FIRST REPORT
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veg-i-trade

safe food for a changing world

Impact of Climate Change and Globalisation on Safety of Fresh Produce

Governing a Supply Chain of Uncompromised Food Sovereignty

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Food, Agriculture and Fisheries, and Biotechnology Knowledge-Based Bio Economy (KBBE)

A summary description of project context and objectives

Fresh produce (e.g. leafy vegetables, tomatoes, soft red fruits) is an important part of a healthy diet. Global consumption levels are expected to increase in the future. However, due to recent disease outbreaks and rapid alerts attributed to fresh produce, concerns have emerged with regard to food safety. This was exemplified by the *E. coli* O104 outbreak in Europe in spring 2011. New food safety challenges are posed by climate change and globalisation of trade. Veg-i-Trade will assess the impact of anticipated climate change and globalisation on safety issues concerning fresh produce and derived food products. In Veg-i-Trade, food safety is reviewed by addressing both microbiological and chemical hazards. The microbiological hazards under consideration are VTEC, *Salmonella*, Norovirus, *Cryptosporidium* and *Giardia* while the chemical hazards encompass emerging mycotoxins (e.g. alternariol, patulin, fumonisins) and pesticide residues.

Veg-i-Trade is a multidisciplinary project comprising both fundamental and applied research. It focuses on the economic structure of the fresh produce global market and on the development of control measures for microbiological and chemical hazards.

Veg-i-Trade research integrates several tools including sampling and analytical testing methods, field studies on pre- and post-harvest practices, quality assurance, modelling and simulation, risk assessment and risk communication. An overview of the conceptual approach of the Veg-i-Trade project is given in the figure below.

Global food market: trade flows, value chain, governance and trading relationships

Using the FAOSTAT database (year 2008) a detailed analysis of the fresh produce production volumes and areas, import/export volumes and trade values was undertaken within the world, EU and Veg-i-Trade partners. This permitted the identification of the countries and commodities (fruits and vegetables) that dominate the international trade in fresh produce. These economical data combined with knowledge concerning the vulnerability of the produce to food safety hazards, climate change and consumption patterns, were used to select the case-studies that are considered within the Veg-i-Trade project. The selected commodities are: lettuce, leafy fresh herbs, strawberries, raspberries, tomatoes, bell peppers, onions, apples, pears, mangos, grapes, carrots and derived products such as fresh-cut produce, (frozen) pulp and concentrates.
Furthermore, flow charts were made of the organisation of the fresh produce supply chain (at the macro-, meso- and micro-level) identifying key stakeholders and activities within the fresh produce supply chain. The legal and/or private requirements or standards in international trade were also described. Based on a case study of the supply chain of hot peppers from Uganda to the EU, the challenges and bottlenecks for developing countries concerning access to the international market were assessed. Value chain description, governance and trading relationships in the export chain of pears from South Africa and mangos from both South Africa and India are being elaborated. A high degree of vertical coordination/integration is evident in both value chains. The primary theme in the pear value chain is integration in order to attain economies of scale and scope and thus interact directly with retail groups. The continued management of activities in the value chain is designed to achieve the best possible return for growers. The mango chain is characterised by a global sourcing theme where the dominant player develops a business model that controls the sourcing of fruit globally in order to sustain consumer service levels and product continuity year-round for retail clients. Of particular interest is the change, for both value chains, from a consignment arrangement between growers and clients (through intermediaries) on an open market to an arrangement of direct orders and specification coupled to meticulous planning. Underlying these developments are the increasingly stringent requirements (quality) that these value chains are compelled to offer consumers in a highly competitive and regulated (safety) environment. In such a market, closer rather than antagonistic exchanges are desirable.

Combination of self-assessment tools, sampling plans and microbial analysis to measure performance of food safety management in the fresh produce supply chain

A diagnostic tool enabling the assessment of 'Horticultural Food Safety Management Systems' activities in the European context was developed and validated. Further study will be undertaken to adjust the instrument to the global context. Three self-assessment tools were constructed allowing assessment of businesses at primary production, processing and trade level, respectively. These diagnostic instruments consist of 64 to 69 indicators and address core activities in the prevention and reduction of microbiological, mycotoxin and pesticide residue contamination. Each indicator uses grids with supporting information for self-assigning implemented food safety management system to situation 1 (basic level), 2 (average level) or 3 (advanced level). Selected indicators and grids as such provide a 'bird's eye view' of the performance level of the current food safety management system, the risk level of the context wherein the actor has to operate, and an indication of the food safety output, illustrated in clear spider web diagrams.
In parallel to the diagnostic tool, a systematic risk-based sampling and microbial analysis plan has been developed and validated, in particular for the lettuce production and fresh-cut processing sector. This is referred to as the *Horticultural Assessment Scheme* (HAS). HAS is aimed at sampling vertically throughout the production process from the start of the crop cycle to harvest or packaged fresh-cut produce. The plan includes sampling of both fresh produce and environmental (including water and food contact materials) samples and analysis of hygiene indicators and enteric pathogens. By sampling at various time intervals during one crop cycle/batch production and repeating this for multiple harvest times/batches, a microbial profile of the production process can be obtained.
To support sampling and analysis in the fresh produce supply chain, methods for the detection of the microbial hazards VTEC, *Salmonella*, *Escherichia coli* (as a hygiene indicator), Norovirus and the protozoa *Giardia* and *Cryptosporidium* were optimised. Reproducible, relatively cheap, user-friendly protocols based upon ISO or NMKL methods were selected for enteric bacteria (including a PCR method for VTEC). A Norovirus multiplex real-time RT-PCR protocol for the detection of the noroviruses GI and GII was selected based upon the CEN WG6 TAG 3 primer set. Spiking and singleplex RT-PCR for the detection the surrogate murine norovirus was used as process control. An evaluation of methods for detection of Norovirus in processing water and four different types of irrigation water (borehole water, rainwater, open well water and river water) resulted in the selection of the most appropriate filtration method for the detection of Norovirus.
The detection of protozoa is based upon elution of oocysts from fresh produce, followed by concentration and isolation by immunomagnetic separation (IMS) and finally detection using a fluorescent microscope. Optimisation of elution buffers and methods and adjustment of the IMS protocol resulted in an acceptable recovery efficiency while being more affordable by many laboratories. The protocols for detection of enteric bacteria, Norovirus and protozoa in fresh produce or water were disseminated to both EU and non-EU partners via a Veg-i-Trade Training Course in Oslo in July 2011. Concurrently, the microbial sampling and analysis plan (HAS protocol) that had been developed within Veg-i-Trade was discussed by all partners.

testing the performances of food safety management

Pre- and post-harvest production practices and water treatment technologies

A review of the current state-of-the-art of pre- and post-harvest preventive measures and interventions along the farm-to-fork continuum to prevent or reduce microbial contamination of leafy greens has been prepared. These control measures vary from physical (e.g. fencing fields), chemical

(e.g. use of sanitisers) to biological interventions (e.g. use of biocontrol). One of the main problems associated with the implementation of these guidelines is that most of the efforts revert to the workers. Awareness and knowledge of the guidelines and procedures are necessary, however the persistence of existing habits and attitudes may influence compliance with procedures. Moreover, in many production processes of fresh produce, some of the most effective interventions (e.g. irradiation, sanitisers, heat treatment) are neither acceptable to the consumer (or national legislation) nor applicable to 'ready-to-eat fresh produce' to eliminate or reduce pathogens to an acceptable level. Therefore, currently, in the fresh produce supply chain, a zero tolerance approach is not feasible. However, adherence to "best practices" from farm-to-fork to control microbial contamination is highly recommended in order to reduce the risk to as low as is reasonably achievable. Further field research on the variability of crop production systems on visual quality and microbial contamination of crops and fresh-cut lettuce demonstrated that higher quality and microbiologically safer leafy vegetables can be provided by using the soilless system as a new growing system although the obtained results will depend on the variety and the season. Studies also showed that the new green and red baby-sized leaves (such as baby-leaf) at immature stage and multi-leaf at mature stage are high-quality lettuce, suitable for the fresh-cut market, as they meet all the specific requirements regarding visual quality, microbial load and high content of phytochemicals occurring naturally in plants. Also the effect of soil amendments prepared from organic wastes (sewage sludge and urban solid waste) on the microbial quality of rocket leaves was evaluated. It was observed that non-composted materials such as pig slurry showed the highest microbial risks. In fact, proper composting of fresh organic amendments via thermal treatment reduces the risk of potential human pathogen survival. Organic wastes properly composted at optimum doses can be considered suitable as soil amendments because increased crop yield without detrimental effects on these natural (potential human disease protecting) phytochemicals including vitamin C content, when the leaves reached the commercial maturity stage.

Given that water quality is closely related to the safety of fresh produce, current information on water quality, water sources and water treatment systems applied in the fresh produce supply chain was reviewed. It indicated that in many countries there is no detailed guidance on the quality of irrigation water or sources that can or may be used in primary production, nor is the concept and the use of "clean" water in fresh-cut industry well defined. The various available water treatment technologies were characterised and selection criteria were developed to support the "fit for purpose" judgement of their use for water disinfection in irrigation practices, hydroponics, and produce processing washing and cooling operations. Potential effects of the removal of pesticide residues was not taken into consideration in the selection tool. All disinfection techniques have pros and cons, the appropriateness of the water treatment being dependent upon the physico-chemical parameters of the water to be treated. Additional aspects such as maintaining a

long-term successful disinfection operation need to be considered as the impact of potential by-products generated for human health, worker safety and the environment. Some techniques, despite being inefficient as stand-alone applications can be efficient for pre-treatment or in combination with other techniques.

Risk assessment: model development to link modified atmosphere packaging, global logistic chain to fresh produce quality and microbiological safety

A model designed to predict the growth of natural microbiota on fresh-cut leafy vegetables based on literature data has been developed. This can be combined with another model developed to predict the overall sensory quality deterioration of water-washed fresh-cut iceberg lettuce based on storage temperature. A preliminary discrete-event simulation model for the case of strawberries supplied from Egypt to the Netherlands and for fresh produce supplied from Spain or locally supplied to the Netherlands has been developed. The model includes advanced inventory control policies, as well as microbial growth models. Growth models of *Salmonella* and *E. coli* can easily be included. In due time, these models will be included in risk assessment studies.

Risk assessment: hazard identification of emerging mycotoxins in fresh produce

It was established that only limited data (and awareness) on mycotoxins in fresh produce are available, except for patulin in apples and derived products. An appropriate extraction protocol and multi-screening detection method using LC-TOF-MS was optimised for screening mouldy tomatoes, bell peppers, onions and soft red fruits (obtained from the various Veg-i-Trade partner countries) for six mycotoxins (e.g. alternariol, fumonisins, ochratoxin A). These samples were also screened for patulin using HPLC methods. Fungi isolated from these mouldy samples belonged to the genus *Penicillium*, *Alternaria*, *Aspergillus* and *Fusarium*. The results of this screening indicate that in particular alternariol and patulin in mouldy tomatoes (and thus also derived tomato products such as concentrates) may be relevant mycotoxins. Furthermore, a potential issue with fumonisin production (FB_2) in mouldy bell peppers is noted. Ochratoxin A has not been detected in this screening study. Patulin was demonstrated to be a relevant mycotoxin for mouldy tomatoes and bell peppers and thus is not only to be associated with mouldy apples or pears (and derived products). Further study is being undertaken to establish the risk factors in the fresh produce supply chain for mycotoxin production and to estimate the associated risk to public health.

Risk assessment: impact of food processing/ preparation practices on pesticide residues

A residue analysis was conducted before and after the cooking and steaming of apples, broccoli and carrots to assess the impact of processing on the residues in vegetables and fruits. Peeling of fruits and vegetables removes the largest part of the pesticide residues. This is especially the case for contact pesticides. Pesticides also get removed in boiling water but become concentrated during stewing or steaming of vegetables. During stewing an important difference was noted between contact and systemic pesticides as the concentration of the former decreased and the latter increased during the process. It can be concluded that food processing reduces the exposure of pesticides in most cases. These findings along with information that has been compiled in databases on pesticides authorised and used for the Veg-i-Trade selected commodities will be applied in due time for elaboration of risk assessment studies.

Climate change: impact of climatic conditions and plant water availability on the visual quality and microbial contamination of crops and fresh-cut lettuce

During field studies in Spain it was shown that seasonality significantly affected the quality of fresh-cut lettuce. During summer, when warmer climate conditions occur, there is a short growing cycle from transplant to harvest and the visual quality of fresh-cut lettuce is reduced by increased browning potential. Furthermore in Spain, to adapt to increasing water scarcity due to climate change, iceberg and romaine lettuces were subjected to reduced irrigation doses by improved water management. In this study it was observed that the maximum lettuce head weight was achieved when the irrigation dose was 25% less than the standard irrigation dose. The standard irrigation dose is based on the evapotranspiration, which is the quantity of water that is actually removed from the surface of the crop due to the process of evaporation and transpiration. By reducing the amount of water by 25 % of the standard irrigation treatment, less water is available on the surface of the tissue, which affects the microbial ecology of the tissue surface, reducing microbial loads and thus contributing to improved microbial quality and safety of the product.

The expected final results and their potential impact and use

Veg-i-Trade unifies 23 international partners from universities, research institutes, SMEs and large industrial partners. It is a highly visible project, widely known within the scientific community, industry and competent authorities, in the EU and throughout the world. Veg-i-Trade functions within a network and its research creates interest among a wide range of persons and stakeholder organisations.
Veg-i-Trade research will support the development of management strategies in the fresh produce supply chain. The application of newly developed self-assessment tools provides an insight regarding weak and strong points in a food safety management system, which can be used in the framework of an internal audit or management review.
Results from the sampling plans at primary production, processing and trade level, using appropriate methods for testing of hygiene indicators and enteric bacteria analysis as selected in Veg-i-Trade, will provide a baseline study and may reveal potential routes for the introduction of pathogens into the fresh supply chain. The Veg-i-Trade research will provide guidance on the implementation of quality assurance recommendations to actors in the fresh produce chain for its particular case studies (fresh leafy vegetables and herbs, soft red fruits, tomatoes). It was noted from literature reviews on i) pre- and postharvest preventive measures and ii) on the quality of water and its sources and water treatment technologies applied in the fresh produce supply chain, that it is important to establish more tailored interventions, taking into account specific contexts and/or demands. The output of Veg-i-Trade research will support the development of technological control measures.

Climate conditions and appropriate water management are thus confirmed to have an important impact on visual quality and microbial safety of leafy vegetables. This finding is significant as it could be concluded that in this specific study in Spain, farmers can reduce the irrigation water dose by 25% while maintaining maximum crop yield and without affecting the visual quality and microbial safety of leafy vegetables. It enables an adaptation strategy to climate change and resulting water scarcity and results in more sustainable crop production practices and a considerable reduction of production costs.
Hazard identification, data collection on the behaviour of both microbial and chemical hazards during processing and storage, logistic models and predictive models of fresh produce quality and safety are all under construction. This knowledge will permit risk assessment studies to be elaborated in due course that will serve as a support to both competent authorities and individual companies for the set-up of their risk management policy and strategies.
Veg-i-Trade's results and the tools developed are exchanged via international collaboration. A well-elaborated dissemination strategy to the end users is a key aspect of Veg-i-Trade. The Veg-i-Trade Training Program in Sampling and Microbial Analysis in Oslo in July 2011 contributed to capacity building in Veg-i-Trade EU and non-EU partner countries. It stimulated the use of an appropriate and harmonised methodology, thus facilitating international acceptance and the exchange of Veg-i-Trade research. Furthermore, the application of the Norovirus RT-PCR detection method for screening of fresh produce also contributed to the debate on the interpretation (in relation to the public health risk) of results obtained via these molecular techniques.

Regarding the *E. coli* O104 outbreak in Europe in spring 2011 (allocated to contaminated fenugreek seeds) it can be concluded that Veg-i-Trade is a timely project. The Veg-i-Trade consortium provided support during and after the outbreak to competent authorities and industry, in Veg-i-Trade partner countries and at EU level by providing background information on *E. coli*, VTEC and the safety of fresh produce. Furthermore, the opportunity was taken to study risk communication by examining the reaction of Belgian newspaper readers to the Belgian press articles. As expected, people were alarmed and concerned, but governmental trust decreases fear and leads to a higher intention to continue consuming fresh produce. Furthermore, Veg-i-Trade promotes dialogue between different stakeholders involved in the international trade and safety of fresh produce and provides a discussion platform.
Reports from the Discussion Forum on "Dealing with food safety issues for fresh produce" on 28th of January 2011 (Ghent, Belgium) and from the Open session on Food Sovereignty on 8th of July 2011 (Oslo, Norway) to raise awareness for ethical issues of trade, food safety standards in relation to the EU General Food law; can be consulted on the Veg-i-Trade website (www.Veg-i-Trade.org).

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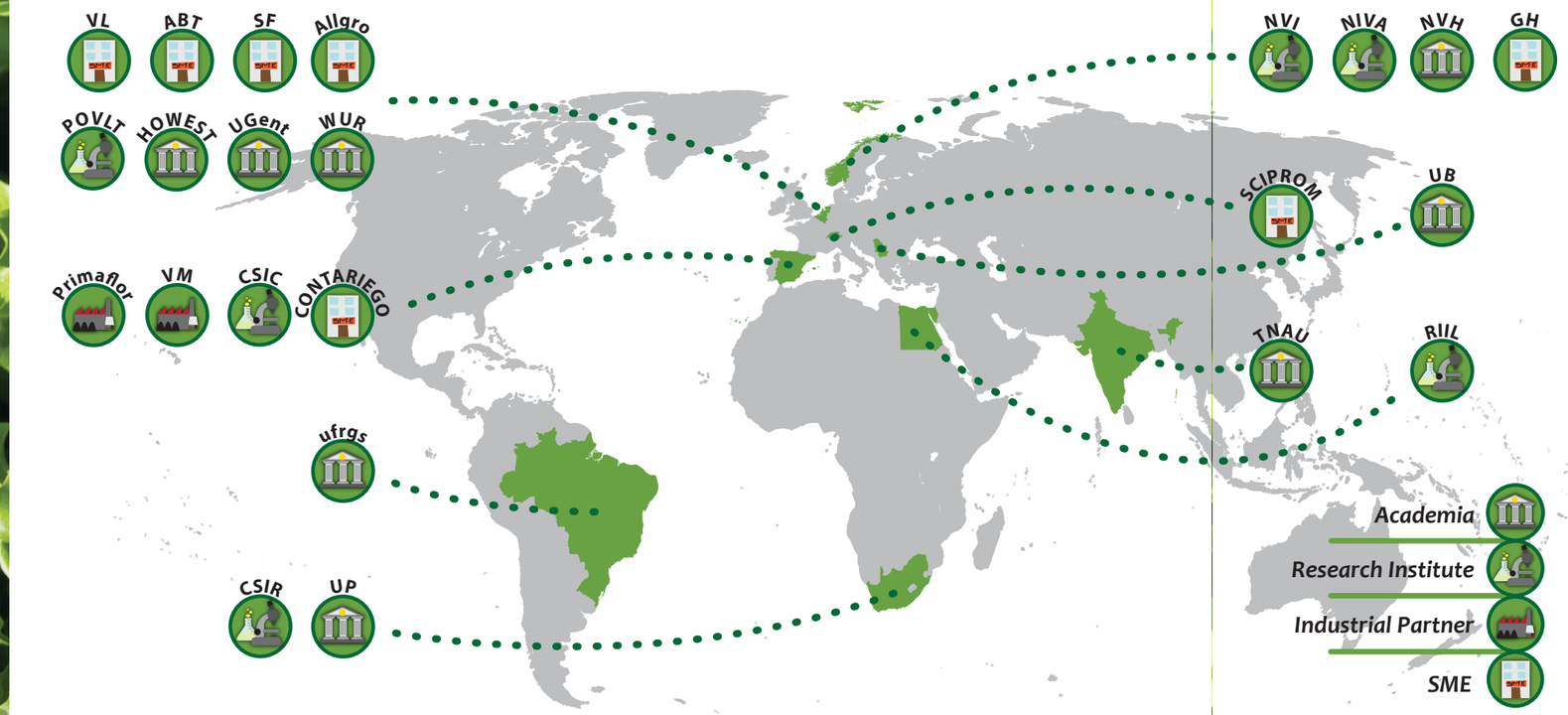
The Veg-i-Trade partners across the world...



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