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10th International FRUTIC Symposium

Quality and Safety of Fresh Horticultural
Commodities

Book of Abstract

07. February 2017
Berlin, Germany



Bornimer Agrartechnische Berichte

Heft 91

Potsdam-Bornim / Berlin 2017

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Preface

Fresh fruit and vegetables are a major source of biologically active compounds (e.g. fibers, vitamins, and minerals) essential for human wellbeing. They are, however, perishable living products that require coordinated measures by growers, storage operators, processors, and retailers to maintain their quality and reduce food loss and waste. Non-destructive techniques for analysing the quality of fresh produce are valuable tools applicable along the supply chain. Fresh produce attributes such as appearance, texture, flavour and nutritional value have been traditional quality criteria, but increasingly safety and traceability are important for all the role players along the supply chain from the farm to consumer.

This FRUTIC Symposium is focused on the quality and safety of fresh horticultural commodities. The Symposium will provide a platform for researchers and practitioners to engage in technical discussions about innovations and new technologies, as well as to explore further areas of research needed in the industry to promote quality and safety of fruit and vegetables. This includes information dissemination, sharing practical experience and developing road maps for the most effective way to reach the common goals.

The FRUTIC Symposium is organized jointly by an enthusiastic group of researchers from the Leibniz Institute for Agricultural Engineering and Bioeconomy (Germany) and the University of Foggia (Italy). For the first time, FRUTIC Symposium is being organised in cooperation with the FRUIT LOGISTICA. It is held at the CityCube Berlin on 7 February 2017, the day before the opening of FRUIT LOGISTICA. Scientists will also present their topics during the subsequent three days of the FRUIT LOGISTICA trade fair, in industry-oriented workshops on specific topics. This event is designed to provide a concerted platform that brings together academics, research scientists and all the role players from fresh produce industry.

The Symposium comprises of 3 keynote talks, 3 oral sessions with 18 lectures, >20 posters, covering all three major topics: pre-harvest; postharvest quality and postharvest safety. The Symposium will provide a wide field for scientists, professionals, and students to present their latest findings and discuss their current work related to basic and applied aspects of all fields of quality and safety of fresh horticultural commodities.

We are very proud to welcome you all in Berlin and we wish you successful presentations, interesting discussions and a happy stay in Beautiful Berlin.

Pramod Mahajan, Manuela Zude, Giancarlo Colelli, Martin Geyer and Christoph Göring

Oral Presentations

Tuesday 7th of February, 2017
Berlin, Germany

08:00 – 08:30 Registration at CITY CUBE, Messe Berlin

08:30 – 09:00 Opening Ceremony

*Mr. Wilfried Wollbold, Global Brand Manager, Fruit Logistica
Dr. Martin Geyer, Head, Department of Horticultural Engineering, ATB*

Session 1 *Chair: Prof. Giancarlo Colelli, University of Foggia, Italy*

09:00 – 09:30 **Keynote by Prof. Hidemi Izumi** (Kindai University, Japan)
Microbiological safety of fresh produce from the farm-to-table food chain

09:30 – 10:00 *Coffee break & poster presentation*

10:00 – 10:15 Application of simplex lattice design for optimization of active modified atmosphere for pomegranate arils based on microbial criteria
Oluwafemi James Caleb, Leibniz Institute for Agricultural Engg.& Bioeconomy, Germany

10:15 – 10:30 Effect of temperature abuse on volatile profile and quality of rocket leaves packaged in modified atmosphere
Maria Amodio, Università di Foggia, Italy

10:30 – 10:45 Plasma processed water (PPW) – an alternative for fresh-cut salad and fresh sprout sanitation?
Uta Schnabel, Leibniz Institute for Plasma Science and Technology, Germany

10:45 – 11:00 Electrolyzed sodium bicarbonate against citrus green mold: inhibition of penicillium digitatum and induction of fruit defences
Antonio Ippolito, University of Bari, Italy

11:00 – 11:15 Scale-up to pilot plant dimensions of plasma processed water generation for fresh-cut lettuce treatment
Mathias Andrasch, Leibniz Institute for Plasma Science and Technology, Germany

11:15 – 11:30 Fungal development and associated rot and mycotoxins during ethylene supplemented controlled atmosphere storage of sweet potato
Sulaiman Sowe, Cranfield University, United Kingdom

11:30 – 11:45 *Discussion*

11:45 – 12:45 *Lunch break & poster presentation*

Session 2	
	<i>Chair: Prof. Manuela Zude-Sasse, Leibniz Institute for Agril Engg.& Bioeconomy, Germany</i>
12:45 – 13:15	Keynote by Prof. Maria Isabel Gil (Spanish National Research Council, Spain) Preharvest conditions affect quality of leafy greens
13:15 – 13:30	Development of cultivation management system in orchard based on ICT <i>Shinichi Kameoka, Mie University, Japan</i>
13:30 – 13:45	StoreNSure: a molecular test to predict the occurrence of black spot on stored carrots <i>Peter Balk, NSure, Netherlands</i>
13:45 – 14:00	Effects of postharvest washing processes on microbial community dynamics associated to endive salad <i>Antje Fröhling, Leibniz Institute for Agricultural Engg.& Bioeconomy, Germany</i>
14:00 – 14:15	Color evaluation of images acquired using open platform camera and mini-spectrometer under natural lighting conditions <i>Atsushi Hashimoto, Mie University, Japan</i>
14:15 – 14:30	Non-destructive method for oil content and moisture content prediction in oil palm fruitlets using electrical impedance spectroscopy <i>Samsuzana Abd Aziz, Universiti Putra, Malaysia</i>
14:30 – 14:45	Impact of mixed fruit loading in storage chamber on quality parameters <i>Namrata Pathak, Leibniz Institute for Agricultural Engg.& Bioeconomy, Germany</i>
14:45 – 15:00	<i>Discussion</i>
15:00 – 15:30	<i>Coffee break & poster presentation</i>

Session 3 *Chair: Dr. Pramod Mahajan, Leibniz Institute for Agril Engg.& Bioeconomy, Germany*

- 15:30 – 16:00 **Keynote by Prof. Christopher Watkins** (Cornell University, USA)
Postharvest handling practices for better quality and longer shelf life
- 16:00 – 16:15 Effect of raw material quality and modified atmosphere packaging on
color and texture retention of wild rocket (*Diplotaxis tenuifolia* L.)
Merete Edelenbos, Aarhus University, Denmark
- 16:15 – 16:30 Non-destructive detection of chilling stress for improving keeping quality
of fresh produce: cucumbers as a model
Victor Rodov, ARO - The Volcani Center, Israel
- 16:30 – 16:45 Lessons learned from the intelligent container
Reiner Jedermann, University of Bremen (IMSAS), Germany
- 16:45 – 17:00 Design of an environmental variables monitoring prototype during
transportation of horticultural products
Francisco Artés-Hernández, Universidad Politécnica de Cartagena, Spain
- 17:00 – 17:15 Inline application of NIR system in produce sorting machines
Schmilovitch Ze'ev, ARO - The Volcani Center, Israel
- 17:15 – 17:30 The use of Janny MT box in cherry storage
Mehmet Ali Koyuncu, Suleyman Demirel University, Turkey
- 17:30 – 17:45 *Discussion*
- 17:45 – 18:00 *Closing Ceremony by Prof. Manuela Zude-Sasse*

18:30 **Welcome Reception at FRUIT LOGISTICA, Palais am Funkturm**

Workshops in Fruit Logistica

Wednesday 8th to Friday 10th of February, 2017

Berlin, Germany

Workshop 1: The Future in Realtime – Quality and Safety



Date
February 8, 2017

Time
15:00 - 15:30

Location
Halle 7.2a, Stand B-04



Two examples of technological solutions which will help to improve the quality and safety of fresh produce as well as convenience products, such as quality and freshness, and at the same time increase safety.

Moderator:

Mike Knowles, Editor, Eurofruit Magazin GB

Speaker:

Prof. Francisco Artés-Hernández, Ph.D., Head of Postharvest & Refrigeration Group. Food Engineering Dep., ETSIA - Universidad Politécnica de Cartagena

Professor Hidemi Izumi, Faculty of Biology-Oriented Science and Technology, Kindai University

Workshop 2: Microbiology – Caught between accuracy and over meticulousness



Date
February 9, 2017

Time
15:00 - 16:00

Location
Hall 17, Kleiner Stern



Requirements for food safety place enormous demands on suppliers, with regulations and maximum levels set by governments and retailer stricter than ever. In spite of this, food safety scares continue to occur. The truth is that modern analytical methods can detect levels that were previously practically unmeasurable. How can the fresh produce sector cope effectively with these new demands?

Presenter / Contact person:

Kaasten Reh, Project Director Events & Awards, Fruchthandel Magazin

Speaker:

Mabel Gil, PhD, CEBAS-CSIC

Udo Lampe, Managing Director, Analytica Alimentaria GmbH, Spain/Germany

Thomas Landwehr, Dole Europe GmbH

Hugh Mowat, Head of Technical, Morrisons Supermarkets, UK

Workshop 3: Big Data – From the cloud to the field



Fresh Produce Forum

Date

February 10, 2017

Time

13:00 - 14:00

Location

Hall 17, Kleiner Stern



Computer based planning of production, drones to help calculate the best use of pesticides, the optimum level of selective irrigation, or determine final crop volumes - modern information technology is becoming the standard. And it is also providing a major contribution to making production more efficient - a crucial factor in times of increasing population levels and climate change.

Presenter / Contact person:

Kaasten Reh, Project Director Events & Awards, Fruchthandel Magazin

Speaker:

Jose Blasco, Instituto Valenciano de Investigaciones Agrarias (IVIA)

Professor Giancarlo Colelli, University of Foggia

Professor Christopher Watkins, School of Integrative Plant Science, Cornell University

Dr. habil. Manuela Zude-Sasse, Group leader Precision Fruticulture, Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB)

Poster Presentations

Tuesday 7th of February, 2017

Berlin, Germany

- P01 Assessing potential benefits and sensitivity to carbon dioxide of different artichoke cultivars
Maria Luisa Amodio, Leonarda Mastrandrea, Francesca Piazzolla, Giancarlo Colelli
- P02 Effect of regulated deficit irrigation on yield and fruit quality during shelf life of sweet cherry
Francisco Artés-Hernández, Victor Blanco-Montoya, Rafael Domingo-Miguel, P.J. Blaya-Ros, Roque Torres-Sánchez, Alejandro Pérez-Pastor, Ginés B. Martínez-Hernández
- P03 Postharvest treatments to control physiological disorders and decay in lemon fruit
Gineés B. Martínez-Hernández, Perla A. Gómez, Benito Orihuel-Iranzo, J. Bretó, Francisco Artés-Hernández
- P04 Modified atmosphere and humidity storage container for strawberry
Graziele Grossi Bovi, Cornelia Rauh, Pramod Mahajan
- P05 Chemical, physical and sensorial characterization of fresh quinoa sprouts (*Chenopodium quinoa* Willd.) and effects of modified atmosphere packaging on quality during cold storage
Tiziana D'Ambrosio, Maria Luisa Amodio, Giancarlo Colelli
- P06 A novel approach for determination of invisible quality changes in modified atmosphere packaged fresh and fresh-cut fruit and vegetables
Alexandru Luca, Justyna Wieczynska, Merete Edelenbos
- P07 The use of natural antimicrobial compounds in packaging of leafy greens: impact on microbial load and sensory quality
Wieczynska Justyna, Alexandru Luca, Ulla Kidmose, Ivana Cavoskia, Merete Edelenbos
- P08 Postharvest chlorine dioxide treatment for quality management of white asparagus (*Asparagus officinalis* L.)
Karin Hassenberg, Susanne Huyskens-Keil, Werner B. Herppich
- P09 Comparison of advanced non-destructive methods to classify healthy and diseased onions
Md. Nahidul Islam, Merete Edelenbos
- P10 Agricultural environment information monitoring by using unmanned aerial vehicle
Jeyeon Kim, Yoshiki Orikasa, Kazuya Kanda
- P11 Basic research of the acquisition of biological information towards the construction of agricultural support system
Kazuya Kanda
- P12 Influence of nitrogen application on ascorbic acid content in cauliflower cultivars after post-harvest storage
Ngwatship Mashabela, Martin Makgose Maboko, Soundy Puffy, Dharini Sivakumar
- P13 Impact of integrated packaging design approach on the quality and shelf life of cauliflower (*Brassica oleracea* var. *botrytis* L.)
Ngwatship Mashabela, Oluwafemi James Caleb, Dharini Sivakumar, Pramod Mahajan

- P14 Combined effects of MAP and postharvest salicylic acid treatment on quality attributes of dill (*Anethum graveolens*) bunches during storage
Mehmet Ali Koyuncu, Atakan Güneçli, Derya Erbas, Cemile Ebru Onursal, Tuba Secmen
- P15 Air circulation management in CA storage of apples based on airflow measurements
Ulrike Praeger, Reiner Jedermann, Chanaka Lloyd, Nico Hartgenbusch, Marc Spuhler, Daniel Alexandre Neuwald, Holger Scaar
- P16 Predictive diagnostics based on gene expression for determining the risk of bitter pit development in apple fruit
Mireia Ibanez, Peter Balk
- P17 Impact of dipping fresh-cut apple slices in different sugar solutions on quality parameters
Guido Rux, Oluwafemi James Caleb, Christian Ulrichs, Susanne Huyskens-Keil, Werner B. Herppich, Pramod Mahajan
- P18 Optimization of apple storage bin for reduced energy consumption in airflow ventilation
Holger Scaar, Ulrike Praeger, Robert Reck-Heinrich, Mark Spuhler, Martin Geyer
- P19 Comparison of plant and soil mapping in *Prunus domestica* L. orchard
Jana Käthner, Werner B. Herppich, Jörn Selbeck, Manuela Zude-Sasse
- P20 Impact of pre-harvest respiratory pattern on post-harvest quality of pear
Nicole Brandes, Manuela Zude-Sasse
- P21 Storage studies with organic 'Galant[®]' apples
Daniel Alexandre Neuwald, Cécile Prunier, Marc Spuhler and Jens Norbert Wünsche
- P22 Plasma processed air (PPA) – an alternative for dry bulk food decontamination?
Uta Schnabel, Jörg Stachowiak, Oliver Schlüter, Mathias Andrasch, Jörg Ehlbeck
- P23 Effects of postharvest storage on the physicochemical properties of seeded and seedless watermelon
Maimunah Mohd Ali, Norhashila Hashim, Siti Khairunniza Bejo, Rosnah Shamsudin
- P24 The influence of nutrient solution different chemical composition on storage durability and the content of pro-healthy components in cherry tomato cultivated in rockwool
Kalina Sikorska-Zimny, Waldemar Kowalczyk, Ewa Badełek, Maria Grzegorzewska
- P25 Modified atmosphere and humidity packaging of fresh produce: Mathematical modeling and experimental validation
Ali Jalali, Grazielle Bovi, Guido Rux, Sadegh Seiiedlou, Manfred Linke, Pramod Mahajan
- P26 Impact of minimal processing on the dynamics of volatile organic compounds emitted from fresh strawberry
Oluwafemi James Caleb, Kathrin Ilte, Werner Herppich, Pramod Mahajan
- P27 Influence of plant nutrition on the fruit quality of tomato
Rowena Haase, Natalie Hütter, Maria Kaletta, Valentin Löw, Michael Pflanz, Dirk Jäger, Manuela Zude-Sasse

Oral Session 1

Microbiological Safety of Fresh Produce from the Farm-to-Table Food Chain

Hidemi Izumi

Kindai University, Kinokawa, Wakayama, Japan

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Fresh and fresh-cut produce can become contaminated with microorganisms along the farm-to-table food chain and can be the source for foodborne pathogens. The degree of contamination varies widely among produce types and is dependent on the environmental conditions during growing to processing of the produce. Therefore, an on-farm food safety program such as Good Agricultural Practices (GAP) and an in-plant food safety program such as Hazard Analysis and Critical Control Point (HACCP) have been recommended to minimize microbial food safety hazards of fresh and fresh-cut produce. However, more intensive and extensive research studies are needed to better understand the interaction of field and plant conditions and various treatments in reducing and regulating spoilage and human pathogens for a decisive food safety.

Our research showed that microbial count was basically higher on vegetables than on fruits. Microbial count on vegetables varied widely within and among produce types, while microbial population in most fresh fruits was below the detection level (2.4 log CFU/g for bacteria and 3.0 log CFU/g for fungi) except for the peel of a few fruits. Approximately 80% of the total isolates were bacteria in vegetables and molds in fruits. Most of the bacteria and molds isolated from produce were phytopathogenic and soilborne organisms, which are non-pathogenic for humans. Microbial count on fresh-cut produce in retail outlets was affected by storage time and temperature and varied widely among produce. The microbial flora characteristics of fresh produce during growing also persisted after harvest and were therefore commonly found on fresh-cut produce.

On-farm sources of microbial contamination are from soil, fertilizer, agricultural water, pesticide solution, and humans at the preharvest level and soil, transport vehicles, dump and rinse waters, packing shed equipment, and humans at the postharvest level. Thus, we have researched preharvest treatments including chlorination of agricultural water and ethyl alcohol spraying on packing shed equipment. Chlorinated water (ca 10 ppm available chlorine) reduced the microbial counts to levels below the lower limit of detection (1.4 log CFU/ml for bacteria and 2.0 log CFU/ml for fungi) in agricultural water, and it also minimized microbial counts and the numbers of microbial species detected in pesticide solution containing chlorinated water for the mixture. The ethyl alcohol (70%) spray reduced the microbial counts and the diversity of microflora on packing shed equipment during packing facility operations. Our findings indicate that uses of sanitizers such as chlorine for agricultural water and ethyl alcohol for packing

shed equipment would be useful in GAP programs of produce.

Major sources of in-plant contamination are from the equipment and machinery used in preparing fresh-cut produce. Fresh-cut products contain microorganisms derived from fresh produce and transferred from the equipment and machinery used in preparing it. We have reported the postharvest treatments including chemical disinfectants such as electrolyzed water and ozonated water and physical treatments such as hot water, superheated vapor, and high-pressure for fresh-cut produce. As regards to chemical treatments, electrolyzed water and ozonated water were evaluated as Japanese-devised alternatives to sodium hypochlorite, because a high concentration of sodium hypochlorite that is widely used in the food industry could cause product tainting, toxic by-products formation, and sodium residue on the product and equipment. The treatments with electrolyzed water (pH 2.7-6.5, 10-80 ppm available chlorine) and ozonated water (5-10 ppm ozone) reduced microbial counts of fresh-cut vegetables by 1-3 logs CFU/g relative to nontreated samples without quality loss. Even if chemical disinfectants are effective in reducing spoilage and pathogenic bacteria, they would not assure complete elimination of pathogens and spore-formers. Thus, application of physical sterilization was investigated to eliminate epiphytic bacteria. Hot water treatment at 100°C for 1 sec and superheated vapor treatment at 110-120°C for 1 sec for cucumber and carrots resulted in 4-log reduction of total bacterial counts and coliform groups to non-detectable levels. High-pressure treatment of 400 MPa for 5-10 min at room temperature for fresh-cut lotus and pineapple would be commercially feasible, because the treatment reduced the microorganisms of the products to non-detectable levels with minimal changes in physicochemical and visual quality. These treatments would be efficient tools to control food safety hazards in HACCP programs.

It is important to consider safety and quality of fresh-cut produce during storage and distribution. In our studies on microbial quality of fresh-cut produce stored in CA/MAP, a 10-20% CO₂ atmosphere helped in reducing microbial population and the diversity of microflora of fresh-cut fruits and vegetables. Therefore, active MAP with initial 10-20% CO₂ in combination with good temperature management would be recommended for the storage of fresh-cut produce from the point of microbiological quality.

These procedures are expected to establish a scientific baseline for designing and improving food safety guidelines that will effectively control microbial quality and assure safety of fresh and fresh-cut produce.

Application of simplex lattice design for optimization of active modified atmosphere for pomegranate arils based on microbial criteria

Zinash Belay¹, Oluwafemi James Caleb², Pramod Mahajan², Umezuruike Linus Opara¹

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² Leibniz-Institute for Agricultural Engineering and Bioeconomy, Department of Horticultural Engineering, Potsdam, Germany

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Active modified atmosphere can be used to reduce respiration rate (RR) and slow down metabolic activity, thereby maintaining quality and extending shelf life of fresh produce. The combined inhibitory effect of high or low O₂ atmosphere with enriched or high CO₂ concentration on microbial growth has been reported. However, the beneficial effects of these atmospheres can be limited due to undesirable changes if the optimum gas composition is not applied. The response to microbial growth on pomegranate arils to changes in storage atmosphere has been studied, but literature is limited on the optimization of gas concentration. Therefore, this study was undertaken in order to optimize the storage gas composition for pomegranate arils (cv. Wonderful) at 10°C based on microbiological criteria. The experiment was carried out according to the simplex lattice mixture design with three factors (O₂, CO₂ and N₂). Seven gas combinations including low O₂ (2-10 kPa), enriched and high CO₂ (2-18 kPa) and 80-96 kPa N₂ were used in varying concentrations and the bacterial, yeast and mould growth were analysed. Data from these analyses were used to fit linear and cubical polynomial models. Pareto analysis showed that the main effect - the three gas components (CO₂, N₂ and O₂; in this order for bacteria and yeast, and CO₂, O₂ and N₂ in this order for mold) as well as their interaction had significant effects on the parameters analysed. Cubical polynomial model described the effect of gas composition on the microbial count effectively. The optimal gas mixture containing 12.67 - 18 kPa CO₂, 2 - 4.67 kPa O₂ and 80 - 82.67 kPa N₂ significantly reduced microbial count on pomegranate arils throughout the storage period.

Effect of temperature abuse on volatile profile and quality of rocket leaves packaged in modified atmosphere

Maria Luisa Amodio, Leonarda Mastrandrea, Sandra Pati, Giancarlo Colelli

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The aim of this study was to investigate the effect of temperature abuse on volatiles profile and quality, as sensorial attributes and Vitamin C of fresh rocket leaves packaged in modified atmosphere (MA). Rocket leaves were packed and stored for 10 days at 0°, 5°C and 8 days at 15°C in order to evaluate the effect of temperature on aroma profile; moreover, storage in MAP at 5°C was also compared to rocket leaves stored in air as a control to assess the effect of gas composition on volatiles. Volatiles were extracted using solid-phase microextraction (SPME) directly in the package headspace and analyzed by gas chromatography coupled to mass spectrometry (GC-MS). The effect of MA was negligible when rocket leaves were stored at 0°C, and detrimental at higher temperatures, which induced anoxia after 6 and 3 days respectively at 5 and 15°C. At this time quality losses were much higher in samples stored in MAP than in air, and some lipid derivatives and sulphur compounds responsible of off-odors perception, were produced as a consequence of tissues degradation. As for terpenes, typical odor compounds, no differences could be attributed to the gas composition, except than for β -pinene and 4-carene. Generally the aroma was best preserved at 0°C, in which any degradation process was observed during 10 days of storage. Temperature also affected the vitamin C content, which was best maintained in packed rocket stored at 0°C, whereas a decrease of ascorbic acid was observed for samples stored at higher temperatures. As for appearance score also for Vitamin C, the main losses were observed when the O₂ level reached value of about 0 kPa corresponding to the highest accumulation of CO₂ in the bag and was best preserved in air. These results confirm, in fact, that when using MA packaging the effect of temperature can't be totally disconnected by the effect gas composition and that even a temperature of 5°C may induce undesirable quality changes in MA packaged samples, if the packaging design is not well designed.

Plasma processed water (PPW) – an alternative for fresh-cut salad sanitation?

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Fresh and fresh-cut produce have a limited shelf life of several days, which allows only a regional distribution of that produce. The limited shelf life and the associated losses of fresh produce have various causes, but especially depend on microbial contamination at all stages in the value chain: production, processing, transport, deployment and also before preparing. In general, a great demand regarding gentle sanitation in the production and processing of fresh produce exists because of the significant economic importance of current losses. As an alternative, non-thermal plasma at atmospheric pressure could be a versatile tool. Therefore, an experimental set-up based on a microwave-plasma source which generates plasma processed air (PPA) containing manifold RNS-based chemical and antimicrobial compounds was used. The PPA was introduced into distilled water or tap water to generate plasma processed water (PPW) which can be applied for the decontamination of packaging material and fresh produce. This is a new and innovative method for the generation of antimicrobial active water. In our experiments, PET stripes, fresh-cut lettuce, and fresh sprouts were contaminated with six different bacteria; *Escherichia coli* K12 (DSM 11250), *Pseudomonas fluorescens* (DSM 50090), *Pseudomonas fluorescens* (RIPAC), *Pseudomonas marginalis* (DSM 13124), *Pectobacterium carotovorum* (DSM 30168) and *Listeria innocua* (DSM 20649); in a concentration of 10^8 cfu ml⁻¹ and subsequently treated with PPW. For PPW production, the plasma was ignited for 5, 15 or 50 s. After a post-plasma treatment with PPW of maximum 5 minutes, a decrease of bacterial load up to 6 log were detected for *P. fluorescens* (DSM-strain) on PET as well as *P. marginalis* and *P. carotovorum* on salad. For all other bacteria and specimen the inactivation rate was lower. Furthermore, visual examinations after 8 days of storage showed only little influences on the texture and the appearance of the tested specimens. The industrial application of PPW was shown by using a small sized pilot plant for washing fresh-cut salad and replacement of commonly used tap water by PPW. The characteristics of plasma and its generated cocktail of long living chemical compounds in air and in water leading to a high bacterial inactivation and offering a wide range of possible applications.

Electrolyzed sodium bicarbonate against citrus green mold: Inhibition of *penicillium digitatum* and induction of fruit defenses

Antonio Ippolito¹, Frida Fallanaj¹, Angela Ligorio¹, Francesca Garganese¹,
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Citrus is one of the most important crops in many countries, widely cultivated in the Mediterranean area. During postharvest phase fruit are susceptible to several diseases, among which green mould caused by *Penicillium digitatum* (Pers.) Sacc. is one of the most serious. Postharvest decay is often a direct result of poor handling practices in the packinghouse environment, since storage bins, wash water, and the various components of the packing line are a source of pathogen contamination. The control of postharvest diseases is vital for maintaining citrus quality, especially in a global market in which transport from producer to consumer may take several weeks. Although synthetic fungicides, such as imazalil, thiabendazole, pyrimethanil, and fludioxonil, are mostly used to minimize postharvest decay, their extensive application has led to the proliferation of resistant strains, which compromise their effectiveness; moreover, other issues are associated with their use, such as risks for human and environmental health and costs for registration/re-registration of active ingredients. Proper sanitation of wash water used in dump tanks for citrus fruit processing is extremely important for delivering healthy produce to the consumer and minimizing postharvest losses. Among different water sanitation methods, electrolysis is gaining particular importance in the food industry. In particular, electrolyzed sodium bicarbonate (eNaHCO₃) proved to control citrus postharvest rots, although its mode of action is almost unknown. We investigated the eNaHCO₃ direct effect on *P. digitatum* and the ability to induce host defenses. The eNaHCO₃ proved to reduce conidia germination and germ tube elongation by 80% within 15 min of treatment, as compared to untreated control. After 45 min electrolysis, spore germination was almost completely suppressed. Electrolyzed water (ew) alone or non-electrolyzed NaHCO₃ showed a lower activity. Moreover, eNaHCO₃ induced the accumulation of ROS, causing an oxidative stress in *P. digitatum* conidia, a collapse of mitochondrial membrane potential, and a decrease in intracellular ATP. Results of specific assays on citrus fruit showed that, when applied in wounds nearby those inoculated with the pathogen, eNaHCO₃ controlled green mold, suggesting the induction of host resistance as a further mode of action. This hypothesis was confirmed by the up-regulation of defense-related genes coding chitinase, peroxidase, and phenylalanine ammonia-lyase (PAL) at 6–12 hpt. As confirmation, the activity of the related enzymes and of β -1,3-glucanase was increased. Therefore, both the direct inhibition of *P. digitatum* and the induction of fruit resistance are important aspects of the multiple

mode of action of eNaHCO_3 against citrus postharvest rots, although the effect recorded on the pathogen was definitively prominent. These findings are particularly interesting for a successful commercial application.

Scale-up to pilot plant dimensions of plasma processed water generation for fresh-cut lettuce treatment

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The increasing demands of society for healthy nutrition in combination with continuously decreasing willingness to spend time for food preparation leads to a rising consumer demand for minimal processed RTE products (convenient food). The USA is the leading nation in the consumption and therefore the biggest market for these kinds of products. Thus, the U.S. Food and drug Administration (FDA) has long term experience in the evaluation of consequences of the consumption of minimal process RTE products. This authority publicized a list of the ten riskiest foods with leafy greens on the top. Sanitation steps based on plasma processes could be an interesting addition to conventional cleaning procedures. Plasma, often introduced as forth state of matter, differs from the gaseous state of matter by a certain amount of free charge carriers caused by ionization processes of the gas atoms and molecules due to the supply of energy. The electrical conductivity allows supplying the energy needed to sustain this state electrically, giving access to a huge variety of plasma generation methods with excitation frequencies from DC to several GHz offering wide parameter ranges e.g. electron energies from 0.5 eV to 10 eV. The treatment of natural products with changing parameters like size, shape or water content is a challenging task for design and optimization of plasma processes. The lack of effectiveness of sanitation processes on the surfaces of food products is a general problem of all discussed methods. In order to overcome these problems a specific plasma process was establish based on a microwave plasma torch operated with compressed air delivering plasma processed air (PPA) as antimicrobial acting process gas. If PPA is brought into contact with water plasma processed water (PPW) is generated which has antimicrobial properties. This PPW process was implemented into a pilot-plant scale salad-rinsing unit in order to demonstrate the scalability and applicability of this treatment procedure. During the trial 45 kg Endive (*Cichorium endivia*) and about 1.500 l of plasma generated disinfectant are consumed. Off the cuff, the process was competitive to industrial established chemical processes.

Fungal development and associated rot and mycotoxins during ethylene supplemented controlled atmosphere storage of sweet potato

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The roots of sweet potato are susceptible to rapid postharvest bio-deterioration such as disease incidence and rotting; these are due to fungal activity which can be exacerbated during storage. The control of fungal development in sweet potato during storage is important because the pathogens affect the roots aesthetic quality, storage life and nutritional value. Additionally, some fungi species might produce mycotoxins which in turn represent a potential hazard to human and animal health.

Application of continuous ethylene in stored sweet potato has been associated with rotting on the proximal and distal ends of the roots and the mechanics behind this occurrence is unknown. This study critically evaluates rotting and the associated fungi development on the sweet potato roots during different CA storage conditions. Roots of sweet potato from a single orange-fleshed cultivar (06-52) were stored in 16L airtight plastic boxes for 12 weeks at 20°C under three treatment conditions: CA (8 kPa O₂ and 5 kPa CO₂), Air, and CA + ethylene (10µLL⁻¹, continuous supplementation). Sampling was done before storage and every six weeks during storage. Three square centimetre of root tissue were collected from the proximal, middle and distal parts of the root and then mechanically mashed in 75mL of sterile water. Serial dilution plating in Potato Dextrose agar (PDA) and Dichloran – Glycerol agar (DG18) culture media was used to evaluate fungal counts.

Results indicated that sweet potatoes stored in CA + ethylene and Air exhibited a significant increase in fungal development and consequently rotting. Significant differences across the proximal, middle and distal parts of the roots were observed across all the storage treatments ($p < 0.05$). Soft and surface rots were predominant at the proximal and distal ends of the root whereas the middle part revealed the least number of fungal growths and rot incidence irrespective of the storage treatment. Roots stored in CA were characterised with significantly less fungal growths and hence less rotting compared to the other two storage treatments. The duration of storage significantly affected the growth of fungi on the roots' surface irrespective of the spatial location. There was a significant increase in fungal activity at the end of storage for sweet potatoes stored in CA+ethylene across all locations; the opposite was the case for those stored in CA. Also storage in Air resulted in an increased fungal development at the middle parts of the roots with concurrent decrease at the proximal and distal parts. Storage of sweet potatoes in CA conditions appears to be effective in mitigating fungal development. Identification of the isolated fungi and evaluation of their potential mycotoxins production are on-going.

Oral Session 2

Preharvest conditions affect quality of leafy greens

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The focus of this presentation is on leafy greens particularly fresh-cut lettuce and baby leaves and the main causes of quality loss such as browning, off-odors and texture loss as affected by different preharvest factors. Raw material variability remains a challenge for fresh-cut and minimal processing as many preharvest factors such as genotype, environmental conditions, agricultural practices, maturity at harvest, harvest time and preprocessing handling affect quality and shelf life of the processed product.

Genotype selection is critical because of their strong influence on the quality and shelf life of the processed product. Breeding companies have to provide selected cultivars with consistency quality along the year, which is not an easy task because of the interaction with different environmental conditions. Results from cultivar selections should be confirmed in different seasons and years. For the selection of cultivars, different lines and cultivars must be cultivated under the same environmental conditions and agricultural practices to avoid the influence of these preharvest factors. Selection of cultivars for the fresh-cut industry should be based on those cultivars with lower response to cutting (wounding). We have standardized a protocol based on image analysis for the screening of cultivars for fresh-cut based on enzymatic browning. We also conducted untargeted metabolomics analyses as biomarkers for the selection of lettuce cultivars with less browning susceptibility after cutting. The membrane integrity after cutting is better maintained in the less browning susceptibility cultivars.

Environmental conditions including temperature, relative humidity, light and rainfall have an important influence on the quality of raw material. These environmental conditions influence the cultivation in different production areas. This means that when lettuce is cultivated in winter with lower temperatures, the fresh-cut product is more susceptible to fermentation and when the product is cultivated in spring is more susceptible to browning. Exposure to increased levels of UV radiation during cultivation increased the concentrations of individual and total polyphenols including anthocyanins in red lettuce cultivars. In our study, radiation and temperature showed positive correlations with the content of phenolic acids and flavonoids that increased as the season progressed from winter to spring. For the same reasons, greenhouse-grown plants have lower levels of bioactive compounds than plants cultivated in open fields. When red lettuce cultivars are cultivated in greenhouse the biosynthesis of anthocyanins is reduced. Thus, in protected culture system that increases yield, allows off-season production, controls abiotic factors and facilitates pest management, new cultivation requirements are now implemented such as the use of leds as one of the relevant tools regulating the

biosynthesis and accumulation of phytochemicals. On the contrary, cultivation in open field increases the resistant of the crop because of the adverse weather conditions and long growing cycle.

Adoption of the most suitable agricultural practices is essential to preserve the quality of the product. Efficient water use by irrigation systems is becoming increasingly important especially in regions with limited water resources. The results showed that irrigation deficit is recommended for quality and economic reasons. Adequate agricultural irrigation practices are needed to both guarantee the sustainability of the environment but also to assure the quality of the whole and fresh-cut produce. Excess of irrigation accelerated cut edge browning and microbiological growth while deficit of irrigation reduced yield. Based on these results, we evidenced that optimization of agricultural practices, particularly irrigation, is of paramount importance to ensure quality leafy greens.

Maturity at harvest is one of the main factors determining quality and the rate of quality changes during postharvest handling and shelf life. It is recommended to harvest leafy vegetables at optimal maturity stage, not only because of the economic benefits for producers but also because the physiological response of plants. For example, for iceberg lettuce, maturity is based on size and head compactness. For baby leaves, leaf length and petiole length are good maturity indicators to assure the quality of the processed product. The browning rate is higher in over-mature lettuce than in mature heads. Maturity also affects processing operations and implies an additional cost, as the more compact heads require more hand labor to take out the leaves in the factory.

Some researchers have reported that time of day for harvest has an impact depending on the species and varieties. Results from our study show that baby spinach for minimal processing could be harvested at any time in winter, while in spring it is recommended to harvest early in the morning. In addition, baby spinach can tolerate a delay before processing of at least 48 h without affecting its quality markedly. In addition, controlled RH after harvest is critical as it can influence the quality and shelf life. Baby spinach exposed to low RH showed the highest stiffness values before processing compared to medium and high RH, indicating higher leaf processability and less possibility of leaf damage during processing.

Development of cultivation management system in orchard based on ICT

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In order to adapt to the changing climate and to promote environmentally friendly smart agriculture with energy saving strategies, the development of science-based agriculture is desired. We have been using wireless sensor network (WSN) eKo using 2.4 GHz radio wave in a mandarin orange orchard as well as in a vineyard to promote smart cultivation management since 2009.

In this study, we have tried to develop the guiding system for farmers to cultivate using various phenological indices. As the sensing part of this system, we deployed new WSN, which consists of the weather station Lufft and TDR type soil moisture sensor. This new system uses 920 MHz radio wave based on Wireless Smart Utility Network that enables long-range wireless communication. Furthermore, the wave attenuation at 920 MHz caused by plant is not significant compared with that at 2.4 GHz. In addition, the data acquired by the WSN were sent to the cloud sensor infrastructure "cloudSense" based on Sensor Observation Service in order to standardize the terminology and units of measures for the advanced web service interoperability. By using these standardized data, we can make a web service that offers various kinds of phenological indices as the secondary information to the farmers at the fields.

We have also established the in-situ field management system using optical sensing techniques from X-ray to mid-IR radiation, which enable nondestructive, chemical-free, simple, and rapid measurement of fruits or trees in order to diagnose the tree vigor and the surrounding environment. Through this system, we can get the information about NBI that shows nitrate balance inside the leaf, chlorophyll content, flavonol content and anthocyanin content by using fluorescent sensor. Especially about quantifying nitrate nitrogen, the FTIR application is suitable. These methods lead us to check the health of trees quickly and find the way to improve the tree vigor of weak one. Furthermore, fluorescent x-ray sensor has a possibility to quantify the loss of mineral necessary for fruit growing. If this could put into practice, we can take a prompt action against the disease symptom.

StoreNSure: a molecular test to predict the occurrence of black spot on stored carrots

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An important problem in carrot production in the Netherlands is the occurrence of black spots during storage. When mature carrot roots are harvested before winter and held in refrigerated storage for several months, black spots can unexpectedly be observed on initially healthy harvested carrots. Black spot can cause the rejection of entire lots for the fresh market when above 5% of the carrots are affected. NSure, a global leader in measuring gene expression in the agricultural chain, has developed the StoreNSure Carrot, a molecular test, already in the market since 2014. It enables to determine whether there is a risk a batch of recently harvested carrots will develop black spots during cold storage for up to 5 months. The test is based on measurement of the activity of carrot specific genes related to the early response to black spot fungi. Activation of such genes indicate a certain risk for the development of black spots caused by at least 5 different fungi (among others *Mycocentrospora acerina*, *Alternaria radicina* and *Chalaropsis thielavioides*, *Rhexocercosporidium carotae*). Long before spots become visible, the test determines the risk. This information helps the user to optimize sales planning and circumvent serious losses. The StoreNSure Carrot test is the only test capable of indicating such a risk, early in storage. It provides the users with a practical tool to optimize post-harvest management, like selective post-harvest treatments and effective management of storage and destination of vegetable.

Effects of postharvest washing processes on microbial community dynamics associated to endive salad

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Fresh produce is naturally contaminated with microorganisms, eventually including human pathogenic and spoilage bacteria. The microbial load of perishables with human pathogenic bacteria is diverse and often leads to food borne diseases. In recent years, the increasing demand of consumers for high quality and safe convenient foods poses a high challenge especially in the area of perishable fresh-cut products. Innovative processes should result in efficient inactivation of microorganisms without affecting product quality parameters. The adhesion of pathogenic bacteria on food surfaces, the penetration of these bacteria into food tissues as well as multi-resistant bacteria hamper the reduction of microorganisms during washing processes and disinfection treatment. Microbiological sampling along the food processing chain is mainly focused on selected indicator microorganisms and unexpected potential human pathogenic bacteria may remain undetected.

The aim of this study was to evaluate the impact of different postharvest processing steps on the microbial community dynamics of endive salad (*Cichorium endivia*) using MALDI-TOF MS (matrix-assisted laser desorption/ionization time-of light mass spectrometry) analysis. Endive salad was sampled at different stages of processing. Washing was conducted using pure tap water or 0.4 mg/l ClO₂ in different washing steps. Total aerobic viable count was evaluated according to DIN ISO standards after washing or after storage for 7 days at 2°C. The obtained colony forming units were analyzed by MALDI-TOF MS to identify the bacteria.

The microbial diversity of endive salad seems to be reduced by the different washing procedures and also after storage of the endive salad at 2°C. Predominately, identified bacteria were belonging to the family Pseudomonadaceae and were found in all processing steps before and after storage. Unfortunately, 50 – 85% of the grown bacteria were not identified by MALDI-TOF MS with changing numbers of unidentified microorganisms along the processing chain. Therefore, a detailed characterization of the microbial community is hampered. However, careful handling is required to prevent the growth of potentially human pathogenic bacteria after decontamination of the product.

More detailed knowledge of the microbial community especially about the unidentified bacteria and its dynamic changes during food processing is important to allow the implementation of tailored decontamination strategies and to ensure food safety.

Color evaluation of images acquired using open platform camera and mini-spectrometer under natural lighting conditions

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Color of agricultural products is practically and commonly used as one of the most important quality indexes through agricultural process such as cultivation, harvesting, sorting and packing. However, the color appearances of the images acquired in the agricultural fields are seriously influenced by the illuminating conditions. We have been studying the color calibration method using the illuminating spectral information. This study aims to develop a quantitative color measurement method proper for the agricultural fields. We then tried to calibrate the color of images taken under the natural lighting conditions using a digital image acquisitions system with the geometrical flexibility between the camera system and the object in consideration of the illuminating distribution on the imaging area. We took the color images of the standard color chart with the plain Red, Green, and Blue sections under the standard and natural lighting conditions using an open platform digital camera, and analyzed the relationship between the color appearance differences of the images based on the illuminating radiance spectral characteristics which were obtained using a mini-spectrometer. Both the digital camera and the spectrometer could be wirelessly connected to a network system. The images were acquired under some positional relationships between the sample and the camera in consideration of the focusing position on the image view. The photosensitive characteristics experimentally represented the same curve as that for the other cameras examined in our previous study. Additionally, the RGB values of the images of the virtual standard color chart could be predicted using the simple spectral futures of the various natural lighting conditions based on the photosensitive characteristics by considering the influences of the positional relationships between the sample and the camera and of the focusing position on the image view. As the results, the simulated RGB values of the images of the virtual standard color chart consistently agreed with the actual ones. Furthermore, the images acquired under the natural lighting conditions using the image acquisition system were successfully calibrated by comparing the color parameters of the virtual standard color chart with those taken under the standard lighting condition.

Non-destructive method for oil content and moisture content prediction in oil palm fruitlets using electrical impedance spectroscopy

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Determination of oil and moisture content in oil palm fruits is important in breeding program for producing good planting materials. This paper introduced a non-destructive technique to predict oil content and moisture content in oil palm fruitlets using electrical impedance spectroscopy. In total of 90 samples of oil palm fruitlets at different ripeness stages were acquired. Electrical impedance measurement for each fruitlet was done using electrocardiogram electrodes connected to a LCR meter at frequency of 1 KHz, 10 KHz, 20 KHz and 100 KHz. The actual oil content in the fruitlets was determined using Soxhlet extraction method while the actual moisture content was determined using standard oven drying method. The variation of electrical impedance values at each frequency was analyzed. The correlation coefficient relating electrical impedance to moisture content was ranged up to 0.81 and the correlation coefficient related to oil content was up to 0.74. This result indicated that the electrical impedance measurement technique has good potential to predict oil content and moisture content in oil palm fruitlets.

Impact of mixed fruit loading in storage chamber on quality parameters

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Ethylene induces detrimental effects in fruit and vegetables when it is produced and as it accumulates through the post-harvest chain. There are many reports describing the negative effects of ethylene and its impact on storage life of fresh produce. The problem is more aggravated in mixed loadings, where both ethylene sensitive and ethylene producing commodities are stored together; this can be highly detrimental as ethylene can easily diffuse from one shelf to the other because ethylene has nearly the same specific mass as air. This study was aimed at investigating the effects of mixed fruit loading and induced ethylene on fruit quality parameters. Three different types of fruits namely, apples (high ethylene producer), green bananas (intermediate ethylene producer and sensitive) and kiwi (low ethylene producer and highly ethylene sensitive) were stored together at 15°C for 10 days. Simplex lattice design was applied in obtaining 7 different experimental combinations with: 3 treatments of single-fruit components, 3 for mixture of two-fruit components, and 1 with mixture of three-fruit components. Different quality parameters weight loss, color, firmness, sensory, TSS, acidity and respiration rate were analyzed in the beginning of the experiment and at the end of storage day 10. Ethylene concentration was also monitored at regular intervals. The result showed that kiwi and banana stored as individual components remained firm and green, at the end of storage period and did not show significant changes in other quality parameters. However, mixed fruit loading had a significant impact on the measured quality attributes of individual fruit ($p < 0.05$). High ethylene production by apples led to significant softening and yellowing of kiwifruit and banana, respectively. Therefore, this study showed the importance of understanding individual fresh produce physiology, and that fruits sensitive to ethylene should not be mixed with those producing ethylene along the cold chain.

Oral Session 3

Postharvest handling practices for better quality and longer shelf life

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The goal of all fruit industries is to provide acceptable quality for the consumer. Postharvest technologies are applied to: reduce metabolic rates that result in undesirable changes in colour, composition, texture, flavour and nutritional status; reduce water loss that can result in loss of saleable weight, reduction in appearance factors such as shriveling, softening and loss of crispness; minimize bruising, friction damage and other mechanical injuries; reduce spoilage caused by pathogen infection, especially of damaged or wounded tissues; and prevent physiological disorders such as chilling injuries. Additional objectives of reduction of chemical usage, avoidance of contamination and maintenance of food safety have become of increasing importance.

The most important technology to maintain quality of fruit during storage and shelf life remains the cold chain, with modified and controlled atmosphere storage (MA/CA) storage applied as a supplement for some fruit, especially apples and pears. Technologies such as edible coatings, heat treatments, sulfur dioxide and irradiation meet specific needs that can make them economically viable for specific products. In addition, the last decade has represented a time of great innovation for the postharvest community, most notably the development of dynamic controlled atmosphere (DCA) and 1-methylcyclopropene (1-MCP)-based technologies. Other postharvest treatments (e.g. nitric oxide, salicylic acid, polyamines, γ -aminobutyric acid) are the subject of intensive investigation, but less clear is their potential for commercial development. In this overview, selected technological innovations are discussed in relation to factors associated with commercialization and their adoption by various industries.

Effect of raw material quality and modified atmosphere packaging on color and texture retention of wild rocket (*Diplotaxis tenuifolia* L.)

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Wild rocket (*Diplotaxis tenuifolia* L.) is packaged in film that creates modified atmospheres (MA) to prevent wilting of the leaves and to ease handling and marketing of the product. Often, the O₂ transmission rate (OTR) of a film is kept at a constant level despite that wild rocket vary in respiration rate at harvest. In this experiment, wild rocket was harvested in the spring and in the late summer and packaged in films with two O₂ transmission rates (OTR's): 2.57 and 17.4 pmols⁻¹m⁻²kPa⁻¹, and stored for 28 days at 5°C. During storage, leaf color and texture was determined by multispectral analysis. Wild rocket harvested in the spring remained greener during storage but lost its texture faster than wild rocket harvested in the late summer. With the 2.57 OTR film there was some modification of the inside atmosphere, down to 14-17 kPa O₂ and up to 4-7 kPa CO₂ depending on the respiration rate of the wild rocket at harvest. With the 17.4 OTR film, the modification inside the package was minor regardless of harvest time. There was no effect of OTR on the color and texture retention of wild rocket during storage as both films allowed enough O₂ for aerobic respiration.

Non-destructive detection of chilling stress for improving keeping quality of fresh produce: cucumbers as a model

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Cucumber (*Cucumis sativus* L., Cucurbitaceae) is one of the most popular fruit vegetables worldwide, normally consumed at immature stage. The vegetable is very perishable due to physiological deterioration and postharvest diseases. The possibility to extend the storage life of cucumbers by refrigeration is limited due to their high sensitivity to chilling injury (CI) at temperatures below 10°C, manifested as pitting, softening, water soaking, yellowing and enhanced fungal decay. Furthermore, almost one-third of cucumbers that reach the consumer's household are wasted during domestic storage, primarily because the temperature of home refrigerators is far too low for cucumbers and causes CI. The objective of our ongoing project is finding efficient approaches to reduce the postharvest losses of fresh produce by alleviating chilling injury (CI) in sensitive crops, e.g. cucumbers. It is commonly accepted today that reversible phase transition in cellular membrane lipids is the primary event in the CI development. Upon extended exposure to low temperature, the malfunction of cell membranes results in secondary irreversible degenerative phenomena. The present research is based on the assumption that nondestructive optical assays of cold-stored cucumbers can allow detecting the onset of chilling stress in order to omit its shift to the irreversible stage. We further suggest that modulation of storage temperature at this transient period will allow alleviating the CI development and maintain the cucumber quality during cold storage. Furthermore, we expect that this work will provide solutions for improved preservation of cucumbers during supply chain and domestic refrigerated storage. After testing various photometric techniques several parameters of chlorophyll fluorescence (Fm, Fv/Fm and PI) as well as autoluminescence photometry and imaging were selected as promising CI indicators showing significant changes during cold exposure, preceding the appearance of CI signs. It was found that first signs of chilling stress are evident after 3-4 days of exposure of cucumbers to chilling temperatures while the injury symptoms (e.g. increase of tissue electric conductivity) are manifested after 7-8 days of cold storage and subsequent shelf life. Furthermore, brief rewarming of the fruit during the transient period with subsequent continuation of cold exposure allowed extending the refrigerated storage of cucumbers without the appearance of CI symptoms. We believe that this approach can be helpful for reducing the wastage of cucumbers during supply chain and home storage. Additional examples of the efficacy of the nondestructive photometric techniques for investigation of CI development and cold tolerance in fresh produce will be given in the presentation.

Lessons learned from the intelligent container

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Temperature deviations during transport and storage still cause a significant amount of food losses. A high share of these losses can be avoided if adequate counter measures are taken in due time, and warehouse and delivery management is updated according to the actual remaining shelf life (RSL) of the product.

The project intelligent container was initiated as a remedy to the problem of transportation losses by providing the user with real-time access to temperature data, local temperature variations inside the container and estimation of the actual RSL.

In the first part of our presentation we will give an overview of the technical system of the intelligent container, the first-expiry first-out (FEFO) paradigm for RSL based warehouse and delivery management, and results from 3 trans-ocean transports of bananas.

The technical systems consist of an internal network of wireless sensors for multiple point temperature measurement and a gateway to forward sensor data and calculated RSL values over external GSM cellular and satellite networks.

The attenuation of radio signals by the high water content of fruits turned out to be a crucial factor for the wireless transmission of product core temperature measurements inside pallets, especially if the common 2.4 GHz band is used. Measurements in an apple storage room verified that a sufficient communication range can be achieved with alternate radio chips, operating at 433 MHz or 866 MHz.

During the test transports, the green life turned out to be the critical parameter for bananas, giving the number of days until a spontaneous start of the ripening process is expected.

We found that it is too short sighted to restrict the system to pure FEFO application. A major challenge for the application of FEFO is high biological variation of fruit and vegetables after harvest. For an exact prediction of remaining shelf life the available non-destructive methods for the characterization of the physiological status of fresh products before transport and storage are not sufficient.

Most improvements of the quality of the fruits was achieved by a warning system for pallets which have a high risk to create a hot-spot, based on measurement and modelling of local temperature changes.

The analysis of the effective cooling per pallet led to improved packing and stowage schemas. This later aspect is evaluated in detail in a new project for monitoring of air-flow profiles by wireless anemometers, although the scope is on cold-storage warehouses instead of transport containers.

A more accurate estimation of the progress of the ripening process would be possible by monitoring of ethylene and CO₂ gas concentration. But transferring sensor technology for ethylene measurement from laboratory scale equipment to mobile devices for in-container measurement is still a striking challenge.

In the second part we will look into already market available technologies and analyze which challenges have still be met to enable a wide application of FEFO in the cool chain.

Currently market available systems fall apart in two groups. On one hand Remote Container Monitoring (RCM) with the target group of logistic service providers. RCM provides real-time access to state of the cooling engine but give only limited support for sensors packed to products in the cargo hold.

On the other, there are wireless temperature data loggers, with the target group of food distributors and gross retailers. Some of these devices already provide options for shelf life modelling. But real-time access is not provided; data can only be transferred after arrival of the transport through a gateway mounted in the warehouse or at the loading platform.

Common standards to forward data from wireless product temperature measurements through the RCM system are still lacking. Furthermore, new business models should provide for an adequate share of additional revenues by improved fruit quality, especially, if the logistic chain is split up into several operators.

Design of an environmental variables monitoring prototype during transportation of horticultural products

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Consumers request the best quality for fruit and vegetables so companies must guarantee that their commodities do not lose quality at harvest during postharvest. This is a delicate issue especially in long distance transportation, since scarce control systems are commercially available to register the main environmental variables affecting postharvest quality. Among such variables, the most important are temperature and relative humidity. Moreover, there are almost no accurate equipment to register those variables and have a real-time information. This work describes the design of a prototype to register temperature and relative humidity and frequently send the information to a platform to be consulted at the client convenience. Sensors connected to a portable and autonomous system, which works as a data logger, conduct the registration of such variables. It process and records the information with wide dynamic range and minimum susceptibility to interference for their use. The information is send by wireless real-time to a monitoring interface based in a web-service system. All process is secure and guarantee that encrypted data managements keeps the information safe though centralized data administration. Besides, this system offers to the customer information about the load location during the supply chain. The geographic location is available thanks to a google-maps service by integrating an autonomous communication equipment, which attach the location information. The self-sufficient system is supplied with a node power, monitored by the microcontroller via an interface measurement, allowing a periodic charge level of sampling. Thanks to all these characteristics, the system is portable and easy-to-use, which means that there is no need for expensive hard-wired infrastructure and the installation do not cause any disruption to the infrastructure. Likewise, the system is cost effective due to the automated record keeping that eliminates manual clipboard checks. Therefore, the designed prototype will revolutionize the sector of refrigerated transportation of horticultural produce thanks to the real-time key environmental variables monitoring system by an accurate, compact, self-installing, self-contained and geolocalizable cost effective equipment.

Inline application of NIR system in produce sorting machines

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High quality agricultural products require sorting according to internal quality attributes such as sugar, water, starch or oil content. Sorting lines are available for many products but generally utilize external sorting such as color, blemish and size or weight. Near Infrared spectroscopy have been proven to be a technology suitable to provide quantitative information on internal quality attributes rapidly and nondestructively. Many publications of prior studies by the authors as well as by others presented the inline prospect of this technology for fruits such as dates, apples, avocado, mango and more. Several commercial machines utilizing this method are available in the market. The objective of the present study is to evaluate the feasibility of implanting NIR mini-spectrometers in the commercial sorting line manufactured by Eshet Eilon (Israel). Two mini-spectrometers were tested: a) VISNIR spectrometer in the range of 530-1100 nm (USB4000, Ocean Optics, USA), b) SWIR spectrometer in the range of 880-1700 nm by STEAG (Germany). Furthermore, the combination of working with both spectrometers in order to have a large scale of wavelengths at the same time was tested. The developed system included special illumination design with suitable optical configuration for scanning the fruits. The tested fruits included dates, apples, avocados, mangos and papayas. The different fruits were evaluated on different suited conveyors. Spectral models were developed using chemometrics methods such as PLS and PLS-DA. The developed models were assimilated in the controller PC of the sorter. Beta site experiments are taking place now days.

The use of janny MT box in cherry storage

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The aim of the study was to examine the use of Janny MT box, a new technology, for cherry storage. In addition, this technology was compared to normal (NA) and modified atmosphere (MAP) storages commonly used in cherry preservation. The 0900 Ziraat cherry variety, the most popular in Turkey, was used as the material. Fruits harvested at optimum stage were transported to the laboratory immediately, and pre-cooled at 1°C. After pre-cooling, fruits were stored at 0°C and 90±5% relative humidity (RH) for 5 weeks in NA, MAP conditions, and in Janny MT box at 2°C. During the storage period, weight loss, change of fruit skin color, stem color, respiration rate, soluble solids content (SSC), titratable acidity (TA), gas composition in package were determined at weekly intervals. Fruits were also evaluated for sensory attributes during cold storage. Samples taken from cold storage in each week were stored for 2 days at 20°C for shelf life and then fruits were re-evaluated. According to evaluation criteria, the Janny MT boxes gave better results than the other storage conditions at the end of the storage period of 35 days.

Poster Session

Assessing potential benefits and sensitivity to carbon dioxide of different artichoke cultivars

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The objective of this study was to assess the potential use of CO₂-enriched atmospheres on storability of different artichoke cultivars and to individuate possibly dangerous concentrations resulting in physiological damages to the tissues. To this aim 2 experiments were conducted. In the first, the effects of 2 levels of CO₂ concentrations of (5% and 20%) combined to 5% O₂ were compared with the control in air on 4 varieties of artichokes: 'Madrigal', 'Opera', 'Opal', and 'Violetto Foggiano'. In the second experiment, atmospheres with 5% O₂ plus 10% 15% and 20% CO₂ were tested on 'Madrigal' artichokes. In both experiments artichokes were stored 21 days at 5°C and quality parameters as physical attributes (respiration rate, weight loss, firmness and color), sensorial attributes (visual quality and browning index) and chemical attributes (ethanol, acetaldehyde, ammonia and total phenolic content, DPPH-antioxidant activity, iron-chelating activity, polyphenoloxidase activity and electrolytes leakage) were evaluated at 0, 7, 14 and 21 storage days. As for the first experiment, artichokes did not show any difference in terms of appearance related to the storage condition, but after removing the first 3 layer of bracts, an extended browning was observed for all varieties except 'Madrigal', which showed only a slight browning during the storage in presence of 5% O₂ + 20% CO₂. All varieties showed to be differently sensitive to the highest CO₂ concentration, indeed, 'Opal' and especially 'Madrigal' artichokes hearts turned brown after respectively 21 and at 14 days of storage. The use of high CO₂ levels positively affected some quality parameters: firmness was best preserved in 'Opal' artichokes; the weight loss for 'Madrigal' and 'Opal' varieties stored for 7 days in controlled atmosphere was lower than for artichokes stored in air. The highest CO₂ level determined the lowest electrolytes leakage on all varieties except 'Opera'. The application of controlled atmosphere with 5% O₂ + 20% CO₂ did not determine great benefits on artichokes, while causing evident metabolic disorders. Due to the sensitivity to internal browning, 'Madrigal' variety was selected to test the effect of intermediate levels of CO₂ in the second experiment. A slight browning on the external surface of artichokes was observed starting by the 14th day for the atmospheres with highest CO₂ concentrations (15% CO₂ and 20% CO₂), and at 21 storage days also for the treatment with 5% O₂+10% CO₂. The 20% CO₂ still caused browning of the artichoke hearts, which was not visible in the other treatments. Treatments with 10 and 15% CO₂ levels showed similar behaviour to storage in air with no production of ethanol and acetaldehyde and preserved the phenolic content and DPPH-antioxidant activity,

which were reduced in artichokes treated with 5% O₂+20% CO₂. Ammonia production was significant higher in artichokes stored in presence of 5% O₂+20% CO₂ than the other treatments. Gas mixture with 5% O₂ + 20% CO₂ was not suitable to store 'Madrigal' artichokes because it determined many qualitative damage especially browning of the hearts and bracts, while 5% O₂+10% CO₂ and 5% O₂+15% CO₂ did not induce any benefit with respect to the air storage causing also a slight darkening of the bracts.

Effect of regulated deficit irrigation on yield and fruit quality during shelf life of sweet cherry

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Regulated deficit irrigation strategies are interesting in regions where water is the main factor limiting production by increasing water productivity maintaining fruit yield and quality, and even improving some quality parameters. Size, color, firmness, maturity index and earliness are fundamental characteristics of cherry fruit for customer approval. The evaluation of such quality attributes at harvest and during shelf life provides useful information. The aim of this work was to study the influence of irrigation strategies on "Prime Giant" cherry quality at harvest and during cold storage and shelf life. The experiment was conducted over 2015-2016 season at "Finca Toli", a 0.5 ha commercial plot of "Prime Giant" cherry, [*Prunus avium* (L.)], in Jumilla, SE Spain. The trees were 15 years old and were grafted onto "SL-64" rootstock. Pollinizer by "Early Lory" and "Brooks". Trees were trained to a vase system, spaced at 5 m x 3 m, drip irrigated with three emitters per tree with a discharge volume of 4 L h⁻¹. Four irrigation treatments were applied: CTRL, RDI100-55, RDI95-65 and Farm. Control treatment (CTRL) was irrigated over the maximum crop water requirements (110% of ET_c) during the entire season. Deficit irrigation treatments, RDI100-55 and RDI95-65 were irrigated to satisfy 100% and 95% of ET_c, throughout the preharvest and 55% and 65% after harvest periods respectively. Meanwhile farm treatment, FRM, was irrigated by the grower according to their own experience. Each treatment, randomly distributed in blocks, was run in quadruplicate. Cherry physicochemical quality was determined after harvest (time t₀), after a cold storage period of 20 days at 0°C and 90% relative humidity (RH) (t₁), and after an additional shelf life period of 5 days at 15°C and 65% RH (t₂). Quality parameters evaluated were fruit dimensions, weight loss, color, firmness, total soluble solids content (SSC), titratable acidity (TA) and maturity index (MI). Geometrical characteristics were measured with a digital caliper, color was determined with a colorimeter Minolta CR 300 (Ramsey, NJ), firmness with a texture analyzer LFRA 1500 (Middleboro, Brookfield, MA, USA) by using a 2 mm diameter probe, SSC by a refractometer and TA by an automatic titrator and pH-meter. Supplied water during 2015 postharvest period was 5265 m³ ha⁻¹ CTRL, 2992 m³ ha⁻¹ RDI95-65, 2551 m³ ha⁻¹ RDI100-55 and 4266 m³ ha⁻¹ FRM while during 2016 preharvest period 2119, 1734, 1888 and 2608 m³ ha⁻¹ was used for CTRL, RDI95-65, RDI100-55 and FRM treatments respectively. Midday stem water potential (ψ_s) was a sensitive indicator for

plant water status, during 2015 postharvest ψ_s presented clearly differences between CTRL and deficit irrigated treatments with mean values of -0.64 MPa, -0.83 MPa, -0.97 MPa and -0.83 MPa to CTRL, RDI95-65, RDI100-55 and FRM respectively. RDI100-55 ψ_s values decreased until -1.9 MPa (DOY 195) which exceed the imposed threshold of -1.5 MPa. As a consequence, RDI100-55 was irrigated as CTRL for the next week. Values of ψ_s lower than -1.5 MPa were reached during long postharvest periods, which would promote reductions in fruit growth and consequently yield decrease in the next season. However, ψ_s mean values during 2016 preharvest period were similar for all treatments, with approximately -0.6 MPa, indicating a no stressful situation due to the water amounts applied to satisfy crop water requirements (ET_c). There were no differences between treatments in fruit yield, neither the first harvest nor the total, 27 t ha⁻¹. Moreover, significant differences were not observed in quality parameters measured at harvest time (t₀), after cold storage (t₁) and shelf life (t₂), decreasing mean values throughout the experiment, particularly color and titratable acidity which at harvest presented mean values of 8.3 and fell to 7.6 g L⁻¹ at t₂. Thus, there were no differences in fruit weight losses between treatments, although RDI treatments showed a trend toward smaller losses during postharvest storage. This could possibly be because of more irrigated treatments are related with bigger dehydration losses. Deficit irrigation treatments reported above saved up to 38 and 33% water without compromising fruit yield and quality parameters regarding CTRL and FRM treatments. Furthermore, deficit treatments showed a high water productivity, 6 kg m⁻³, calculated as fruit produced (kg) per water applied (m³), compared to the one obtained for CTRL and FRM (3,9 kg m⁻³). Considering 0.25 € m⁻³ as the average water price in the growing area where this study was developed, deficit treatments saved from 575 to 700 € ha⁻¹. These results support deficit irrigation scheduling use in sweet cherry trees. However, should be evaluated and adjusted in next seasons.

Postharvest treatments to control physiological disorders and decay in lemon fruit

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Physiological disorders and decay of lemon (*Citrus x limon*) may greatly reduce the postharvest quality of this citric leading to great economical losses. This experiment studied the effects of different postharvest chemical treatments [Fortisol Ca (1%), Fortisol CaPlus (1,5%), Philabuster (0,2%) and Ortocil (1%)], and their combinations, by immersion (30 s) to control decay (*Penicillium italicum* and *P. digitatum*), chilling injury and adustiosis in lemon fruit (*Citrus x limon* Fino). Lemons were stored for 33 days at 7°C, which simulated a long transportation period, followed by 5 days at 22°C, simulating a commercialization period. The Ortocil+Philabuster treatment completely avoided the decay after transportation and commercialization periods. Fortisol Ca and Fortisol CaPlus reduced chilling injury and adustiosis by 55-70 and 40-50%, respectively. The incidence of such physiological disorders was even reduced in a greater extend when combined treatments of Fortisol Ca and Fortisol CaPlus with Ortocil+Philabuster were used. In particular, the treatment Fortisol CaPlus+Philabuster+Ortocil completely avoided the incidence of chilling injury and adustiosis. In conclusion, a combined treatment of Fortisol Ca or Fortisol CaPlus with Ortocil+Philabuster may greatly control decay and physiological disorders, such as chilling injury and adustiosis, in lemon fruit during transportation and commercialization periods.

Modified atmosphere and humidity storage container for strawberry

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Fresh produce are unique among food products since they remain respiring and transpiring after harvest and their shelf life is shortened as consequence of these processes. Appropriate packaging is one of the essential methods for protecting and maintaining the quality of fresh produce, as it prolongs the shelf life of produce from growers to consumers. However, improper control of respiration may lead to undesirable results such as low O₂ concentration and consequently anaerobic respiration; accelerated physiological decay; and shortened shelf life. The resistance of plastic films for water vapour permeation usually far exceeds that of produce surfaces. Therefore, most water molecules evaporated from the produce do not escape through the film and remain inside the packages, enhancing the water vapour pressure in the package headspace and or condense on fruit and tray wall surfaces. In turn, the condensation accelerates spoilage and considerably shortens storage life. In this context, this research work targets to design a storage container for creating optimal modified atmosphere and humidity for strawberry. Integrative mathematical modelling based on respiration, transpiration and heat transfer characteristics of the selected product was applied for selecting the size of permeable membranes (NatureFlex, Xtend and Polypropylene). Experimental validation was performed at 5 °C for 14 days and involved measurement of O₂, CO₂, humidity, condensation, weight loss, and sensory evaluation. The results based on computer simulations and experimental validations will be presented.

Chemical, physical and sensorial characterization of fresh quinoa sprouts (*Chenopodium quinoa* Willd.) and effects of modified atmosphere packaging on quality during cold storage

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The aim of the study was the characterization of the quality attributes and the evaluation of postharvest performance of 'Real' and 'Regalona Baer' quinoa (*Chenopodium quinoa* Willd.) sprouts. Germination ratio, weight, water content, texture, color, phenolic content, and antioxidant activity were evaluated on sprouts. 'Regalona Baer' gave a better performance showing higher germination and weight increase (44% and 49%, respectively) than 'Real'. Moreover, 'Regalona Baer' showed a higher phenolic content with value of 9.1 μmol gallic acid g⁻¹ DWB, while 'Real' only had 4.9 μmol gallic acid g⁻¹. A separate experiment was performed to study the effects of different modified atmosphere packaging conditions in order to extend the shelf life of ready-to-eat fresh quinoa sprouts. Passive and active MAP with 5 % O₂ + 20 % CO₂ were tested using micro-perforated PP bags. Chemical (ethanol and acetaldehyde content), physical (texture and color) and sensorial attributes of quinoa sprouts were evaluated during storage at 5°C. Among sensorial properties appearance, color, green odor, grassy odor and off-odor were evaluated using anchored subjective scales. Results show that the 'Real' quinoa sprouts in passive MAP showed the shortest shelf life characterized by a fast decrease of texture, browning on the surface, as well as a production of off-odor after

1 day of storage. In the same storage conditions 'Regalona Baer' sprouts were still marketable, showing a higher appearance and color scores. 'Regalona Baer' in active MAP showed a greater turgidity and crispiness compared to samples stored in passive MAP. Therefore, 'Regalona Baer' quinoa sprouts, which showed the better quality attributes, packaged in PP micro-perforated with a gas composition of 5% O₂ + 20% CO₂ could be a potential solution for extending the shelf life as a ready-to-eat product.

A novel approach for determination of invisible quality changes in modified atmosphere packaged fresh and fresh-cut fruit and vegetables

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Many fresh and fresh-cut fruit and vegetables are delivered to consumers in modified atmosphere packages (MAP). At purchase, freshness is evaluated based on the appearance of the product inside the package. However, freshness is also influenced by the odor of the package headspace upon opening. Packages with perceivable off-odors may lead to consumer rejections, food waste and lack of re-purchase because consumers automatically rate such products quality as low.

Formation of unusual odors, the so-called off-odors, may develop from the use of inappropriate raw materials, harsh processing and handling, and inappropriate packaging designs and storage conditions. Measurement of the volatile organic compounds (VOCs) in the headspace of packages can reveal presence of specific off-odors. Results for packaged wild rocket stored at 5°C and 10°C for 8 days showed higher off-odor scores (15-point scale) at 10°C (5.2) than at 5°C (1.5) and higher concentrations of dimethyl sulfide and dimethyl disulfide at 10°C (0.71 and 0.13 ng per g produce) than at 5°C (0.08 and 0.02 ng per g produce). It was found that the scores of the perceived off-odors could be related to the package headspace concentration of dimethyl sulfide and dimethyl disulfide.

The VOC method is promising and can be used to provide consumers with better quality MAP fresh and fresh-cut fruit and vegetables as this method can reveal the invisible quality changes of fresh produce in the supply chain.

The use of natural antimicrobial compounds in packaging of leafy greens: impact on microbial load and sensory quality

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Control of microbiological quality of leafy vegetables is essential, especially in the case of organic vegetables, which are more susceptible to microbial attack as they are produced without agrochemicals. Natural antimicrobial compounds in packaging may be an innovative and safe solution to inhibit microbial growth and maintain quality after harvest. The aim of this study was to evaluate the impact of selected natural antimicrobial compounds (eugenol, carvacrol or trans-anethole) on the quality of packaged organic wild rocket. The active compounds were incorporated into pellets. One sachet containing 1 g of pellets was placed in an empty tray that was then filled with 100 g of organic wild rocket and wrapped with laser perforated polypropylene film. After 7 days of storage at 5°C, sensory descriptive analysis showed that the natural antimicrobial compounds masked off-odors that impaired the sensory quality of wild rocket but had no effect on the microbial load.

Postharvest chlorine dioxide treatment for quality management of white asparagus (*Asparagus officinalis* L.)

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In Germany, white asparagus is an economically important, highly appreciated but extremely perishable crop that is increasingly offered as fresh convenience product. Because losses caused by microbiological spoilage can be up to 30%, optimization of postharvest treatments is essential for supply chain management of asparagus. Tap water washing reduces spear surface attached microorganisms by only 1 – 2 log. Addition of sanitizers to washing waters may effectively reduce microbial loads. However, some sanitizers are less successful than initially assumed and/or negatively affect produce quality. Recently, chlorine dioxide (ClO₂) was tested as an alternative sanitation agent for fresh produce. This investigation aimed to evaluate effects of ClO₂ washing water on microbial load and physiological properties of white ‘Gijnlim’ asparagus spears during simulated shelf-life. During four growing seasons, freshly harvested spears were washed, sorted and randomly separated into batches. Respective batches were subjected to ClO₂ (5 mg l⁻¹, 30 s or 50 mg l⁻¹, 30 or 90 s) and tap water (controls), and stored for up to 4 d at 20°C. Total aerobic mesophilic bacterial counts (TAMBC), yeast and mould counts, and various quality parameters of spears were analysed at harvest, and on days 2 and 4. TAMBC of controls increased from 4.4 x 10⁵ to 3.9 x 10⁷ cfu gFM⁻¹ during 4 d of storage; TAMBC of treated spears (c(ClO₂) = 5 mg l⁻¹, t = 30 s) was one log lower than that of controls after storage. Increasing ClO₂ concentrations to 50 mg l⁻¹ and extensions of treatment (t = 90 s) did not further reduce TAMBC. Yeast counts (controls) alternated between 10² and 10⁴ cfu g⁻¹ at harvest and increased one to two log during storage. No ClO₂ effect on yeasts was observed irrespective of treatments. Washing with ClO₂ (c = 50 mg l⁻¹, t = 30 s) resulted in 0.5 log lower mould counts after 5 d; extending treatments to 90 s reduced moulds by another 0.5 log. Vitamin C content, respiration rate and dry matter were not affected by ClO₂-treatments. Therefore, ClO₂ may be an appropriate sanitizer to minimize microbial load on asparagus spears.

Comparison of advanced non-destructive methods to classify healthy and diseased onions

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During cold storage, onions are lost due to loss of skin, skin cracking, sprouting, rooting, mass loss and development of diseases. Among these defects, spoilage of onions due to diseases may lead to significant losses. Different diseases exhibit different symptoms and symptoms may be visible on the outer surface or only inside. Diseases with external symptoms can be detected easily by non-destructive visual inspection and machine vision techniques. Detecting internal diseases, however, needs either destructive or advanced non-destructive techniques as the diseased part may develop in the core of the onion.

Near-Infrared (NIR) spectroscopy is a non-destructive technique, which is suitable for the analysis of product with higher water and carbohydrate contents. However, NIR spectroscopy can only measure at one point at a time. Thus, quality assessment using this technique may provide incorrect information if sampling points are too few or the area of the infected tissue is too small. Spectral Imaging, which combines machine vision and spectroscopy, overcome these limitations as both spatial and spectral information are acquired simultaneously. Commercial sorting machines are available for size and quality sorting of onions. However, it is not clear how well these machines sort onions into healthy and diseased onions and it may lead to misclassification and food losses. False positives result in sorting reduce profit of the farmer and false negative may lead to consumer dissatisfaction and rejection. The objective of this study was to compare the efficiency of Spectral Imaging and NIR spectroscopy to classify healthy and diseased onions. Onions were sorted after six months of cold storage into healthy and diseased onions using a commercial sorting machine (Sammo, Longbardi). The sorting machine consisted of NIR spectrophotometer for internal quality measurement, a laser scattering unit for detecting volume, scale splitting, loss of scales, and external diseases, and a weighing unit for detecting foreign. From the machine-sorted onions, 15 first-class, healthy and firm onions (size 40 – 80 mm with intact outer dried scales, no visual symptoms of diseases, and a firm feeling) and 30 diseased onions (size 40 – 80 mm with intact outer dried scales and no visual symptoms of diseases) were selected. Onions were numbered, and subjected to non-destructive measurements by Multispectral Imaging using a VideometerLab (Videometer A/S, Hørsholm, Denmark), Hyperspectral Imaging using two custom built Hyperspectral Imaging systems; one at a wavelength of 419 nm to 1116 nm and another at 1016 nm to 1742 nm (Newtec Engineering A/S, Denmark), and Fourier Transform Near Infrared Spectroscopy using

AgriQuant FT-NIR (Q-interline). All onions were visually inspected after the non-destructive measurements and the inner and outer scales were assessed for diseases after halving the bulbs. From this assessment, only 13 out of the 30 diseased onions were rated as diseased and the number of bulbs was thus reduced to 13 to have a similar sample size.

Spectra from the non-destructive methods were pre-processed and a Partial Least Square Discriminant Analysis, (PLS-DA) classification model was built with these data. Hyperspectral Imaging at wavelengths between 1016 nm to 1742 nm showed better performance with higher sensitivity and specificity compare to the other methods. Overall, Spectral Imaging provided better classification of onions than NIR spectroscopy.

Agricultural environment information monitoring by using unmanned aerial vehicle

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Introduction

In the field of agriculture, it is difficult to initiate the newcomer into the know-how of expert farmer because there are many task depending upon experience and perception of the farmer and aging of the farmer. To solve these problems, there has been a great discussion about utilization of Information and Communication of Technology (ICT) in agricultural field in recent years. Especially, the environment information monitoring of farming field is one of important tasks to be solved. For example, there is the environmental information collection of crop growing condition, working information, and various sensor information in a field. And then, it is possible to support the decision making (agrochemical spraying, harvest time, and so on) by linking the know-how of skilled farmers with the collected agricultural environment information. Furthermore, it is able to improve productivity and take climate change measures. To monitoring the environmental information in accordance to the goal is one of the big issues.

The conventional method of the agricultural environmental information monitoring can be divided into Ad-hoc type and server installation type. Ad-hoc-type transfer the sensor information to the server by communicating between sensors. Ad-hoc type has the problems that the communication range of sensor is small because of energy efficiency, and it is difficult to establish stable communication by environment change. Server installation type has various sensors and camera. User can access server from a remote place using the 3G and WLAN and so on. Furthermore, the sensor information can also be transferred to the cloud server. But, it is difficult to install in a farming field where cannot ensure the power supply because the energy consumption is big.

On the other hand, Unmanned Aerial Vehicle (UAV) is used in various field in recent years. For example, the maintenance management for an infrastructure, the recognition of disaster conditions, the farming field, and so on. To stably collect the environmental information in a place that is difficult to ensure the power supply in farming field, it is possible to use UAV. But, it does not clarify the use condition and the way of the usage of UAV.

In this paper, we propose the agricultural environment information monitoring system using UAV and clarify the use condition of UAV to stably collect the environment information in farming field that it is difficult to ensure the power supply. In addition, we

develop the field sensor module to stably collect the information when UAV cannot conduct autonomous flight because of wind, rain, and so on. And then, an operation check is performed. We show the results that the system collected stably the environment information by outdoor experimentations.

Agricultural environment information monitoring system by using UAV

To stably collect the various agricultural environmental information in a farming field that is difficult to ensure the power supply, UAV carry out the autonomous flight periodically along the prepared route, and the information collection device equipped on UAV collects the information of sensors that is installed at required place in a farming field. The collected information is transferred on a server by using wireless LAN after UAV went back to home. The following elemental technologies is needed to implement this system:

- * Autonomous flight: To carry out the autonomous flight along the prepared route, UAV use the position information of GPS. When the wireless communication range of sensor is considered, the precision of GPS is enough to collect the environment information.
- * Sensor module: If UAV cannot fly autonomous by a gusty wind and rain, it is necessary to record the environment information periodically. Furthermore, it must also be considered in addition to the energy efficiency, the expandability and synchronization of sensor module.

Sensor Module

The sensor module records the information that sensors measure the periodically. And, When the transmission request of the information collection device is received, the module sends all of the recorded information. The sensor module includes various sensor, micro-computer, and wireless communication.

We consider the sensor module using Arduino that is microcomputer. Arduino has merits that the power consumption is small and it is easy to extend the various sensor. The system needs the following technologies:

- * Memory function: When UAV cannot fly autonomous periodically, the sensor information is recorded in a memory. If the sensor module receives the communication request, the recorded information is sent to the information collection device on UAV. Sensor module record sensor data in an external memory.
- * Energy efficiency: The long-time operation in a place that is difficult to ensure the power supply is requested for sensor module.
- * Extensibility: It is necessary to add sensors easily to sensor module as need because various sensors are used in agricultural field.
- * Synchronization: To measure sensors on time, it is important to synchronize the sensor.

Performance evaluation

The sensor module consists of microcomputer (Arduino UNO), three kind of sensor (temperature, humidity and soil sensor) and Zigbee communication system (TWE-Lite DIP). In response to a communication request, the sensor module transfer the sensor data to the information collection device (Nexus 5) that is mounted on UAV. The sensor module includes the 4 types of sensors that are temperature, humidity, and soil sensor.

UAV which is used in experiments is Phantom 3 Advanced (DJI) and the information collection device (Nexus 5) has Zigbee communication to receive the environment information. The information collection device sends the communication request to sensor module when UAV approaches a sensor module, and receive the recorded environment information of various sensor.

We experimented in the campus ground (75 m by 125 m) and installed the sensor modules in 4 places. The flight altitude is 6m and the speed is 5 m/s. The sensor module collects the sensor information every 5-minute and UAV fly every one hour. The number of trial is 5 time. The system showed the results that are to stably collect the environment information.

Conclusions

We described the proposition of the agricultural environment information monitoring system by using UAV and carried out the performance evaluation. And then, we developed the sensor module to stably collect the environment information when UAV cannot fly autonomous periodically and performed operation check in a farming field. Finally, we showed the effectiveness of the system by outdoor experimentations.

Future work is the autonomous battery power supply for UAV. To implement the full autonomous flight of UAV, the autonomous battery power supply is one of the important issues to be solved.

Basic research of the acquisition of biological information towards the construction of agricultural support system

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In recent years, studies of agricultural support systems that use measurement technologies, sensor development, and information and communication technology (ICT) have been actively conducted. Storage and analysis of environmental information have also become easier. However, judgment about the conditions of crops still relies on skilled farmers. Moreover, data utilization is difficult for new farmers and young farmers. Therefore, it is necessary to quantify the experience and intuition that skilled farmers have. Then one can connect the explicit knowledge obtained through analysis of data. It is necessary to establish a system that makes it possible for younger workers to inherit skills quickly. To provide future farmers high-quality and high-efficiency cultivation management systems, and to enable growing environment measurement, acquisition of quantitative biological information and information related to growth is necessary. Therefore, a new sensing technology based on plant physiology must be developed. As described in this paper, we propose and develop a new sensor that specifically examines leaf color, which is a useful indicator for the determination of biological information related to crops. To produce a useful sensor, one must understand the biological aspects related to crops and crop application methods. Nitrogen is the ingredient that most affects yields. It plays an important role in life-sustaining crops. This nutrient is usually absorbed from the soil, but the amount of the required nutrient can vary because the amounts of absorption differ depending on the growth stage of the plants. Consequently, nitrogen contents also vary. Therefore, ascertaining the nitrogen contents of crops presents an important means to grow good crops efficiently. Judging the leaf color to ascertain the nitrogen contents is a technique that has been used since ancient times. Reportedly, the nitrogen content of the crops is proportional to the available elements of chlorophyll, which forms green leaves. Therefore, the crop nitrogen contents can be estimated roughly as "green color density = chlorophyll amount". We can assess whether estimation using this property of crop growth can be done using optical measurements of chlorophyll amounts. To assess the leaf color, the spectrum of the near-infrared region from the visible light region is measured using a spectrometer. After light enters a leaf, the light emitted from the rear surface of the leaves can be measured after repeated light scattering and absorption in the canopy. Some light wavelengths are absorbed because of the chlorophyll pigment. Therefore, the output light wavelength differs from the input wavelength. The spectrum which chlorophyll affects is acquired by measurement with light from the spectrometer.

Crop of research subject is a Japanese mustard spinach. Simultaneously, leaves were measured using a chlorophyll meter (SPAD-502Plus; Konica Minolta, Inc) to ascertain the actual chlorophyll contents in leaves. The measured spectrum is compared to the amount of chlorophyll measured by the chlorophyll meter.

The wavelength (676.791nm) which is most affected by chlorophyll in the leaf was ascertained. In addition, the relation between the absorption spectrum at the characteristic wavelength and the change in the chlorophyll amount was obtained. Results suggest the possibility of estimating the amount of chlorophyll in the leaf by optical measurements of the characteristic wavelength. These results suggest that this measurement can be used for comprehension of the growth state of crops.

Influence of nitrogen application on ascorbic acid content in cauliflower cultivars after post-harvest storage

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Cauliflower, like broccoli and cabbage, belong to the cruciferous family of vegetables which has been shown to be effective in fighting certain forms of cancer and reducing the risk of cardiovascular disease mortality. In general, freshly harvested fruits and vegetables including cauliflower contain more ascorbic acid (AA) than those held in storage and they show a gradual decrease in ascorbic acid content as the storage period increases. The quality loss of cauliflower is mainly due to yellowing of the head and the development of undesirable odour, which limits its shelf life and consumer acceptance. Temperature management is the most important tool to extend the shelf-life and indirectly delay losses in nutrients such as ascorbic acid. Commercial cultivars (Largardo, Eskimo and CF 744) of cauliflower were planted at the Agricultural Research Council-Vegetable Ornamental Plant Institute (VOPI) Roodeplaas, South Africa. The plants were treated with six different levels of nitrogen: 0, 60, 90, 120, 150 & 180 kg/ha. The experiment was conducted in the Randomised Complete Block Design (RCBD) with four replications. Nitrogen level at 120 kg/ha was considered the control, as it is commercially used. Curds were harvested at an optimum maturity 70 days after transplanting. Medium-sized cauliflower curds after removing the outer leaves, sorting and without washing, were packed in cling film wrap and stored at 1°C, 90–95% RH for 14 days. Changes in curd colour, physiological loss, weight loss, spoilage and sensory quality were evaluated at weekly intervals up to 14 days. Ascorbic acid content of each sample was assessed in duplicate using the 2, 6 dichloroindophenol method of titration. The results show a gradual decrease in AA content as the storage temperature or duration increases. Nitrogen fertilisers, especially at high rates, seem to decrease the content of AA in cauliflower; however, nitrogen application at 120 kg / ha retained and maintained the AA which prolonged shelf-life till day 14 with maximum retention of the white colour of the curd, minimum spoilage, weight loss and good sensory quality attributes. Decreases in AA content occurred when the cauliflower curds deteriorated. This condition maintained the ascorbic acid content for at least 7 days and also maintained the visual quality of the cauliflower heads. Increasing the amount of nitrogen fertiliser from 0 to 120 kg / ha increased the content of AA in cauliflower and the greatest losses in weight occurred at higher levels of nitrogen application. The rate of

weight loss increased with the progression of time during the storage period. Curds produced under 150 kg N/ha showed decay with discolouration (yellowing) by the second week sufficiently to be unfit for consumption, while curds produced under low nitrogen application showed a few spots of decay at day 14. The use of cling wrap film should be avoided as this leads to accumulation of excessive moisture resulting in huge spoilage loss. The present study thus suggests that nitrogen application at 120 kg / ha should be recommended to farmers producing cauliflower as it retained moisture and enhanced the shelf-life of cauliflower.

Impact of integrated packaging design approach on the quality and shelf life of cauliflower (*Brassica oleracea* var. *botrytis* L.)

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Decay, mould and wilting are the common postharvest problems of fresh-cut cauliflower (*Brassica oleracea* var. *botrytis* L.) in the supply chain that are encountered at the collection stage by consumers. The aim of this study was to evaluate the effects of packaging design on the quality attributes of fresh-cut cauliflower. The set objectives were (i) to study the produce physiological responses on transpiration rate (TR), respiration rate (RR) and ethylene production under various storage conditions (temperatures: 1, 5, 10 and 15°C) and relative humidity (RH) (60, 76, 86 & 96%), which will guide in package design; and (ii) to evaluate the impact of packaging and optimal storage condition on the quality of fresh-cut cauliflower. Respiration and ethylene production for the uncut and fresh-cut cauliflower were determined using closed system technique, while TR was determined based on weight loss approach. The RR of fresh-cut cauliflower was significantly ($p < 0.05$) higher (120 mg/kg.day) than that of the uncut cauliflower (77, 5 mg/kg.day) at 5°C. Storage temperature was found to have significant impact on RR and ethylene production rate ($p < 0.05$), likewise high storage RH had significant influence on TR. Measured TR declined from 20.5 to 3.1 g/kg.day, with increase in RH from 60 to 96% at 5°C. Mathematical models accurately predicted RR and TR as a function of various storage conditions and showed good fitting to the experimental data ($R^2=0.98$). Using mathematical models for RR and TR, an optimal package was designed in order to achieve equilibrium modified atmosphere and RH inside the package for fresh-cut cauliflower. Package performance was evaluated under different storage temperatures for 12 days. Physicochemical parameters viz headspace gas composition, weight loss, total soluble solids, titratable acidity, pH, anthocyanin and microbial load were analysed. Optimized package design and low temperature simultaneously best retained and maintained quality attributes of fresh-cut cauliflower, thus, prolonging the shelf-life.

Combined effects of MAP and postharvest salicylic acid treatment on quality attributes of dill (*Anethum graveolens*) bunches during storage

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The effects of combinations of modified atmosphere packaging (MAP) with salicylic acid treatment on storage and shelf life quality of dill (*Anethum graveolens*) leaves were investigated. After harvest dill leaves were dipped in an aqueous solution containing different concentrations of salicylic acid (1, 2 and 4 mM) for 2 minutes. The control group was immersed in distilled water only for 2 minutes. Treated samples were dried with blotting paper and placed in modified atmosphere package and stored at 0°C and 90±5% relative humidity (RH) conditions for 25 days. After cold storage, samples were kept at 10°C and 55-60% RH for 2 days to simulate commercial practice (shelf life), and analyzed for same quality parameters performed during cold storage. Weight loss, color, respiration rate, gas composition in package, soluble solids content (SSC), titratable acidity (TA) and some biochemical parameters such as vitamin C content, total phenolic compounds and total chlorophyll content were determined initially and at 5 day-intervals. The dill bunches were also evaluated for sensory attributes during cold storage and shelf life. According to the results, salicylic acid treatment has allowed the dill leaves to stay green longer than those of control group. 1 mM dose of salicylic acid was the best treatment for prolonging the storage and shelf life of dill leaves with keeping the quality.

Air circulation management in CA storage of apples based on airflow measurements

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Cooling of fresh produce is an important cost factor for producers and retailers of fruit and vegetables due to high power consumption. The fan operation for air circulation in controlled atmosphere (CA) storage requires 30 to 40% of the total energy consumption. There is a high potential for saving energy in cool storages by optimizing air circulation management based on actual measurement of the airflow close to the fresh produce. The research project 'COOL' aims to optimize air circulation management that involves multiple tasks: development of a new sensor for airflow measurement, modification of the stacking layout of bins and design of plastic bins for storage of apples. The project is being funded by the German Federal Ministry for Economic Affairs and Energy (BMW) from 2015 until 2017 and the project consortium involves three research institutes and five industrial partners. Initial studies were carried out 2015 in a CA storage room (50 t) to measure the airflow distribution in one gap between two bin rows and also within a single bin containing apples (~300 kg). Within the storage room, plastic bins (total 163) were stacked in three rows with a gap width of 13 cm between the bin rows. The cooling air was circulated by 5 fans (outlet air speed of 3 to 4 m s⁻¹) located above the plastic bins. The airflow profile in one gap between two rows of plastic bins was measured by 30 wireless directional anemometers attached to the side wall of bin. For the measurement of airflow in a vertical or horizontal direction, the anemometers were turned by 90° between two subsequent tests. A sensor for non-directional airflow measurement was used to measure airflow inside a plastic bin containing apples, which was placed at three different positions in the stack. In addition, in the horizontal gap above the fruit of the same bin the airflow was measured with standard directional hot wire anemometers.

The measurements were performed at 4 different fan speed levels varying between 25% to 100% which correspond to an average airspeed in the gaps of 0.3 m s⁻¹ and 0.8 m s⁻¹, respectively. Between the fruit within a bin, much lower airspeed ≤ 0.1 m s⁻¹ was measured. Change in fan speed had an immediate impact on the airspeed in the gaps and between the fruit inside the bins.

Interestingly, reducing the fan speed level for minimizing energy consumption did not show any negative impact on apple quality. Further experiments are in progress to investigate the influence of the bin stacking layout (gap width and the fan position) on the airflow distribution.

Predictive diagnostics based on gene expression for determining the risk of bitter pit development in apple fruit

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Bitter pit is a common disorder in apple that manifests as dark spots on apples late in the growing season or during storage. While this physiological disorder has been associated to low calcium levels in the fruits, it remains difficult to manage. Indeed growers lack effective predictive methods and can only make educated guesswork upon secondary evidence (e.g., orchard's historical record, fruit mineral content) which may be influenced by various other determinants. The setup of a reliable method for prediction in the early stages of fruit development would allow grower to make a selective application of counter-measures at the orchard, thus reducing Calcium inputs and production costs when the risk is low, leading to an efficient use of resources and reduction of losses. Notwithstanding its impact at the orchard level, bitter pit often appears during post-harvest. As well as growers, packing houses lack reliable methods for predicting bitter pit incidence during storage. Prediction of bitter pit incidence during storage would allow efficient post-harvest management, like selective post-harvest treatments and effective management of storage and destination of the fruit. Within the EU funded project AppleGenie, which is coordinated by NSure, a molecular test is being developed for apple fruit, based on gene expression, that will predict the susceptibility to bitter pit at two times: at harvest and after long-term storage at the packing house(post-harvest).

Impact of dipping fresh-cut apple slices in different sugar solutions on quality parameters

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Fresh-cut fruits sector has shown consistent growth, due to change in consumer lifestyle and growing demand for convenience, nutritional and safe “ready-to-eat” fresh-cut fruits (fresh-cuts). Fresh-cuts responses to wounding induced by minimal processing include increase of respiration, enzymatic browning of cut surfaces and softening tissues and reduced shelf life. Higher respiration rates could indicate a more active metabolism and is a key parameter for optimising postharvest treatments. Furthermore, minimal processing could induce microbial growth due to released exudates. Complete immersion of fresh-cuts in sugar-syrup is one of the general industrial practices adopted to minimize the adverse impact of minimal processing and to extend shelf life. However, there is limited information available on the physiological responses and changes in physiochemical quality of fresh-cuts immersed in sugar solution. Thus, this study investigated the impact of complete immersion of fresh-cut apples in varying concentration of sugar-syrup solution: on respiratory behaviour and quality attributes. For this, fresh-cut apple slices, were placed in solutions with different sugar concentrations (0 – 30%) and air (as control) store at 13°C for 6 days. Respiration rate were continuously measured to calculate the real-time respiration rate. Sugar-syrup solution with 13.4 - 20% showed the best applicability to maintain fresh-cut apples quality and slow down physiological processes. Enzymatic browning of fresh-cut surfaces was considerably reduced in samples immersed in sugar-syrup solution compared to those in the control.

Optimization of apple storage bin for reduced energy consumption in airflow ventilation

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Apples are stored usually in large bins in stacks up to 8 bins in the refrigerated cold storages. Main structural requirements for the bins are high stability and low mechanical load of the fruit in order to avoid produce losses during the storage period of several months. The layout of commercial bins is configured based on empirical assumptions and varies only marginally for bins from different manufacturers. The percentage of the opening area is on average 7 to 11% of the bin side walls and the bottom area. In contrast, fully filled bin with apples leaves a hollow space of 41%. Thus, a typical bin wall has higher air resistance than the bulk inside the bin. The resulting effect is high pressure loss in the ventilated storage room due to the bin design. The fan operation consumes up to 40% of the electrical energy for CA-stored of apples. Therefore, there is a need to optimize the bin design considering a balance between the opening area and structural requirement that will lead to considerable reduction of the energy use for the ventilation.

In the present study, numerical analysis based on CFD were performed to simulate the effects of varying bin opening area on airflow and finally experimental validation was performed in a wind channel. Different wall types with high opening area up to 40 % and their drag coefficient with and without apples were considered for the tests. Besides the airflow behavior, the bin walls were tested with regard to the mechanical load of the fruit. Therefore, the filling operation was performed in order to exclude the risk of produce damage due to increased opening area. The structural requirement for stacking of up to 15 bins was considered in the new bin wall design. The results will be presented in terms of the impact of the modified layout of the bin for apple storage on airflow using CFD-simulations. Further results will include the energy usage due to reduced fan speed and also the effects on product quality.

Comparison of plant and soil mapping in *Prunus domestica* L. orchard

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Precision fructiculture addresses site or tree adapted crop management. In the present study, the soil apparent electrical conductivity, ECa, and plant water status were analysed in plum production (*Prunus domestica* L 'Tophit plus'/Wavit) targeting (i) the spatial characterization of the soil ECa and yield, (ii) instantaneous water status, and (iii) cumulative pattern of water status and yield. The plum orchard is located on a hill (3.15°) in temperate climate (Potsdam, Germany), capturing 0.37 ha with 156 trees. The ECa of the topsoil (0-0.25 m) was measured using a Wenner array with the centre at the tree stem with a resistivity meter (4-point light hp, LGM, Germany). Plant measurements were carried out on each tree. Laser scanner (ALASCA XT, IBEO Automobile Sensor GmbH, Germany) was employed to measure the leaf area ratio [hits/tree]. The leaf water potential [MPa] was recorded by means of a pressure chamber (Plant water status console 3000, Soilmoisture Equipment Corp, Santa Barbara, USA). Thermal radiation of the canopies was measured by thermal imaging (ThermaCam SC 500, Flir Systems, USA). From the thermal images the crop water stress index, CWSI, was calculated. Soluble solids content of fruit [°Brix] and yield [#fruits/tree] were measured at the harvest date. Statistical analyses were carried out using the statistical package for MATLAB® (R2010B, MathWorks, U.S.) and the free algorithms for spatial analysis. The soil ECa showed small scale variability in the range 1.3 mS/m to 76.7 mS/m. In our study, spatial pattern of ECa were correlated with leaf water potential, CWSI, yield and fruit quality. The regression analysis showed high adjusted coefficient of determination, R^2_{adj} , considering soil ECa and CWSI at $R^2_{adj} = 0.72$, leaf area ratio at 0.77, while lower coefficients were found for yield and fruit quality. The preliminary results of ANOVA considering CWSI show differences with $F = 4.43$ ($p = 0.038$) and yield with $F = 6.70$ ($p = 0.001$). However, spatial variability of CWSI as well as leaf area ratio showed higher correlation coefficients and even increased significance level compared to soil data. Time series of hot-spot, again, point to more information obtained from plant data.

Impact of pre-harvest respiratory pattern on post-harvest quality of pear

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Commercially available pear show high variability in fruit quality. Particularly, fruit flesh firmness is crucial for consumers acceptance. In order to draw conclusions about the influence of pre-harvest respiratory pattern on post-harvest fruit flesh firmness, European pear (*Pyrus communis* L.) 'Conference' grown in commercial orchards in Germany, were analyzed in four consecutive years. Ethylene production was recorded gas chromatographically, while CO₂ emission was measured in closed system by optical infrared sensor. The results revealed two pre-harvest respiratory patterns: On-years showed a pronounced respiration peak followed by drop of respiration rate. Off-years were characterized with late ethylene production, but no respiratory increase considering the average of fruits. Storage experiments were carried out in 2015 (on-year) and 2016 (off-year) considering the fruit quality after storage and in shelf life. Storage took place in sealed chambers at 1°C in controlled atmosphere (CA: 1 - 3% CO₂, 1.5 - 2.5% O₂) and in air (NA) followed by post-storage shelf-life at 20°C. Pre-harvest as well as post-harvest, fruit flesh firmness [N/cm²] was measured according to Magness-Taylor using a 11 mm diameter plunger. The appearance of on- and off-years had no influence on the increase of respiration rate during post-storage shelf-life. Analogous to respiration rate, decrease of fruit flesh firmness during shelf-life occurred in both, on- and off-years. Comparing fruit flesh firmness at removal from storage, pear harvested in an on-year 119 days after full bloom (dafb) (CA: 128.38 ± 15.61; NA: 127.66 ± 12.24) and 126 dafb (CA: 112.18 ± 9.16; NA: 105.47 ± 20.57) as well as pear harvested in an off-year 131 dafb (CA: 90.62 ± 5.74; NA: 83.23 ± 4.58) and 148 dafb (CA: 71.96 ± 14.06; NA: 78.89 ± 7.55) showed similar progress of decrease. Despite divergent pre-harvest respiratory pattern, at the end of shelf-life, entire 'Conference'-pear met the consumer requirements of buttery and mellow flesh. Based on the results, fruit flesh firmness is more influenced by time of harvest after full bloom and storage conditions than by pre-harvest respiratory pattern.

Storage studies with organic 'Galant®' apples

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The new apple variety 'Galant' has interesting characteristics for organic growers in Southwest Germany due to its good fruit yield per hectare and resistance against apple scab. The effect of various storage conditions on fruit quality parameters and fruit disorders of 'Galant' apples was evaluated in 2015/16. The experimental treatments were harvest time/ fruit maturity (early, middle, late), storage temperature (1, 3°C), controlled atmosphere (CA) storage at 1 kPa O₂ and >0.7 kPa or 2.5 kPa CO₂ with a CA delay (after 3 or 21 d of storage) and regular air (RA). Fruit were removed from storage after 3 and 7 months (January and May, respectively). Assessments were conducted after 7 d shelf-life at 20°C. In January, at the first storage removal, flesh firmness was very similar to harvest values, except for fruit in RA which showed lower firmness. However, at the second evaluation after 7 months storage, fruit firmness had decreased remarkably. Fruit stored at 1°C compared to 3°C were firmer as were fruit kept under 2.5 kPa CO₂ compared to 0.7 kPa, but CA-fruit were generally firmer as fruit in RA. Earlier harvested fruit showed higher firmness than fruit from the later harvest dates. Unexpectedly, fruit with no CA delay were softer than fruit from either the 3 or 21 CA delay treatments. At the first storage assessment no physiological disorders or fungal rots were observed, however; following 7 months storage, considerable incidence of flesh browning, brown heart and scald were found (23%, 59% and 20%, respectively). Storage studies conducted in 2014/15 and 2015/16 indicate, that 'Galant' apples have a restricted storage life, even under CA conditions. Quality losses occur between 3 and 7 months. Further investigations are still required to improve the storage recommendations for this new cultivar.

Plasma processed air (PPA) – an alternative for dry bulk food decontamination?

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The majority of storable bulk and powdered food are dry vegetable produce. Especially, grains and their grinding products are one of the most important food worldwide. Apart from basic foostuffs, herbs and spices are also important for nutrition especially in Europe. Adequate storage of these produce guarantees storability of month up to years at room temperature without affecting the consumers' health. However, many produce are contaminated with high numbers of fungal and bacterial spores as well as human pathogens like *Salmonella* sp. or EHEC species. Therefore, cases of salmonellosis by consumption of dry herbs or herbal teas and of EHEC by consumption of sprouts produced from contaminated seedlings occurred during the last years. Commonly, a lot of different microorganisms and pathogens including insects, larvae and eggs, occur at dry bulk plant food. Therefore, the aim of this running project is to identify the possibility of plasma processed air (PPA) for microbial decontamination of such produce without affecting the food quality by a dry plasma-based technology. First results for bacterial spores of *Bacillus atrophaeus* on technical specimens and wheat will be presented. The treatments will be done in lab-scale size to find an optimization process for up-scaling.

Effects of postharvest storage on the physicochemical properties of seeded and seedless watermelon

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The physicochemical changes in fruits can be influenced by postharvest handling during the storage period. This study was carried out to evaluate the changes in the physicochemical properties (firmness, soluble solids content, pH, moisture content and colour) of seeded and seedless watermelons during three weeks of postharvest storage. The physicochemical properties were analysed over seven interval days (day 0, day 4, day 8, day 12, day 15, day 18, and day 21) to observe the changes between both varieties. The results indicated a decrease in the firmness, soluble solids content, and moisture content values, whereas the pH values increased for both the seeded and seedless watermelons. The changes of colour varied among the colour parameters (L^* , a^* , b^* , chroma, hue). The L^* , b^* , and chroma values increased whereas the a^* value reduced. The hue angle value exhibited different results as the value increased for the seeded watermelon and decreased for the seedless watermelon. No significant difference was reported between the storage day and type of cultivar with regard to the changes of colour and firmness. The findings indicated that the changes in physicochemical properties of the seeded and seedless watermelons during storage could have a major impact on the determination of fruit quality.

The influence of nutrient solution different chemical composition on storage durability and the content of pro-healthy components in cherry tomato cultivated in rockwool

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The aim of the task was to determine the effects of different nutrient solution and used biostimulator (bio-algeen) on the quality of cherry tomato. Studies were carried out in a greenhouse on rockwool slabs. There were examined six different nutrient solutions. Standard nutrient solution (control) and experimental objects: enlarged level of components in relation to standard nutrient solution about 20%, the enlarged level of components (Ca, K) about 10% in relation to standard nutrient solution; the enlarged level of components (Ca, K) about 20% in relation to standard nutrient solution; the addition of the PK bloom booster type Bio-algeen on the beginning of cultivation; the PK bloom booster additive under the stress conditions. Harvested tomatoes were placed in boxes lined with PE (polyethylene) and stored in two temperatures (12°C and 18-20°C). Every 7 days there were conducted qualitative and chemical analysis of the fruits. After 28 days storage there were no visible differences between the objects. The commercial value of fruit stored in temp. 12°C was very good (8.4-8.9 points), while at 18-20°C from 7.0 to 7.3 points (due to loss of firmness; using 9-point scale). Vitamin C content decreased during storage. After 28 days the most vitamin C contained tomatoes grown on slabs with addition of biostimulator in stressful conditions (50.05 mg/100 g FM), stored in temp. 18°C, the lowest vitamin C content was determined in tomatoes grown on slabs with 10% enlarged level of calcium and potassium (34.48 mg/100 g FM), stored in temp 12°C. Most total sugars were found in tomatoes grown in slabs with nutrient solution with enlarged level of components in relation to standard nutrient solution about 20% (12,43%) and stored in 12°C. During storage in all objects there were decreasing in acidity of tomatoes. The most lycopene after 28 days storage was determined in cherry tomatoes grown on slabs with standard nutrient solution (control) (124.54 mg/100 g FM), the least in tomatoes grown on slabs with biostimulator applicated in stressful conditions (22.52 mg/100 g FM) (both results obtained for tomatoes stored in temperature 18-20°C).

Modified atmosphere and humidity packaging of fresh produce: Mathematical modeling and experimental validation

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Modified atmosphere and humidity packaging (MAHP) is used to extend shelf life and maintaining the quality of fresh fruits and vegetables by modifying desired gas concentration and relative humidity inside fresh produce package. Several factors affect the optimum design of MAHP, most of which are time and or temperature dependent. Hence, there is a vital need for a simulation tool that includes all affecting parameters and the interactive behavior of different phenomena such as respiration and transpiration of fresh produce, moisture absorption and heat and mass transfer affecting the package gas composition and water vapour. One of the most challenging problems in this regard is MAHP of fresh produce with high transpiration rates especially under varying ambient conditions such as temperature and relative humidity. Hence the moisture absorption kinetics of humidity regulating trays containing different concentrations of sodium chloride in the structure as an active humidity absorber substrate were integrated to a comprehensive simulation program for MAHP design as a potential solution to overcome this challenge. A number of validation experiments including using two types of humidity regulating trays were conducted to evaluate the robustness of the simulation program under constant and varying temperature conditions during storage period and predicting gas composition, humidity and moisture condensation dynamics in packaged strawberry. The simulated results were satisfactory so that the predicted equilibrium headspace humidity was very close to measured values. Therefore, the simulation program was found to be a convenient tool to virtually test the package under a broad range of environmental conditions such as temperature and humidity resembling real supply chain conditions and ensure proper selection of packaging systems for the optimum performance.

Impact of minimal processing on the dynamics of volatile organic compounds emitted from fresh strawberry

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Change in composition and concentration of volatile organic compounds (VOCs) is one of the primary indicators in the sequence of postharvest degradation processes in fresh and minimally processed produce. Due to the high volatility and variable concentration of VOCs, understanding the impact of sample processing and incubating temperatures on the volatile profile is essential. This study investigated the effects of minimal processing on the change in composition and relative abundance (%) of VOCs emitted from strawberries. A total of 70 VOCs belonging to six chemical classes were identified via gas chromatography-mass spectrometry (GC-MS). The volatile profile obtained for strawberries were significantly ($p < 0.05$) influenced by minimal processing and the headspace incubating temperature. Aldehyde chemical group were most abundant in strawberry puree (34%) compared to sliced (18%) and none was detected in the headspace for the intact fruit sample. Esters were most abundant in the sliced strawberry (63%) compared to intact fruit (51%) and puree (49%) samples. Increasing the incubating temperature of sample vials from 60°C to 80°C resulted in three fold increase in number of VOCs. This investigation showed that postharvest analysis of VOCs of fresh produce towards the determination shelf-life/quality, requires detailed understanding of essential parameters influencing evolution of volatiles. Thus, caution should be taken in metabolic profiling and interpretation of GC-MS data for aroma compounds of fresh produce.

Influence of plant nutrition on the fruit quality of tomato

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Losses along the supply chain, up to the point of sale may be reduced, when the actual developmental stage of fruit and its quality are considered in the processes and during marketing. Thus, it is recommended for growers and traders to monitor the quality of perishable horticultural products. This study was aimed at (i) the changes of fruit quality considering vitamin C, carotenoids and chlorophylls, and (ii) if these quality traits can be influenced by the mineral nutrition during cultivation. In total 112 tomatoes (*Solanum lycopersicum* L. 'Bogota') grafted on 'Emperador' were examined. The plants were cultivated in a greenhouse on rock wool with artificial assimilation lighting of 450W (SON-T, Philips, Niederlande) and population density of 2.5 shoots/m². At visual appearance of the first blossoms all plants were subjected to varying fertilizer compositions with four repetitions: control, N+, N-, Mg+, Mg-, Mn+. Four equatorial measurements have been done on the fruit, using hand held spectrophotometer (PA1101, CP, Falkensee). The OECD - color cards were visually compared. Subsequently, acidity analysis was made by titration (T50, Mettler Toledo) and soluble solids content was determined by refractometry ((PR-1, Atago Co. Ltd., Japan). An assay of the vitamin C content was measured by a test-kit (RQflex2, Merck, Darmstadt). Photometrically on the non-polar fruit extracts the following pigments were determined: chlorophyll a, b, pheophytin a, lutein, and lycopene. A significant increase of titratable acids was found for all treatments during the progress of ripening till 51 days after full bloom (dafb). On the one hand the total acid content of Mn+ was decreased compared to control at the end of the trial period. The tomatoes with an excess of magnesium had the highest acid content. Chlorophyll content decreased during fruit development, while the carotenoids content increased. In the Mg+ and N+ variants, the chlorophyll level appeared higher compared to other variants. The degradation rate of chlorophyll was similar in Mg+ and Mg- fruit, while enhanced chlorophyll decrease was found in N+ compared to N- or other samples. This indicates an earlier harvest for N+ tomatoes. The data of non-destructive analyses by means of OECD cards and handheld spectrophotometer suggest a correlation with chromatographic approach. But in comparison with former studies the correlation appeared relatively low. The trial ended 58 dafb with OECD stadium 5 and 7 for N- and N+ variants, respectively. Accordingly, this trial was finished too early for a deeper insight into the potential of the methods over the entire period of fruit development. In the framework of a student project in the study program PHYTOTECNOLOGY at the Beuth University of applied Science Berlin the present poster was ranked in the first place.

Non-contact monitoring of the firmness of nectarines cv. 'Magique' using VIS-NIR hyperspectral reflectance imaging

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Understanding the changes that occur during maturation is necessary to develop non-destructive tools capable of monitoring the internal quality of fruit to ensure suitable handling, shipping and marketing. In the case of nectarines (*Prunus persica* L. Batsch var. *Nucipersica*) firmness is a good predictor of potential shelf life. Hyperspectral imaging has been shown as a powerful fruit inspection system to assess ripeness features or to detect damages or contaminants in different fruits. For this reason, hyperspectral imaging technique in the visible and near infrared region was evaluated to predict and monitor nectarine firmness.

A total of 150 nectarines cv. 'Magique' without any defect was selected, grouped in batch of 25 samples and stored under controlled conditions until senescence. 300 hyperspectral images of the intact fruits were acquired using a camera coupled to two liquid crystal tunable filters capable of acquiring images with a spatial resolution of 0.14 mm/pixel in the range 450–1040 nm. Flesh firmness was analysed in both sides of the fruit using a texturometer provided with a 6 mm flat plunger and a speed of 1 mm/s.

A partial least square (PLS) model was performed to correlate reference values of firmness with the spectral information preprocessed using SNV. An R^2 value of 0.87 and an RPD of 2.8 were obtained. A proper wavelength selection was performed in order to reduce the large amount of information contained in the hyperspectral images by mean of variable importance in projection (VIP) scores. A total of 10 optimal wavelengths, located in the VIS (670-730 nm) and NIR (970-990 nm) regions were used to build a new model. PLS model using the optimal wavelengths maintained a similar performance as the full model with values of R^2 of 0.83 and RPD of 2.4. Finally this model was used to visualize successfully the firmness prediction in the surface of each fruit using colour mapping.

These results indicated that hyperspectral imaging has a great potential for real time monitoring of the evolution of intact nectarine firmness in industrial setups.

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