

International Stakeholder Workshop on Best Practice for the Control of Human Pathogenic Microorganisms in Plant Production Systems, Dublin 2019

Report Summary

There is an increased emphasis on and observance of food-borne diseases associated with fresh produce, due in part to changes in the processing, agronomy and distribution of fresh produce but also in the increasing trend for the consumption of minimally processed and raw, ready-to-eat crops. A recent meeting of European experts and commercial growers, assembled under the HuPlant Cost Action assessed the current European situation in relation to the safety of horticultural produce under the themes of (1) protecting fresh produce from microbial pathogens, (2) control strategies and sampling and (3) risk assessment and risk based sampling. The following report details the discussions and observations which emanated from that meeting, including a list of recommendations, aimed at (1) Growers, (2) Regulators and Advisors and (3) Scientists. For growers recommendations include reinforcement through clear communication on the need to prevent initial contamination of produce through the adoption of good microbiological safety practice, utilising on farm risk assessments and a focus on avoidance of initial contamination rather than a reliance on decontamination efforts. This can be achieved through approaches such as the adoption and incorporation of good agricultural practice and good hygiene into standard operating procedures on farm. Recommendations to regulators and advisors include balancing communication messages to growers, indicating what is required of them, but also equally, clearly explaining why it is necessary. Additionally it was felt that additional supports and materials could be made available to growers, particularly to smaller growers, to assist in the training of staff on the importance of biological safety practice, particularly in sectors where staff turnover may be high and differences in the native languages spoken. Finally recommendations to scientists include a greater emphasis on knowledge transfer and also to, where possible focus knowledge transfer efforts into developing clear recommendations which growers can implement. The interaction between the plant microbiome, potential pathogens, environmental conditions and agricultural practices requires a greater level of attention and research to aid in predict the risk of human pathogen establishment. Overall it was recognised that through increased interaction and information exchange between stakeholders will enable better understanding of the issues and opportunities faced by the horticultural sector and the co-creation of advice through participation of all stakeholders can assist in reducing the risk of contamination of horticultural produce.

Introduction

This report emanates from a workshop that was organised by the HUPLANTcontrol COST action (CA16110; Control of Human Pathogenic Microorganisms in Plant Production Systems; Wp1, Wp4 & Wp5; <https://huplantcontrol.igzev.de/work-plan/>), and brought together international researchers, regulators, growers and other stakeholders focused on examining best practice for the control of human pathogenic microorganisms in plant production systems. The workshop was hosted by Teagasc (the Irish Agriculture and Food Development Authority) at the Teagasc Food Research Centre in Dublin on the 2nd and 3rd Sept 2019. Participants comprised a multidisciplinary group of international scientific experts, including researchers in food microbiology, plant microbiology, soil microbiology, microbial ecology, agricultural production, horticulture, microbial pathogenicity and virulence, risk assessment and food safety management. The participants recognised the positive effects of fruit and vegetable consumption on human health and the gut microbiome. There was also an acknowledgement of the substantial improvement of understanding of the plant microbiome brought about by technological advances in microbiology in recent years, which has enhanced our capacity to examine microbial communities on plants, including the occasional occurrence of human pathogens.

The aim of the workshop was to bring together relevant stakeholders to examine biological hazards and control strategies in plant production systems in order to ensure the microbiological safety of horticultural products. The main focus was on pathogens¹ of human health importance that are zoonotic² in nature but that can occasionally become incorporated into plant microbiomes³, and thus may constitute a risk to human health in horticultural produce. The outcomes of the workshop may be useful as an input for food or public health policy recommendations at an EU level. With a particular focus on examining interventions used across Europe and the interpretation of the regulatory landscape in various EU countries for undertaking risk analysis to support control measures, the workshop aimed to generate a series of best practice recommendations that could feasibly be implemented by growers, policy makers, advisors and scientists, and identify barriers to implementation of current best practice.

The initial day and a half was divided into three main sessions:

- 'Protecting fresh produce from microbial pathogens',
- 'Control strategies and sampling',
- 'Risk assessment and risk based sampling'.

Each comprised of a series of overview talks by expert scientific, regulatory or advisory speakers followed by breakout sessions of participants that focused on a series of key questions (the questions addressed are outlined in Appendix 1). A specific horticulture industry stakeholder event was held on the afternoon of the second day to disseminate the workshop outputs, where participants were also asked to voice their perspectives on what they saw as the biggest issues for growers with respect to potential contamination of produce with human pathogens and what they perceived as the gaps in knowledge. Participants also discussed which control measures they thought to be technically feasible/acceptable by consumers, policy makers, and companies, what information would be helpful

¹ pathogens: disease causing organisms

² Zoonotic pathogens : disease causing organisms whose primary host is within animals but that can be transmitted to other hosts, including humans

³ plant microbiome: the community and activity of micro-organisms living together in and on plants

to growers to better manage the risk of microbial contaminants in fresh produce and what form they would like to get information in. In total 50 participants took part in the workshop over the 2 days. The aim of this report is to summarise key discussion points from the workshop and outline a series of recommendations derived from the views of participants that would enhance microbiological safety of horticultural products. This report should be viewed as a reflection on European horticulture as a whole and the recommendations may need to be evaluated at individual country and region levels.

Key workshop discussion points:

The below is a summary of the key discussion points of the workshop that have been organised under the following headings: challenges and trends, assessing risk, sanitation and knowledge gaps.

Challenges and trends

- There is increased emphasis on, and observance of, foodborne disease associated with fresh produce due to a range of factors. These include: changing consumer consumption patterns; larger scale production and more complex distribution networks; increasing levels of processing to enhance shelf life; changing environmental production conditions, improved detection and identification methods, and an increased understanding that human pathogens can become incorporated into the plant microbiome that has resulted in a greater amount of testing and detection. Changing consumer consumption patterns encompass changes in eating patterns of food (e.g. mode and volume of consumption) and packaging requirements (e.g. reduction in packaging) which may affect fresh fruit and vegetables' safety. In some cases food is being consumed in a manner that may not have been anticipated by the grower/producer, such as the consumption of raw mushrooms in salads for example.
- Many growers/producers are moving away from low risk crops (for e.g. crops that are generally cooked) to higher value minimally processed or ready-to-eat crops that have an increased inherent microbiological risk. Reassessment of risk and upskilling of staff is required.
- Discussions emphasized the critical importance of personnel in maintaining food safety and the importance of having a culture of food safety on the farm. All grower/producer employees need to be food safety aware and any weak links in the food safety chain can introduce issues. A key challenge for growers is the high staff turnover in horticultural production - over 90% per annum in some instances! This has implications for training and education, and growers, particularly smaller growers, felt help is needed on how to deal with essential internal training and documentation in the context of high staff turnover. There was discussion on the need to communicate why food needs to be safe and how to achieve this from a Good Agricultural Practice and Good Hygiene Practice perspective. The advice to use visuals and repeat training as frequently as is possible to reinforce messages was highlighted and to 'Keep it simple!'. The importance of a communication strategy that uses different communication, knowledge exchange and training methods for different target audiences (guidance notes, meetings, video clips etc) was discussed so that all in the business develop a food safety culture. The use of different languages for communications and 'Active Learning' was advised. It was also suggested it would be beneficial for staff to have a food safety coach or a buddy system.

- A key challenge in some European countries is how to convince the small producers who do not want to formally register as producers (but who may sell produce in short supply chains or with no good traceability to market) to comply with microbiological safety guidance. It is unclear what the impact of these producers is on overall disease incidences and consumer confidence.
- There is some uncertainty around key terminology with people interpreting terms in different way for example risk vs hazard or decontamination vs disinfection. There needs to be a consensus on terms used so everyone is clear about what is being discussed.
- The spatial and temporal heterogeneity of pathogen occurrence in the field, the crop (e.g. inner or outer leaves) and the final product was noted. This makes sampling more difficult. Often pathogens are present in low levels making detection difficult.
- Growers reported finding it difficult to benchmark themselves and to know how they were doing with regard to food safety, particularly in light of commercial sensitivities that are an issue within this sector. There was discussion about how to bring together growers in a platform to get best practices shared while taking this into account.
- The shift to monoculture and larger scale produce production systems may pose issues, as if something goes wrong in terms of food safety then the grower is more vulnerable. It may also pose issues for farm sustainability for e.g. soil health.
- The behaviour of pathogens in the environment and their interactions with other members of the plant microbiome is dynamic and dependent on the prevailing environmental conditions for e.g. experimental studies have shown that the temperature matters in whether Shiga toxin-producing *E. coli* is outcompeted by microbial bioinoculants⁴.
- Many studies have shown that antimicrobial components can work effectively in a controlled lab environment but this does not necessarily mean they will be effective in the non-controlled and more heterogeneous conditions of the field. There is therefore a need to demonstrate efficacy of antimicrobial agents at pilot, field or processing plant scale to translate into practical advice on the use of such agents for growers.
- With the more widespread use of whole genome sequencing⁵ it may be possible to identify more isolated cases and dispersed outbreaks, aiding epidemiological investigation.
- The potential of biological control options for the human pathogens, such as phage⁶, were discussed. It was also noted that consumer acceptance of such technologies, should they be developed, is currently unknown.

Assessing and managing risk

- Food safety management needs to be risk based and safety cannot be reliant on testing alone.
- It is the responsibility of growers/producers to produce safe food. Whilst it is not possible to eliminate risk entirely the grower needs to use all information at their disposal and carry out due diligence to develop a reasonable assurance and inform on risk. When considering

⁴ Microbial bioinoculants: Living microorganisms that are considered to possess traits that can confer a positive benefit to plants

⁵ Whole genome sequencing: A method of analysing the entire genomic DNA information of an organism

⁶ Phage (short for bacteriophage): A virus that infects bacteria or archaea

whether food is safe, the grower must consider how the food is usually used by the consumer, as well as subsequent processing and distribution.

- Microbial risk in plant produce is a function of the crop type, how it is produced and how it is consumed.
- Within quality assurance schemes it is important that where parameter thresholds are prescribed that threshold values are associated with risk and underpinned by scientific evidence. This is key to avoid placing an unfeasible burden on the grower in efforts to achieve an unachievable 'zero' risk.
- A gap can exist between regulation and the reality of production. EU legislative documents are not really designed to be digested directly by producers and need to be translated into appropriate language for the relevant region / production type. Many good guidance documents are available both nationally and internationally which effectively translate legislation into practice. Nonetheless it is sometimes difficult for growers to navigate documents and determine which are relevant to them. Guidelines may not be mandatory but should evolve towards best practices within the sector. In the EU each country is required to notify the European Commission of their national guidance documents and a register of these is maintained.
- There is sometimes a disconnect between regulators and the growers who are required to adhere to the regulations. In some cases growers feel that there is a mismatch between what food safety regulations require and best agronomic practices. Growers may not understand or have the time to read the paperwork which may be lengthy. Efforts have been made in some countries to produce simplified versions of the guidelines in simplified language (For example https://www.fsai.ie/publications_fresh_produce/). The question of feasibility of some of the guidelines was discussed e.g. getting soil out of 'produce' after heavy rain or the provision of sanitary infrastructure (toilet with hand washing facilities/warm water) in the field.
- The distinction between primary production and food processing is not clear-cut to growers. Once you cut produce you move to processing which has more stringent hygiene requirements i.e. you move from Good Agricultural Practice (GAP) to Hazard Analysis & Critical Control Point (HACCP)
- Implementation of GAP is very relevant but needs to be nuanced to the specific grower context and needs to be altered if production practices change. GAP as defined by FAO also takes into account economic, social & environmental sustainability. GAP is guided by HACCP principles (HACCP not mandatory) & the precautionary principle (think/consider before you act.).
- Inspections by competent authorities can be both random and reactive to factors such as local knowledge (e.g. new producers supplying local shops need attention), complaints, outbreak investigations etc
- Traceability is critically important for the integrity of the food chain and for use in outbreak situations.
- Growers out-sourcing risk assessments to tick the boxes for quality assurance schemes may not understand the risk assessment themselves. People are central to assessing risk. If they do not understand the risk they cannot assess and mitigate. There is a need to consider/appreciate that in reality risks change with every crop, every season, every field etc. But even for growers who understand the risk assessment there is a lack of understanding on how changing a step or process in the primary production chain changes the risk and the

impact it may have on produce safety. In addition, some risks may be difficult to identify. There is also a cost to the grower of buying in knowledge.

- Unpredictable risks may also arise that are out of the control of growers.
- An internal audit is needed to help growers assess risk, and is a requirement to verify that you are doing well. All the factors that could contribute to risk need to be identified in a systematic manner for e.g. seed, soil, compost, water etc. Once the hazards are identified the probability of encountering them needs to be determined. This is difficult and often growers lack an understanding of the terminology and background knowledge needed to underpin risk-based ranking. Risk-based rating requires expert knowledge and the likelihood of risk is sometimes difficult to judge. The importance of hazard training for quality managers was emphasised.
- There are a wide range of practical tools available to growers. There is now considerable international expertise and experience across a wide range of organisations and sectors in managing human pathogen risks in plant production systems. There also has been great efforts to produce guidance documents and leaflets to support growers both at a European level and in individual countries. Advisory services and discussion groups were also identified as a very helpful tool, although there is some reluctance from some growers to share commercially sensitive information with potential competitors. Free tools such as the fresh produce tool developed by Food Standards Scotland <http://freshproducetool.foodstandards.gov.scot/> can be a great help to growers. Amongst growers chemical contamination data and maximum residue levels are better understood than microbiological risks.
- It was noted that there is sometimes a conflict between quality assurance scheme requirements and standards required by food-safety agencies that is difficult for growers to overcome. Growers and retailers are often underrepresented in discussions resulting in development of guidance/legislation. These groups have a lot of information that contribute to improved safety practice and better engagement may facilitate better adherence to best practice.
- Without feedback or case studies on outbreaks/disease incidences the impacts of issues around microbial safety are largely unseen by growers, so availability of information and continual re-enforcement of the topic is required, as there are many concerns competing for growers' attention. Trends need to be established to help motivate action. There is not a clear understanding of how often fresh produce is responsible for foodborne outbreaks or for sporadic cases. This may be due to a lack of epidemiological evidence or lack of access to such evidence.
- There was discussion on what is a sufficient risk assessment. A grower might have a small percentage of their time to dedicate to this type of risk assessment. How can they do it well enough and how much effort does it need?
- There are some practical questions around microbial sampling that growers need additional guidance on for e.g. where to take the samples and when, what to do with the sample and how to interpret/respond to the results. Meaningful sampling needs to be emphasised. Increased sampling may be needed if any issues are observed but also baseline sampling is needed to compare/ benchmark to 'good conditions'. If samples are taken but nothing is done with the results, money is being wasted, with no safety benefit. The purpose of the sampling should be considered and there should be validation of sampling location/treatment.

Water/crop sanitation

- Microbial hazards are well documented, with water being of primary importance. Growers/producers need to assess what are good sources of water to use and whether they need treatment. If unsure sampling and testing is needed. A key question is how clean is clean enough with respect to irrigation water (Potable vs clean water vs agricultural water). Surface water is at highest risk and quality can change rapidly in response to weather events. Any water or crop sanitation treatment needs to be appropriate, for example risk from irrigation is different for a root crop vs a leafy crop. There is a need for case studies for growers to give practical examples. There is also a need for more guidance on when to treat and when not to treat water for irrigation. In some cases it was reported that growers are being driven to treat water regardless of water quality by retailers. Water treatment should be risk-based and should not be prescriptive. The risk also differs with the type of irrigation used for e.g. drip or flooding versus overhead sprinklers. Methods that promote more contact with the edible portion of the crop result in greater exposure to risk. Some additional decision support or risk ranking is needed for growers to make the appropriate decisions.
- With respect to sanitising water treatment, technology companies may have a vested interest in selling a particular system so may either overstate the risk or sell equipment that is not effective. Where technologies are applied to treat water is important that the grower has the knowledge to operate it effectively.
- The FAO/WHO (2019) has defined the concept of “clean water” as fit for purpose. The requirements for water quality use along the food chain must be considered in context, taking into account the purpose of the water use, potential hazards associated with the water use and whether there is any subsequent measure to decrease the potential for contamination further along the food chain. The availability of water and water quality are different in each country, region, context, setting and food establishment, and improvement in water quality should be incremental, as proposed in WHO’s approach to drinking water safety. While water quality will be different in each context, it can be fit to use for certain purposes. Deciding whether water is fit for purpose, assessment of the source water, potential hazards linked to this water source, treatment options and their efficacy, multiple barrier processes and the end use of the food product (e.g. if eaten raw as a ready to eat product) must be considered.
- With respect to the effect of utilising a sanitising agent on plant microbiome, growers may assume that a sanitiser will work to protect the crop from human pathogen contamination, but may not be aware of consequences of their use, both from a chemical risk perspective and the impact on antagonistic effects conferred by the plant microbiome. The effect that sanitation can have on produce and product microbiomes needs further investigation. More data on how biocide use impacts on microbiomes is needed.
- Utilisation of reclaimed water is a biological safety issue, particularly in countries where water is scarce. Sometimes a mixture of reclaimed water and groundwater is used so a question arises regarding the applicable legislation.
- Testing of water samples gives a snapshot in time. There is a need to assess trends and where peaks are identified to take corrective measures, but indicators not directly linked to pathogen species.

- The sustainability of production from a water perspective needs consideration. For example in Ireland, where it rains regularly, irrigation may not be an issue but elsewhere there may be extremes in weather conditions which may impact on irrigation i.e. poor quality waters may need to be treated with higher doses of disinfectants which could result in residue issues.

Knowledge gaps

- There is currently a poor understanding of the impact of different soil microbiomes on the microflora that will end up in different horticultural produce and the impact of this on the control of human pathogens. There is a lot we do not know about soil/plant microbiota and the impact they have on food safety or pathogen persistence. We also don't fully understand the impact of agricultural practice on this relationship.
- Societal drivers to updating packaging and removal of single-use plastics may have consequences and implications for human pathogens in plant production systems.
- The significance of opportunistic pathogens, which may be present in plant production systems, is not yet clear.

Recommendations:

Based on discussions at the workshop we propose the list of recommendations below (that were co-created by attendees) that we feel could feasibly be implemented by growers, regulators, advisors and scientists, and that would enhance the implementation of current best practice that underpins food safety.

For growers

- Growers should be aware that **some farm management practices can result in the introduction of microbial pathogens** into crops that can result in serious illness of consumers. Some pathogens have a low infectious dose rate so even small numbers of pathogens introduced through the production process can result in illness, product recalls, significant financial impacts and loss of consumer confidence. The microbiological risk is greater where the produce will be eaten in a raw state as a ready to eat food. Growers must adopt good microbiological safety practice at farm level to reduce human zoonotic pathogens' transmission risk on fresh fruit and vegetables
- Once the produce is contaminated, pathogens can survive on the produce for a prolonged period and decontamination efforts such as washing/disinfection are often not effective. Therefore, **the focus should be on preventing any human zoonotic pathogen contamination events in the first place.**
- Amongst the most effective measures that can be employed to reduce human pathogen contamination of plants are the **adoption and incorporation of good agricultural practice (GAP) and good hygiene** into standard operating procedures on the farm. These may include measures such as: microbiological assessment of the environment (e.g. soil, water), fencing crops, the provision of personal protective equipment, access to toilets and hand-washing stations for workers, a sick leave policy that is cognisant of biological safety, cleaning and

disinfection of equipment, keeping produce off the floor, and in some situations disinfection of waters

- **The training of staff is critical to ensuring the microbiological safety of the produce.** It is important that all staff working along the produce production chain have an understanding of biological safety practices and the reasoning behind them. Where there is a high throughput of staff, the training and training material should be suitable to effectively communicate best practice to staff, taking into account differences in language competency, education, cultural behaviour and literacy e.g. pictorial guide, videos etc (e.g. refer to <https://www.nestle.com/sites/default/files/asset-library/documents/library/documents/suppliers/best-practices-suppliers-minimizing-microbia-contamination-fruits-vegetables-herbs-spices-long-version-2018-part-1.pdf>)
- **Good guidance is available on best practice for biological safety of produce** within national and international guidance/regulatory documents for example:
 - The Food Safety Authority of Ireland (FSAI) Guidance Note No.31 Fresh Produce Safety in Primary Production in Ireland. Available at: https://www.fsai.ie/publications_GN31_fresh_produce/
 - FSAI Guidance Note 32 - Fresh Produce Safety in Processing and Retail in Ireland. Available at: <https://www.fsai.ie/WorkArea/DownloadAsset.aspx?id=16054>
 - FSAI plain English leaflet on Fresh Produce Safety. Available to download at: https://www.fsai.ie/publications_fresh_produce/
 - European Commission notice on guidance document on addressing microbiological risks in fresh fruits and vegetables at primary production through good hygiene. Available at:
 - [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52017XC0523\(03\)](https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52017XC0523(03))

It is important that growers have a clear understanding of the content of these documents and avail of training and resources that are provided to become familiar with them.

- Microbiological hazards are well identified in the available guidelines (including water, manure, worker hygiene, animals, equipment/facilities, inputs (for e.g. seeds), soil, dust/aerosols, temperature control, and transport) but **the relative significance of each potential hazard in terms of its contribution to human pathogen contamination differs between farms and situations.** It is therefore important that hazard identification and mitigation approaches are nuanced by a grower for his/her own farm as he/she has the best understanding of production processes being employed. This is the reason that each farm needs to undertake its own risk analysis.
- **Microbiological quality of water to be used for irrigation or hydroponics is of particular importance in safeguarding produce.** Growers should be particularly mindful of the source of water used and be vigilant of indications of changes in its quality e.g. colour changes, smell, indicator organism (e.g. *Escherichia coli*) prevalence. Water quality, particularly surface water, can change very rapidly i.e. within a period of hours in response to weather events and even a short term reduction in water quality can introduce a pathogen into a crop.
- **A wide range of water disinfection technologies are available for use in horticultural production systems** currently, including chlorination, UV, filtration, hydrogen peroxide, ozonation and sedimentation. These technologies are applied to maintain an appropriate microbiological quality of the water to avoid cross-contamination. With respect to choosing a

disinfection technology, should this be required, the characteristics (physical, chemical and biological) of the water are more important than the crop in question.

- If growers outsource the preparation of **documentation for biological safety**, it is important that the content of that documentation **is understood by those who will be implementing practices** identified in the documentation. Otherwise, documentation compliance will not necessarily result in safe food chain management. Training of staff implementing the safety practices will be needed to ensure this does not occur.
- Growers should be cognisant of the fact that human zoonotic pathogens are often present transiently and in low numbers, making them difficult to detect. Thus, **microbiological sampling of produce**, while informative with respect to validating control processes and risk assessment, **does not guarantee safety of produce**. The type, frequency and response to microbiological sampling should be determined by the aim of the sampling and should be risk based to be meaningful.
- **Staff should be aware of what actions are needed**, and under what circumstances, where there is a critical control process failure or in response to microbiological sampling results in order to safeguard consumers of produce.
- Growers should be cognisant that **a wide range of management and environmental factors can influence the behaviour and survival capacity of human pathogens on plants**. These include factors such as crop variety, tillage practice, crop rotation, weather, fertilisation, nutrient availability, pesticide use, irrigation water (type, mode of application), time-seasonal/diurnal differences, manure application, temperature, animal activity etc.
- There is evidence that **the plant microbiome³ may be suppressive** to the establishment of human pathogens¹ in produce. While research is in its infancy in this area there are indications that this effect is likely to be greatest where biodiversity within the plant and soil microbial community is the greatest. Farmers and growers can best promote microbiome diversity by incorporating agricultural practice that reduces disturbance, prevents physical damage to soil (for e.g. through compaction or erosion), enhances soil organic matter and avoids over fertilisation.
- Growers should be aware that **consumers may consume produce in a manner unintended by the grower** in response to social trends, which may increase risk of disease for example raw mushrooms eaten within salads.

For Regulators/Advisors/Consultants

- When communicating best practice/regulations to growers, regulators and advisors should indicate **not only what should be done but the reasoning as to why**. This approach is more likely to result in good practice uptake.
- **Additional supports and materials for growers**, and specifically small growers, on the importance of biological safety practice, would be welcome to help provide training on farm to an often high throughput of staff working in this sector. These supports and training materials should take into account differences in language competency, education, cultural behaviour and literacy amongst staff.

- Good national and international guidance exists but **assistance is needed by growers to direct them to, and help them navigate through, relevant documents.** The availability of such assistance can vary between countries.
- Growers are often unclear which preventative procedures would be most effective to implement within the context they are working in and what the costs of these preventative measures would be. **Additional guidance/training and/or decision support tools** on this would be welcome.
- Where possible **feedback from disease incidents/outbreaks/product withdrawal events should be communicated** in a manner, which protects the identity of affected parties, but is also accessible to the Horticultural sector and scientific community. This would assist in motivating adoption of good practice, understanding potential risk and incorporating lessons learned. Growers were often unclear of how often fresh produce is responsible for foodborne illness and how important this issue is. Providing disease incidents/outbreaks statistics and real examples would be of assistance in communicating this.
- Consider establishing a **confidential benchmarking scheme** for the benefit of growers, whereby growers can see how they perform relative to their peers in biological safety, without compromising competitive interests. This has the potential to be sensitive, however, so would need to be managed appropriately by a competent authority as a tool to encourage best practice without resulting in undue burden on growers.
- Growers have indicated that they would like **additional advice** on protecting their crops when dealing with the now more commonly occurring **extreme weather events** including heavy rainfall and drought – a short guidance document (potentially coordinated by a working group on biological hazards from run-off and flooding) focused on this would be beneficial.
- Growers are often unclear on what indicator organism to use, what the purpose of sampling is, how to interpret a positive result and what action to take. Some **additional training** in this area would be beneficial. Additional guidance on what pathogens¹ are of most concern in which crops would also be beneficial.
- It was noted that knowledge transfer currently focuses on agronomy advice and growers would welcome the **combination of microbiological safety advice with agronomic/crop specific advice, including aspects such as plant and soil health.** This may be beyond the general professional expertise of an agronomist so would require some input from microbiological experts.
- Growers have indicated that **simple actionable advice/guidance** provided by a variety of communication modes, including videos, small grower advisory groups, active learning approaches, social media, visual aids, real-life examples and buddy systems for seasonal workers would be most effective.
- Advice to growers should be based **on science-based evidence** and where possible on the basis of properly linked outbreaks.
- **Better engagement is needed between quality assurance schemes and regulatory agencies** charged with food safety to ensure that there is no conflict between practices prescribed to growers.

For scientists

- Greater emphasis on **knowledge transfer** is needed to relate the best scientific knowledge into simple recommendations that can be adopted by growers to enhance biological safety.
- Additional research is needed to understand the **interactions between the plant microbiome, pathogens, environmental conditions and agricultural practices**. Further research is needed to predict the risk of human pathogens' establishment under **different cropping, environmental and agricultural management scenarios**.
- It was considered that it should be possible in the future to design agricultural practices aimed at directing microbial communities towards higher antagonism against human pathogens. However, currently there is insufficient empirical data available to be sufficiently predictive of potential outcomes. In the absence of additional data, **agricultural practice that enhances soil/plant diversity is likely to be the most effective** at reducing pathogen establishment.
- It is unclear what the **impact of sanitation measures will be on the plant/soil microbiome and the resultant impacts on potential suppressive effect of the plant/soil microbiome** on pathogen occurrence. Sanitation measures that lower the diversity of the plant microbiome or wipes out the endemic community may provide an opportunity for exploitation by pathogens but removal of sanitation options would present a difficult scenario for growers, as they could not rely on the protective effect of the microbiome where outcomes cannot be predicted. Further research is needed in this area.
- Emerging risks, the complexity of distribution networks, global availability etc., climate change, consumption trends, impact of agricultural practice biodiversity were amongst the **knowledge gaps** identified, requiring a multidisciplinary approach.
- Given the short timelines from harvest to consumption associated with fresh produce, continued research efforts are needed to develop sensitive **rapid detection techniques and tests that growers can implement themselves** to test inputs, including water, and produce for indicators of microbial pathogens. This could also potentially assist in epidemiological surveillance.
- Additional research is needed on what the impact of future **no or reduced packaging trends** will be on biological safety of produce.
- **Multiples and large supermarket chains should be better integrated into stakeholder discussions** on biological safety of horticultural crops, and better informed of what happens in the field so they get an understanding of risks and how growers can practically work to mitigate the risks.
- Additional research is required in assessing **the risk of extreme weather events on biological safety of horticultural crops**.
- It was evident that there were **differences in understanding around language and terminology** used between different stakeholders. Efforts should be made to ensure that there is consensus on terminology so that everyone understands the same terms in the same way e.g. the definition of a risk versus a hazard.
- Many studies have shown that antimicrobial components can work effectively in the lab but this does not necessarily mean they will be effective in the field. There is a **need to demonstrate efficacy at pilot or field scale** to translate into practical advice for growers.

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Report compiled by Fiona Brennan (Teagasc), Kaye Burgess (Teagasc), Mieke Uyttendaele (University of Gent), Nicola Holden (SRUC), Grace Choto (AHDB), Ana Allende (CSIC), Adam Schikora (Julius Kühn Institute) and Michael Gaffney (Teagasc)

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Appendix 1 – Workshop agenda

Monday September 2nd

9.00- 9.15 Welcome, Introduction to HUPLANT cost, Introduction to Workshop aims and output **Kaye Burgess & Fiona Brennan, Teagasc**

What recommendations can we provide growers to reduce the risk of microbial contaminants in fresh produce?

Session 1 - Protecting fresh produce from microbial pathogens

9.15 – 10.15 Talks

EC guidance on microbial safety of fresh produce – **Ana Allende, CSIC, Spain**

Fresh Produce Safety FSAI Guidance – **Shaun Smith, Food Safety Authority of Ireland.**

Legislative Basis for Fresh Produce Safety: Implementation and Issues – **Aidan O'Donnell, Department of Agriculture, Food & the Marine, Ireland**

10.15-10.45 Tea and coffee

10.45 -11.45 Breakout Session

Session 1 - Questions

Where are the knowledge gaps in protecting fresh produce from microbial pathogens?

What are the knowledge gaps regarding preventative measures in agricultural procedures?

What are the main contamination sources of microbial pathogens in fresh produce production?

What advice can we give growers in identifying and controlling contamination sources?

11.45-12.30 Reporting from breakout sessions

12.30-1.30 Lunch

Session 2 Control strategies and sampling

1.30-2.30 Talks

'Clean' irrigation water – but how clean is clean? – **Grace Choto, Agriculture and Horticulture Development Board, UK**

Ecology of HPMP on plants and the complication of internalisation for control strategies – **Nicola Holden, James Hutton Institute, UK**

Upscaling research from lab to pilot scale in plant production systems - **Kaye Burgess, Teagasc, Ireland**

2.30-2.45 Tea and coffee

2.45 – 3.40 Breakout Session

Session 2 - Questions

What equipment is used for disinfecting water and for what crops?

What hygiene and sanitary measures can be effectively employed to reduce HP MO contamination of plants?

How do agronomic activities influence HP MO behaviour in plants?

Can agricultural practices aimed at directing microbial communities towards higher antagonism against HP MOs be designed?

What is the impact of sanitising applications on HP MO-buffering microbial communities in plants or products derived from plants?

3.40 – 4.15 Report from breakout sessions

4.15pm – 5.15pm Tour of horticultural facilities at Teagasc Ashtown

Evening dinner (TBA)

Tuesday September 3rd

9.00-9.30 : Wrap-up of main conclusions from Day 1 => summary of conclusions & questions for Grower/Horticultural industry workshop

Session 3 – Risk assessment and risk based sampling

9.30-10.30 Talks

Practical implementation of risks assessment in providing guidance on food safety of fresh produce - **Enda Cummins, University College Dublin, Ireland**

Risk-based sampling strategies for microbial safety in plant production systems –**Liesbeth Jacxsens, University of Gent, Belgium**

Vegetables and human pathogens: which pathogens are there, where do they come from, and how can we deal with them? - **Lucas Wijnands, RIVM National Institute for Public Health and the Environment, The Netherlands**

Fresh Produce Risk Assessment & The Fresh Produce Tool - **Marianne James, Food Standards Scotland.**

10.30-11.00 Tea & Coffee

11.00-12.00 Breakout Session

Session 3 - Questions

What constitutes a risk?

How should growers assess risk?

What practical tools/guidance are available to growers?

Where are the knowledge gaps?

What water quality parameters are used / tested?

Why should we sample and how should we advise growers/researchers to sample?

12.00 -12.45 Breakout session reporting

12.45-1.00 Summary of conclusions and questions for Grower/Horticultural industry workshop

1pm-2pm Lunch

Grower/Horticultural industry workshop (2pm - 4.30pm)

2.00-2.15 Welcome - **Michael Gaffney, Teagasc & Mieke Uyttendaele, University of Gent**

2.15-3.15: Talks

Impact of Ag practice on Microbiomes – **Fiona Brennan, Teagasc, Ireland**

How to assess risk: a practical approach - **Mieke Uyttendaele & Liesbeth Jacxsens, University of Gent, Belgium**

Summary from main workshop: **Mieke Uyttendaele, University of Gent & Ana Allende, CSIC**

3.00-4.00 Round table

Workshop - Questions

-What do growers see as the biggest issues?

- Where are the gaps in knowledge?

- Which control measures they think are technical feasible/acceptable by consumers, policy makers, companies?

- What information would be helpful to growers to better manage the risk of microbial contaminants in fresh produce?

- What form would they like to get information in?

4.00- 4.30 Summary