romania	328	364	386	362	395	1.9 %
Bulgaria	100	100	92	90	96	0.5 %
Spain	95	102	91	89	91	0.5 %
Total	**12 961**	**16 619**	**17 085**	**19 285**	**2 112**	**100.0 %**

NR: Not reported at the time of production of the table.

Table 21: Cranberry imports from intra-EU in metric tons (Source: FAOSTAT)

Importing Country	2007	2008	2009	2010	Share in 2010
United Kingdom	6 726	9 586	9 456	10 296	59.5 %
Netherlands	2 507	3 346	3 463	4 172	24.1 %
Belgium	593	703	748	902	5.2 %
Germany	181	139	275	539	3.1 %
Spain	34	15	301	411	2.4 %
Latvia	227	157	47	250	1.4 %
Italy	75	73	204	174	1.0 %
Portugal	0	23	10	135	0.8 %
Sweden	12	39	78	94	0.5 %
Finland	17	56	61	82	0.5 %
Ireland	21	52	22	74	0.4 %
Denmark	28	102	154	66	0.4 %
France	42	41	101	55	0.3 %
Austria	15	40	42	27	0.2 %
Lithuania	57	7	13	13	0.1 %
Bulgaria	0	0	9	9	0.1 %
Slovakia	0	1	5	7	0.0 %
Estonia	3	8	1	4	0.0 %
Malta	0	0	1	0	0.0 %
Total	**10 538**	**14 388**	**14 991**	**17 310**	**100.0 %**

Table 22: Production of other berries in metric tons (Source: FAOSTAT for 2007/2011; EUROSTAT for 2012)

Producing Country	2007	2008	2009	2010	2011	2012	Share in 2011
Italy	71 000	87 200	92 000	84 700	85 000	NR	51.2 %
Poland	38 851	46 927	39 302	57 035	50 578	64 600	30.5 %
Spain	2 800	2 200	5 000	7 000	7 000	NR	4.2 %
United Kingdom	5 400	5 300	6 100	5 950	5 866	NR	3.5 %
Extra-EU	6 178	5 232	5 136	5 208	5 471	5 527	3.3 %
Romania	2 200	2 442	2 585	2 422	2 643	NR	1.6 %
Czech Republic	1 067	1 243	1 041	1 200	1 461	NR	0.9 %
Sweden	1 320	1 364	1 360	1 500	1 400	NR	0.8 %
Netherlands	1 185	1 004	1 272	1 111	1 368	NR	0.8 %
Lithuania	500	650	747	1 236	1 135	800	0.7 %
Greece	1 111	1 036	1 065	967	904	NR	0.5 %
Austria	4 553	3 227	2 160	945	849	900	0.5 %
Estonia	120	403	501	471	388	NR	0.2 %
Latvia	359	315	367	379	363	NR	0.2 %
Germany	299	177	224	219	304	NR	0.2 %
Finland	151	141	206	158	264	NR	0.2 %
Ireland	171	182	218	225	216	NR	0.1 %
Bulgaria	300	221	244	200	212	NR	0.1 %
Slovenia	124	104	107	129	177	NR	0.1 %
Portugal	83	110	120	126	120	3 900	0.1 %
Malta	172	187	102	112	114	NR	0.1 %
Belgium	78	63	81	83	100	NR	0.1 %
Slovakia	56	180	130	91	87	NR	0.1 %
Total	**138 078**	**159 908**	**160 068**	**171 467**	**166 020**	**75 727**	**100.0 %**

NR: Not reported at the time of production of the table.

Table 23: Imports of other berries from extra-EU in metric tons (Source: EUROSTAT)

Exporting Country	2007	2008	2009	2010	2011	2012
Mexico	2 173	2 740	2 738	2 442	2 950	2 748
Serbia	2 608	1 371	1 400	1 866	1 485	1 503
FYROM[(a)]	0	19	0	288	489	70
Guatemala	64	114	415	334	263	670
United States	458	155	139	125	164	89
Uruguay	4	8	11	17	28	3
Morocco	51	305	47	15	21	0
South Africa	1	5	39	34	16	18
Chile	43	35	23	27	16	0
China	11	70	126	24	14	17
Brazil	60	52	31	12	10	4
Russia	254	0	0	0	1	258
Argentina	216	291	115	2	1	1
Other	238	69	53	24	14	147
Total	**6 178**	**5 232**	**5 136**	**5 208**	**5 471**	**5 527**

(a) FYROM: Former Yugoslav Republic of Macedonia

Appendix C. Results of controls for Norovirus carried out on consignments of frozen strawberries originating from China during the period 1 January - 31 December 2013 in EU plus Norway

Table 24: Results of controls for Norovirus carried out on consignments of frozen strawberries originating from China during the period 1 January - 31 December 2013 in EU plus Norway

Quarter during 2013	Number of consignments	Number of physical checks carried out	Number of non-compliant physical checks [(a)]
Quarter 1: 1 January – 31 March 2013	315	23	1
Quarter 2: 1 April – 30 June 2013	302	21	1
Quarter 3: 1 July – 30 September 2013	435	29	0
Quarter 4: 1 October – 31 December 2013	315	25	0
Total for 2013	1367	98	2

(a) Norovirus detected

GLOSSARY

Aggregate or accessory fruits are clusters of small fruits derived from the separate carpels of a single flower, whereas the individual little fruits on a multiple fruit can be traced back to separate flowers themselves tightly bunched in a head-like flower cluster. Carpels are one of the individual female reproductive organs in a flower.

Berries are small, spherical or ovoid, fleshy and juicy fruits. This does not correspond to the botanical definition of berries (true berries), which refers to fruits formed by the transformation of the whole ovary. Many true berries are not included in the commercial category of berries (e.g. tomatoes, melons, grapes), and some fruits included in the commercial and common usage category of berries used here are not true berries but are aggregate or accessory fruits (e.g. blackberry, raspberry, strawberry).

Calyx is the envelope that surrounds the reproductive parts of a flower and it is typically divided into lobes called sepals. Sepals are frequently green. The calyx can be considered to be an integral part of some fruit. In the case of strawberries, they are defined as the green leafy cap, which is often included on the fruit at retail.

Clean water is clean seawater (natural, artificial or purified seawater or brackish water that does not contain microorganisms, harmful substances or toxic marine plankton in quantities capable of directly or indirectly affecting the health quality of food) and fresh water of a similar quality (Regulation (EC) No 852/2004)[29].

Decontamination treatments are mechanical, physical, and chemical treatments, which are applied to eliminate contaminants, including microbial contamination. They can be applied to water, surfaces, equipment and areas.

Disinfectants are agents or systems that kill or eliminate microrganisms found on inanimate surfaces or environments. Within this Opinion, disinfectant agents or systems are defined as those decontamination agents applied to eliminate microorganisms in water.

Fertigation is the application of fertilizers, soil amendments, or other water-soluble products through an irrigation system.

Food of non-animal origin include those derived from plants and comprise a wide range of fruit, vegetables, salads, juices, seeds, nuts, cereals, herbs, spices, fungi and algae, which are commonly consumed in a variety of forms. Categorisation of FoNAO, as considered in the scope of this Opinion, is discussed in Section 2.2 of EFSA Panel on Biological Hazards (BIOHAZ) (2013).

Food Safety Criteria are defined in EU legislation for the microbiological acceptability of food products and are criteria defining the acceptability of a product or a batch of foodstuff applicable to products placed on the market (Regulation (EC) No 2073/2005)[30]. If a Food Safety Criterion is not met for a product or batch of foodstuff, then this should not be placed on the market or, if it already has, should be considered for recall.

Fresh Produce refers to fresh fruits and vegetables that are likely to be sold to consumers in an unprocessed or minimally processed (i.e. raw) form and are generally considered as perishable. Fresh produce may be intact, such as strawberries, whole carrots, radishes, and fresh market tomatoes, or cut

[29] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 30.4.2004, p. 1-54.

[30] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. OJ L 338, 22.12.2005, p. 1-26.

during harvesting, such as celery, broccoli, and cauliflower[31]. In the scope of this Opinion fresh produce also applies to fresh-cut produce, such as pre-cut, packaged, ready-to-eat salad mixes.

Fungicide is a specific type of pesticide that controls fungal diseases by specifically inhibiting or killing the fungus or fungal spores.

Good Agricultural Practices (GAP) apply available knowledge to address environmental, economic and social sustainability for on-farm production and post-production processes resulting in safe and healthy food and non-food agricultural products (FAO, 2003).

Good Hygiene Practices (GHP) relate to general, basic conditions for hygienic production of a foodstuff, including requirements for hygienic design, construction and operation of the plant, hygienic construction and use of equipment, scheduled maintenance and cleaning, and personnel training and hygiene. A developed and implemented GHP programme is a pre-requisite for HACCP system (EFSA, 2005).

Good Manufacturing Practices (GMP) cover the principles needed to design plant layout, equipment and procedures for the production of safe food. This includes hygienic operation and cleaning and disinfection procedures. The codes and requirements may be formally specified by e.g. Codex Alimentarius Committee on Food Hygiene (EFSA, 2005).

Harvest is the process of collecting mature crops from the fields and immediate handling.

Hydro-cooling is one of several postharvest cooling methods available to growers, packers, and shippers to reduce the temperature of the crops. This technique consist in dumping produce into cold water, or running cold water over produce to remove heat.

Hydro-coolers produce chilled water and then move this water into contact with the produce.

Hydroponic culture represents a type of soil-less growing system where fertilizer ingredients are in solution in the root environment of the plants, and any solid media in the plant root environment will not significantly interact with the fertilizer in the water of the system. The plants in the system absorb the nutrients they need for growth from the water available in the root environment. Common solid media used in hydroponic culture include perlite and rockwool. Soil is not used in a hydroponic system (Brown, online).

Hygiene Criteria are criteria indicating the acceptable functioning at pre-harvest, harvest and on farm post-harvest production prior to processing and are proposed to verify and validate Good Agricultural Practices (GAP) and Good Hygiene Practices (GHP).

Individually quick frozen fruits (IQF) are fruits that are ultra rapidly frozen to very low temperatures (-30 to -40 °C) designed to bring the inside of the product to a temperature of -18 °C as quickly as possible. Rapid lowering of the temperature also makes it possible to pass quickly below the critical temperature of 0 to 5 °C at which intracellular liquids freezes. When the quick freezing process is used, these liquids solidify to form extremely small crystals of ice and the cellular structure is left intact, whereas, in the ordinary freezing process, where low temperatures are reached more slowly, the texture of the product is altered, the liquids forming large ice crystal which lacerate the tissues. Individually quick frozen fruits remain in individually separate pieces Apart from low temperature, there is a physical change within the food by conversion of the moisture in it, into ice crystals (Pruthi, 1999).

[31] FDA Guidance for Industry: guide to minimize microbial food safety hazards for fresh fruits and vegetables. 1998. http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/ProducePlantProducts/ucm064574.htm

Minimal processing for berries in this Opinion is defined as any action applied at post-harvest to the product, namely cleaning, cutting and washing as well as freezing. Other processes such as heating, smoking, curing, maturing, drying, marinating, extraction, extrusion or a combination of those processes are excluded.

Pesticides cover insecticides, acaricides, herbicides, fungicides, plant growth regulators, rodenticides, biocides and veterinary medicines. Pesticides are chemical compounds: a substance or mixture of substances, or microorganisms including viruses used in plant protection to: (i) kill, repel or control pests to protect crops before and after harvest; (ii) influence the life processes of plants; (iii) destroy weeds or prevent their growth; (iv) preserve plant products[32].

Potable water is water which meets the requirements laid down in Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption (mainly microbiological and chemical criteria) (Regulation (EC) No 852/2004)[33].

Post-harvest is the stage of crop production after harvest and includes on-farm cooling, cleaning, sorting and packing.

Pre-harvest incorporates all activities on the farm that occur before crop products are harvested.

Process Hygiene Criteria are criteria indicating the acceptable functioning of the production process. Such criteria are not applicable to products placed on the market. They set an indicative contamination value above which corrective actions are required in order to maintain the hygiene of the process in compliance with food law (Regulation (EC) No 2073/2005)[34].

Processing are any actions that substantially alter the initial product, including heating, smoking, curing, maturing, drying, marinating, extraction, extrusion or a combination of those processes (Regulation (EC) No 852/2004).

Sanitizers are chemical agents that reduce microorganisms on food contact surfaces to levels considered safe from a public health viewpoint. Appropriate sanitization procedures are processes, and, thus, the duration or time as well as the chemical conditions must be described. In some cases, the definition of sanitizing refers a process which reduces the contamination level by 99.999 % (5 logs). Within this Opinion sanitizers are defined as those decontamination agents applied to reduce the level of microorganisms on berries.

Soil-less cultures are various methods and techniques developed for growing plants without soil. These methods include a great diversity of systems, from the purely hydroponic, which are based on the supply of water and nutrients only (e.g. nutrient film technique, or NFT), to those based on artificial mixes that contain various proportions of soil. In between these extremes lie a great number of soil-less or minimal soil methods that make use of some sort of growth medium, which is either inert (e.g. rockwool slabs, polyurethane chunks, and perlite) or not inert (e.g. gravel culture, sand culture, and peat bags) (Papadopoulos, 1991).

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[32] Based upon definition available at http://ec.europa.eu/food/plant/plant_protection_products/index_en.htm

[33] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 30.4.2004, p. 1-54.

[34] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. OJ L 338, 22.12.2005, p. 1-26.