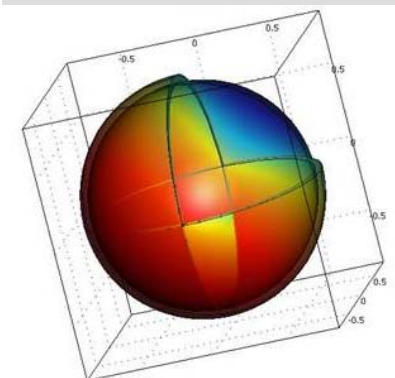




**ATB**  
Agrartechnik Bornim

**Postharvest  
unlimited 2008  
Abstract**

**November 5-7, 2008  
Berlin**



**Bornimer Agrartechnische Berichte**

Heft 64

Potsdam-Bornim 2008



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## Preface

After Leuven in 2000 and Sydney in 2004 the 3<sup>th</sup> Symposium Postharvest UNLIMITED 2008 takes place in Berlin. Since the first meeting several topics have been changed, but the main objective “keeping quality of fruit and vegetables in the supply chain” still remains and becomes even more a focus in the world-wide discussion. The Symposium is linked with the final meeting of the COST Action 924 “Enhancement and preservation of quality and health promoting components in fresh fruits and vegetables”.

The scientific Program, 55 papers and about 90 posters, is subdivided in the five topics of COST Action 924:


1. Improvement of the agri-food chain in terms of quality, healthiness and safety;
2. Postharvest physiology and metabolomics: the interaction of post harvest scenarios with biochemical and physiological aspects and processes;
3. Alternative methods for increasing shelf life and safety;
4. Non-destructive methods for quality assessment; and
5. Modelling as a tool for integration and management of the whole chain.

The meeting is co-sponsored by the European Community and we want to say thank you for that.

The symposium is organized by the Leibniz-Institute for Agricultural Engineering Potsdam-Bornim (ATB) in close co-operation with the Faculty of Agriculture and Horticulture at Humboldt University of Berlin.

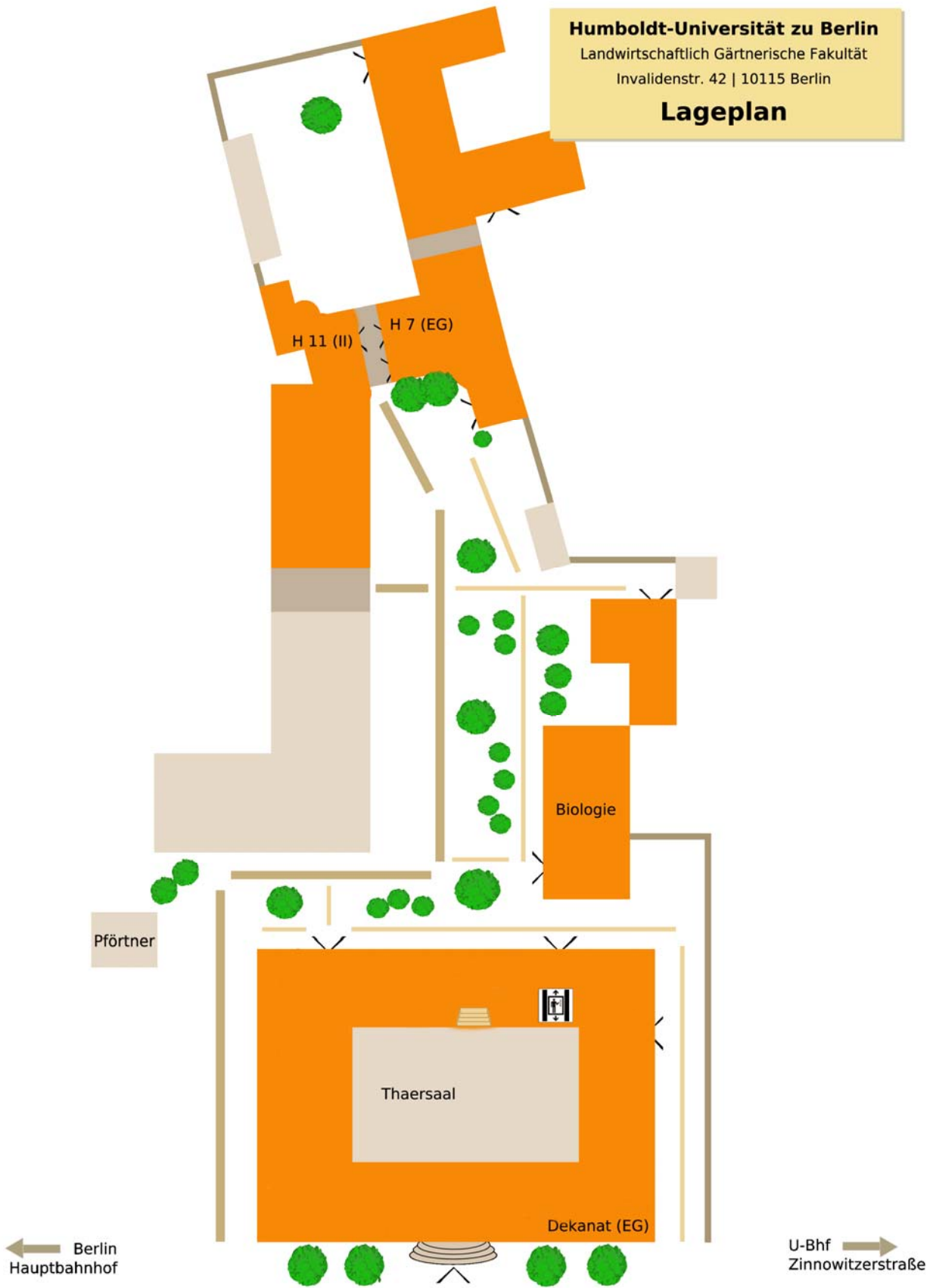
We are very proud having the meeting here in Berlin and we wish you successful presentations, interesting discussions and a happy stay in Berlin.

Potsdam, in July 2008



Dr. rer. agr. Martin Geyer

Head of Department Horticultural Engineering, Leibniz-Institute of Agricultural Engineering Potsdam-Bornim e.V. (ATB)



## PROGRAM

### Tuesday, 04. November 2008

14:00 – 18:00	Workshop: Fruit and Vegetable Products with Improved Nutritional Properties (EU-Project Healthy Structuring).	<b>Seminar Room 1231, 2<sup>nd</sup> floor</b>
15:00	Registration	<b>Thaersaal</b>
16:00	Cost-meeting	<b>Dekanatssaal</b>
18:00	Get-together	<b>Thaersaal</b>

### Wednesday, 05. November 2008

<b>09:00 – 10:50</b>	<b>Opening Ceremony</b>	<b>HS 7</b>
09:30	Welcome by Prof. Dr. Reiner Brunsch Leibniz-Institute for Agricultural Engineering Potsdam-Bornim e.V. (ATB)	
	Welcome by Prof. Dr. Bart M. Nicolai Katholieke Universiteit Leuven	
	Welcome by Prof. Pietro Tonutti Chair ISHS Postharvest and Quality Horticulture Commission, Pisa	
09:50	Effect of postharvest conditions and treatments on health-related quality of vegetables and fruits <i>Gunnar B. Bengtsson</i>	

**11:00 - 12:30      Session 1: Improvement of the agri-food chain in      HS 7**  
**terms of quality, healthiness and safety**

Chair: *Gunnar B. Bengtsson*

11:00              Quality attributes of old *Lactuca* varieties and their suitability for local markets: first results of a pilot-project to promote the on-farm conservation of crop genetic resources

*Cornelia Lehmann, Susanne Huyskens-Keil, Gunilla Lissek-Wolf, Rudolf Vögel*

11:20              Studies on fruit development stages and adjudging maturity indices of European plum cv. Hauszwetschge (clone: wolff) for extended postharvest life

*Neeraj Baghel, Felix Lippert*

11:40              Flesh carotenoid profile in climacteric near-isogenic lines of melon obtained from non-climacteric parentals: Implications in fruit design

*María Jesús Rodrigo, Javier Mauricio Obando-Ulloa, Wim Deleu, Lorenzo Zacarías, Jordi García-Mas, Antonio José Monforte, Juan Pablo Fernández-Trujillo*

12:00              Agricultural tramline system - A lift and link to upland vegetable supply chain in the Philippines: Alimodian experience

*Arlene Joaquin*

**11:00 – 12:30      Session 3: Alternative methods for increasing shelf      HS 11**  
**life and safety**

Chair: *Haïssam Jijakli*

11:00              Comparison of a palladium-promoted ethylene scavenger to 1-methylcyclopropene in manipulating ethylene-induced ripening in avocado cv. Hass fruit

*Marjolaine D. Meyer, Leon A. Terry*

11:20              Low oxygen pretreatment inhibited ripening and reduced superficial scald in Bartlett pear

*Edna Pesis, Susan Ebeler, Elizabeth Mitcham*

11:40              Effect of acetic acid vapour on sensory quality of strawberries

*Karin Hassenberg, Martin Geyer*

12:00              How do alternative storage methods affect the storage potential of carrots?

*Merete Edelenbos, Lars P. Christensen*

*Lunch*

**13:30 – 15:00      Commented Poster Session      Thaersaal**

*Coffee break*

**15:30 – 17:00    Session 2: Postharvest physiology and metabolomics: the interaction of postharvest scenarios with biochemical and physiological aspects and processes    HS 7**

Chair: *Miquel Vendrell*

- 15:30            Variation of fructo-oligosaccharides in asparagus spears during storage under different temperature regimes  
*Noureddine Benkeblia*
- 15:50            Isolation and characterization of the monodehydroascorbate reductase gene from *Vaccinium corymbosum* cv. Bluecrop and the impact of CA-storage on its expression and on the level of ascorbic acid  
*Jamil Harb, Basel Khraiwish, Wolfgang Frank, Josef Streif*
- 16:10            Spatial and temporal profile of non-structural carbohydrates in pre-climacteric Sri Lankan mango (*Mangifera indica* L.) fruit  
*Thanaraj Thiruchelvam, Leon A. Terry*
- 16:30            Biochemical and textural ripeness assessment of avocado fruit from different origins  
*Sandra Landahl, Leon A. Terry, Marjolaine D. Meyer*

**15:30 – 17:00    Session 3: Alternative methods for increasing shelf life and safety    HS 11**

Chair: *Paolo Bertolini*

- 15:30            Eliciting the endogenous resistance mechanism of phytoalexins production against pathogens in citrus fruits by mediation of limonene hydroperoxides or by wounding oil glands  
*Shimshon Ben-Yehoshua, Victor Rodov, B. Nafussi*
- 15:50            Post harvest quality of mango (*Mangifera indica* L.) fruits as affected by irradiated chitosan coating  
*Nadeem Akhtar Abbasi, Mehdi Maqbool, Zafar Iqbal*
- 16:10            Effect of atmospheric pressure plasma treatment on the stability of flavonoids  
*Franziska Grzegorzewski, Oliver Schlüter, Jörg Ehlbeck, Lothar Kroh, Sascha Rohn*
- 16:30            Effects of CA treatments and temperature on broccoli colour development  
*Rob Schouten, Xiaobing Zhang, L.M.M. Pol Tijsskens, Olaf van Kooten*

*Coffee break*



**17:30 – 19:00    Session 2: Postharvest physiology and metabolomics: the interaction of postharvest scenarios with biochemical and physiological aspects and processes    HS 7**

Chair: *Christian Larrigaudiere*

- 17:30            Abscission of bunch tomatoes during storage  
*Orit Dvir, Nir Moran Nir, Inon Farber, Delila Beno-Moualem, Shimon Meir, Amnon Lichter*
- 17:50            The role of ethylene response-pathway components in avocado ripening  
*Vera Hershkovitz, Haya Friedman, Eliezer E. Goldschmidt, Rosa Ben-Arie, Oleg Feygenberg, Edna Pesis*
- 18:10            Effects of polyethylene thickness, photoperiod and initial stage at harvest on ripening of two varieties of tomato (*Lycopersicon esculentum* Mill) fruits  
*Abiola Titilola Aborisade, Adejumoke Febisola Ayibiowu*
- 18:30            Mechanical properties of artificial cell walls  
*Justyna Cybulska, Els Vanstreels, Bart Nicolai, Artur Zdunek, Krystyna Konstankiewicz*

**17:30 – 19:00    Session 4: Non-destructive methods for quality assessment    HS 11**

Chair: *Martin Geyer*

- 17:30            Measuring apple texture quality with acoustic emissions  
*Dorota Konopacka, Artur Zdunek, Krystyna Konstankiewicz, Katarzyna Jesionkowska*
- 17:50            An user's evaluation of the acoustic technique to assess apple quality in Southern Europe  
*Diana Molina-Delgado, Simo Alegre, Christian Larrigaudiere, Inmaculada Recasens*
- 18:10            New nondestructive method based on spatial-temporal speckle correlation technique for evaluation of apples quality  
*Artur Zdunek*
- 18:30            Non-destructive determination of post-harvest ripening of *Capsicum annum* cv. Kárpia  
*Tamás Zsom, Viktória Zsom-Muha, László Baranyai, Werner B. Herppich, József Felföldi, Csaba Balla*

**Thursday, 06. November 2008****09:00 – 10:50 Plenary Session HS 7**

09:00 Ripening regulation and postharvest fruit quality  
*Josef Streif*

09:50 Emerging technologies for assessing postharvest quality of horticultural products  
*Renfu Lu*

**11:00 - 12:30 Session 1: Improvement of the agri-food chain in terms of quality, healthiness and safety HS 7**

Chair: *Oliver Schlüter*

11:00 Temperature effects of using returnable plastic crates  
*Chris Bishop, Alan Gash*

11:20 Water condensation in plastic film packages during handling of stone fruit in the postharvest chain  
*Manfred Linke, Inka Gerbert, Oliver Schlüter, Martin Geyer*

11:40 A novel active packaging to maintain quality and increase shelf life and safety of table grapes  
*Daniel Valero, Fabian Guillen, Domingo Martinez-Romero, Salvador Castillo, Pedro J. Zapata, Maria Serrano*

12:00 Callus hair growth within the outer cortex of mature apples of Fuji and Fuji sports: its relevance to post-harvest storage and the distribution of phytonutrients and allergens  
*Mary Parker, Walter Guerra*

**11:00 - 12:30 Session 2: Postharvest physiology and metabolomics: the interaction of postharvest scenarios with biochemical and physiological aspects and processes** **HS 11**

Chair: *Manuela Zude*

11:00 Response of 1-methylcyclopropene treatment on quality preservation and shelf life extension in plum fruits (*Prunus domestica* and *P. salicina*) under multiple temperature regimes  
*Neeraj Baghel, M. S. Joon, Michael M. Blanke, Felix Lippert*

11:20 Comparative study of techniques to restore the ripening process in 1-MCP treated 'Blanquilla' and 'Conference' pears  
*Ma Angeles Chiriboga, Wendy Schotsmans, Christian Larrigaudière*

11:40 A search for both 1. Volatile and 2. New non-volatile and water soluble cyclopropene antagonists of ethylene action  
*Raphae Goren, Edward C. Sisler, Moshe Huberman, Eliezer E. Goldschmidt, Joseph Riov, Akiva Apelbaum*

12:00 Conjugated trienes,  $\alpha$ -farnesene and storage disorders in 'Abbé Fétel' pears treated with 1-MCP  
*Maristella Vanoli, Maurizio Grassi, Paola Zerbinì, Anna Rizzolo*

**12.30 Firmenpräsentation** **Thaersaal**

*Lunch*

**14:00 – 15:30 Commented Poster Session** **Thaersaal**

*Coffee break*

**16:00 – 17:30 Session 2: Postharvest physiology and metabolomics: the interaction of postharvest scenarios with biochemical and physiological aspects and processes** **HS 7**

Chair: *Pawel Konopacki*

16:00 Hormonal control of sprouting of sweetpotatoes in storage  
*Muhammad Usman Ahmad Cheema, Deborah Rees, Mark Taylor, Andrew Westby*

16:20 Metabolomic evaluation of 'Braeburn' browning  
*David Rudell, James Mattheis, Erin Felicetti, Yanmin Zhu*

16:40 Developing protocol for exporting quality mangoes to China  
*Malik Aman Ullah, Malik Abdul Jabbar, Rajowana Ishtiaq Ahmad*

17:00 Kinetic modelling for optimal packaging and storage of sweet cherries  
*John Mawson, Pittiporn Ounsuvan, P. Dhamvithee*

**16:00 – 17:30 Session 4: Non-destructive methods for quality assessment HS 11**

Chair: *Bart M. Nicolai*

- 16:00 Spectral properties of 'Jubilaeum' plums: a non-destructive approach to assess the fruit quality  
*Sanu Jacob, Eivind Vangdal, Alessandro Torricelli, Lorenzo Spinelli, Maristella Vanoli, Paola Zerbini, L.M.M. Pol Tisjkens, Emmanuel Madieta*
- 16:20 Investigation of ripening process of fruit and vegetable samples with acoustic method  
*Jozsef Felfoldi, Viktoria Zsom-Muha*
- 16:40 Non-destructive measurement of water flow in small plants using cold neutron radiography - an application to investigate rose bent neck symptom -  
*Uzuki Matsushima, Wolfgang Graf, Nikolay Kardjilov, André Hilger, Takashi Nishizawa, Werner B. Herppich*
- 17:00 A robust strategy for the use of chlorophyll fluorescence as a non-invasive method to assess physiological damage of fresh produce  
*Deborah Rees, Pojana Simantara, Andrew Westby*
- 19:30 **Symposium dinner**  
Neues Glashaus  
Botanischer Garten  
  
Am Fichtenberg 17  
12165 Berlin-Steglitz

**Friday, 07. November 2008**
**09:00 – 10:50 Plenary Session HS 7**

- 09:00 Fruit genomics and postharvest fruit quality  
*Ian Ferguson*
- 09:50 Importance of ISA-Fruit project for European fruit growers, fruit market and consumers  
*Alex C.R. van Schaik*

**11:00 - 13:00 Session 1: Improvement of the agri-food chain in terms of quality, healthiness and safety HS 7**

Chair: Marjan *Simčič*

- 11:00 Understanding total antioxidant and bioavailable antioxidant assay protocols for fruits and vegetables: What they tell us and their limitations  
*Peter M.A. Toivonen*
- 11:20 UV-B and gamma radiation as physical elicitors to promote phytochemicals in brassica sprouts in pre- and postharvest  
*Susanne Huyskens-Keil, Monika Schreiner, Angelika Krumbein, Christian Ulrichs, Inga Mewis, Eberhard Janata*
- 11:40 Postharvest photobiological treatment: an approach to simultaneously improve nutritional value, keeping quality and food safety of fruits and vegetables  
*Victor Rodov, Tzipora Tietel, Yakov Vinokur, Batia Horev*
- 12:00 Determination of pathogen viability in fruit and vegetable processing by means of flow cytometry  
*Antje Fröhling, Lena Hausdorf, Michael Klocke, Oliver Schlüter*
- 12:30 PeaPle - a decision support system of new generation  
*Pawel Konopacki, Jakub Nadulski, Guglielmo Costa, Carlos Crisosto, Ria Derkx, Séverine Gabioud, Isabel Lara, Christian Larrigaudiere, Hanne Lindhard Pedersen, Krzysztof Rutkowski, Josef Streif, Angelo Zanella, Alex van Schaik*

**11:00 - 13:00    Session 5: Modelling as a tool for integration and management of the whole chain    HS 11**

Chair: *Werner B. Herppich*

- 11:00            3-D microscale modelling of gas diffusion in fruit tissue  
*Quang Tri Ho, Pieter Verboven, Hibru Kelemu Mebatsion, Bert E. Verlinden, Stefan Vandewalle, Bart M. Nicolai*
- 11:20            Modelling the effect of 1-MCP on the ripening of avocado fruit  
*Maarten Hertog, Salvador Ochoa-Ascencio, Bart M. Nicolai*
- 11:40            Modelling post harvest vase life of two gerbera cultivar using fuzzy logic and genetic algorithms  
*Ehsan Davarynejad, Ali Tehranifar, Mahdi Nasiri-Mahalati, Gholam Hosain, Mohsen Davarynejad, Zeinab Ghayoor*
- 12:00            Water loss in horticultural products. Modelling, data analysis and theoretical considerations  
*L.M.M. Pol Tijskens, Sanu Jacob, Rob Schouten, Juan Pablo Fernández-Trujillo, Noelia Dos-Santos, Eicind Vangdal, Maristella Vanoli, Paola Zerbini*
- 12:30            3-D virtual fruit microstructure modelling  
*Hibru Kelemu Mebatsion*

*End of meeting*

**14:00 – 18:00 ProSenso.net2 Workshop**

HS 7

14:00 – 14:15 Welcome by Andreas Jacobi (Projekträger Jülich)  
Introduction by Martin Geyer (ATB)

**14:15 – 16:00 SESSION I – Process chain cereal grain**

Chair: *Werner B. Herppich (ATB)*

Detection of mycotoxine producing fungi in cereal grain crops  
- Identification of fusarium-infected wheat plants with digital image processing. Field and lab experiments

*E. Bauriegel (ATB), H. Beuche (ATB), K.-H. Dammer (ATB), A. Giebel (ATB), W.B. Herppich (ATB), J. Intreß (ATB), B. Möller (ATB), B. Rodemann (BBA), U. Urbansky (Symacon)*

Identification of mycotoxine producing fungi in the processing of grain  
- Non-invasive determination of mycotoxine producing fungis on grains

*M. Kumke (UP), C. Rasch (UP), F. Lewitzka (Optimare), M. Ditz (ATB), C. Idler (ATB)*

- Detection of mycotoxine producing fungi on grain – capabilities and limitations when using gas-sensor-arrays

*A. Walte (Airsense), M. Ditz (ATB), C. Idler (ATB)*

Model-based control of grain dryers

- A new microwave sensor for on-line measurement of grain moisture content as a core element for reliable process control

*J. Mellmann (ATB), K. L. Iroba (ATB), L. Kocsis (ATB), U. Schlemm (TEWS), H. Richter (TEWS)*

Assessment of socio-economical and ecological efficiency of sensor application in food production chains

- Technology assessment for sensor application in the grain production chain

*René Maack (ATB), Annette Prochnow (ATB)*

*Discussion*

*Coffee Break*

**16:30 – 17:45 SESSION II – Process chain fruit, vegetable, potatoes**

Chair: *Oliver Schlüter (ATB)*

Assessment and evaluation of risks of quality loss in perishable horticultural produce

- MC-Simulation approach for improving the feasibility of the new sensor system

*M. Zude (CP), L. Baranyai (ATB), M. Geyer (ATB)*

Biosensors for the detection of pathogenic microorganisms

- Concepts for determination of pathogens in fruit and vegetable processing using PCR-techniques and flow cytometry

*A. Fröhling (ATB), H. Adamzig (ELBAU), A. Walter (BESSY), L. Hausdorf (ATB), M. Klocke (ATB), O. Schlüter (ATB)*

Modular system for quality monitoring in the logistic chain

- Shelf life prediction model and sensor technology – state of the art

*M. Linke (ATB), Th. Hübert (BAM), C. Lang (BAM), H. Quaas (ESYS), D. Baltaci (ATB), M. Geyer (ATB)*

*Discussion*

17:45 – 18:00 Resume by Martin Geyer





## **Section 1**

# **Improvement of the agri-food chain in terms of quality, healthiness and safety**

## Fruit genomics and postharvest fruit quality

*Ian Ferguson*

*HortResearch, Auckland, New Zealand*

*Corresponding author: iferguson@hortresearch.co.nz*

The increasing availability of genomic data for our major fruit crops is supporting the drive to develop new and novel fruit cultivars with consumer-driven attributes. These are changing from the traditional properties of taste and texture, to those which have most appeal in international markets, including human health attributes, novelty, such as new colours and appearance, and convenience, including properties such as peelability and controlled ripening (ready-to-eat). Despite the genomic research which is being undertaken, only now are we starting to see possibilities in terms of genetic markers for post-harvest qualities of fruit, and better understanding of molecular control of such fruit properties. These developments are illustrated with new research on genetics of flavour components of fruit, of ethylene action, colour development, and postharvest changes, including the use of microarrays and analysis of gene families. The demand of developed and emerging world markets and those of sustainable production mean that we might have to reassess our approach to postharvest research. We may be faced with a future of fruit production almost exclusively near-to-market, with genetically modified crops of great novelty, with enhanced levels of attributes which need to be maintained under storage, requiring substantially higher levels of product differentiation, and under the constraints of sustainable production. This may need a new set of postharvest technologies and approaches.

## Understanding total antioxidant and bioavailable antioxidant assay protocols for fruits and vegetables: What they tell us and their limitations

*Peter M.A. Toivonen*

*Pacific Agri-Food Research Centre, Agriculture and Agri-Food Canada, Food Safety and Quality Program, Summerland British Columbia, Canada*

*Corresponding author: toivonenp@agr.gc.ca*

There are numerous reports in the literature that document the antioxidant content of fruits and vegetables and how these antioxidants change in response to handling, storage and processing. This information is useful for many purposes but, if these data are to be more useful to health researchers, there should be consideration given to at least three issues that have not been widely incorporated into the existing work. The first consideration is the chemistry of the antioxidant methods. While there are many total antioxidant measures, most of them fall into two categories in regards to the chemistry of the assay; 1) hydrogen atom transfer reactions, and 2) electron transfer. It is not surprising that many of these measures appear to be highly correlated. The second consideration is whether the assay is measuring the discrete, intended target groups of antioxidants. Current extraction procedures generally result in test solutions containing phenolics and other soluble antioxidants such as ascorbic acid. Ascorbic acid is highly active as an antioxidant and will interfere in nearly all antioxidant assay protocols. For example, if the goal of the work is to understand the antioxidant activity of phenolic constituents, then extract clean-up procedures must be incorporated into the protocol to remove interference by ascorbic acid and other interfering constituents. The last consideration is that of bioavailability. The most commonly used extraction procedures are indiscriminate and relatively harsh and as a consequence more constituents are extracted from the fruit or vegetable matrix than would be by the human digestive system. Data suggests that less than a third of the antioxidant potential measured using conventional extraction is extractable when using simulated digestive fluids. The implications of these three issues are discussed in detail.

## UV-B and gamma radiation as physical elicitors to promote phytochemicals in brassica sprouts in pre- and postharvest

Susanne Huyskens-Keil<sup>1</sup>, Monika Schreiner<sup>2</sup>, Angelika Krumbein<sup>2</sup>, Christian Ulrichs<sup>3</sup>, Inga Mewis<sup>3</sup>, Eberhard Janata<sup>4</sup>

<sup>1</sup> Humboldt-Universität zu Berlin, Quality Dynamics / Postharvest Physiology, Berlin, Germany

<sup>2</sup> Leibniz-Institute of Vegetable and Ornamental Crops Großbeeren/Erfurt, Quality, Großbeeren, Germany

<sup>3</sup> Humboldt-Universität zu Berlin, Urban Horticulture, Berlin, Germany

<sup>4</sup> Hahn-Meitner-Institute Berlin GmbH, Berlin, Germany

Corresponding author: [susanne.huyskens@agrار.hu-berlin.de](mailto:susanne.huyskens@agrار.hu-berlin.de)

Inverse associations between vegetable and fruit intake and chronic diseases, such as cancer and cardiovascular diseases, have been demonstrated in numerous epidemiological studies. Phytochemicals have been indicated to be responsible for this protective health effect. It is known that distinct changes in phytochemicals can be triggered by the application of physical (e.g. UV and gamma irradiation), chemical (e.g. methyl jasmonate, salicylic acid) and biological (e.g. microorganisms) elicitors during production and postharvest operations. Thus, pre- and postharvest elicitors, such as ultraviolet and gamma irradiation inducing the synthesis of phytochemicals in plants, may be used to obtain fruit and vegetables enriched with phytochemicals for sale as fresh market products or used as raw material for functional foods and supplements, thereby promoting higher consumption of these health-promoting substances. The application of gamma radiation and short-term UV radiation is known for disinfection of pathogenic organisms in numerous food products. Losses in food industry due to microbiological spoilage (e.g. *Listeria monocytogenes*, *Salmonella spp.*, *Escherichia coli*) have been estimated as high as 30%. Due to new food safety regulations (HACCP concept, traceability), the optimization of postharvest treatments and storage requirements is an essential tool for the food supply chain management of perishable commodities. Thus, the aim of our investigation was to evaluate the stress mediated plant responses to physical elicitors (UV and gamma radiation) on characteristic phytochemicals (glucosinolate, carotenoid, phenols) and health-promoting compounds (hydrocolloids and antioxidative activity) in brassica sprouts in pre- and postharvest. The application of gamma and UV-B radiation showed a pronounced effect on the synthesis of various health promoting substances. Results are discussed in terms of how these physical treatments elicit an effect on secondary plant metabolism as well as on the subsequent phytochemical composition. Furthermore, possibilities and constraints for the application and transfer in food chain systems are outlined.

## Quality attributes of old *Lactuca* varieties and their suitability for local markets: first results of a pilot-project to promote the on-farm conservation of crop genetic resources

Cornelia Lehmann<sup>1</sup>, Susanne Huyskens-Keil<sup>1</sup>, Gunilla Lissek-Wolf<sup>1</sup>, Rudolf Vögel<sup>2</sup>

<sup>1</sup> Humboldt-Universität zu Berlin, Quality Dynamics / Postharvest Physiology, Berlin, Germany

<sup>2</sup> Verein zur Erhaltung und Rekultivierung von Nutzpflanzen in Brandenburg, Greiffenberg / Uckermark, Germany

Corresponding author: [cornelia.lehmann@agrار.hu-berlin.de](mailto:cornelia.lehmann@agrار.hu-berlin.de)

In a pilot project, we examined the chance to maintain genetic resources of plants by commercial utilization of old vegetable varieties. We choose *Lactuca sativa* as a model plant because relative to other crops it is easy to grow, has a short period of cultivation and a huge number of various accessions are available from gene banks. In preliminary field trials we examined more than fifty gene bank accessions and identified several varieties with attractive attributes like special shape, colour or name. In the next step, we tested their suitability for market gardening in co-operation with several local gardeners in the region of Berlin and Brandenburg, Germany. The market gardens cultivated a selected subset of varieties throughout the season to test field performance, yield and quality attributes and supplied the products to the market in their customary manner (farmer's market, farmer's shop, direct delivery to the customers as 'Abokisten', health food shop) to test marketing success. We further analysed the set of old varieties for dry matter, nitrate and phenol concentrations and tested shelf life as well as sensory quality. We found low nitrate concentrations. Phenol concentrations varied among varieties, however red coloured varieties had not necessarily more phenols than green ones. We identified some old butterhead lettuce and also some old romana varieties with delicate leaves of a special fine taste. From the set of gene bank accessions, we selected a first group of old varieties with good quality attributes and suitability for market gardening as a fundamental basis to establish a collection of *Lactuca* cultivars suitable for commercial utilization in local market gardens as a tool to maintain old varieties on-farm. The pilot project was funded by the Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV/BLE) FKZ: 05BM007/2.

## Studies on fruit development stages and adjudging maturity indices of European plum cv. Hauszwetschge (clone: wolff) for extended postharvest life

Neeraj Baghel<sup>1</sup>, Felix Lippert<sup>2</sup>

<sup>1</sup> New Delhi Institute of Management, Management, New Delhi, India

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Proper picking maturity plays a vital role in determining the storage life of plum fruit. The present study was undertaken with an aim to adjudge optimum harvesting stage of European plum for maximum quality retention and extended shelf life. Harvesting of fruits was initiated at colour breaker stage and concluded at self dropping stage. Harvesting was done at weekly interval and seven harvesting stages were characterized viz. harvesting stage -I (HS-I i.e. colour break stage), HS-II, HS-III, HS-IV, HS-V, HS-VI and H-VII (overripe stage, i.e. 42 days after colour break). Fruit weight, specific gravity, hue angle, total soluble solids, TSS/acid ratio and total sugars increased whereas fruit firmness, saturation index ( $C^*$ ) and acidity content of fruits was found decreasing from HS-I to HS-VII. Development of typical blue-purple colour of European plum was represented by negative  $b^*$  values (maximum at HS-VII,  $-2.01 \pm 0.27$ ). Regression analysis showed a strong relation between ethylene produced by fruits and changes in sucrose content ( $R^2=0.885$ ) and loss of firmness ( $R^2=0.774$ ). Oxygen consumed by fruits and  $CO_2$  produced was also found strongly related ( $R^2=0.875$ ) indicating active respiration throughout growth period. Correlation studies indicate high significant and positive coefficient value of sucrose with fructose (0.941) and glucose (0.894). Fruit composition of  $25.90 \pm 0.13$  g fruit weight,  $1.05 \pm 0.01$  g  $cc^{-1}$  specific gravity,  $58.78 \pm 1.78$  shore firmness,  $15.26 \pm 0.72$  ml  $kg^{-1} h^{-1}$   $CO_2$  production rate,  $1.33 \pm 0.14$  RQ,  $18.86 \pm 1.37 \mu l$   $kg^{-1} h^{-1}$  ethylene production rate and  $13.06 \pm 0.86$  TSS/acidity ratio gave maximum storage life at  $20^\circ C$ . Among various harvesting stages observed, HS-V (i.e. 28 days after colour break) was adjudged as the optimum harvesting stage for European plum.

## Temperature effects of using returnable plastic crates

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The use of returnable plastic crates (RPCs) throughout the supply chain for perishable and non-perishable items has greatly increased over the last few years. One of the main reasons for their adoption has been the reduction of packaging waste and, in particular, cardboard. Their adoption has come at the same time as an increased emphasis on maintaining temperatures in the cool chain. This investigation considered 2.5 kg bags of potatoes and 2.5 kg nets of oranges in traditional 15 kg cardboard and supermarket-type stackable plastic crates. The results showed that, with the greater free area of the plastic crate there is potential for the product to warm up more quickly. For netted product in plastic crates the flesh temperatures can increase in the first three hours at up to three times the rate for product in cardboard crates. In the case of bagged product the increase in flesh temperature was twice as high for the plastic crates. In moving air of  $1.5 \text{ ml ms}^{-1}$  the temperature of bagged product was found to be about four times as great for the plastic crates as for cardboard crates. The adoption of a plastic wrap delayed the effects by approximately one hour.



## Flesh carotenoid profile in climacteric near-isogenic lines of melon obtained from non-climacteric parentals: Implications in fruit design

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Some carotenoids are precursors of melon fruit aroma. Beta-carotene and B-cryptoxanthin also has provitamin A activity, while lutein and zeaxanthin have a role in preventing macular degeneration. However, poor information is available about the genetic basis of carotenoid biosynthesis in melon that can serve for future quality-oriented breeding programs or postharvest applications in the agrifood chain. A collection of aromatic near-isogenic lines (NILs) with different climacteric behavior obtained by two non-aromatic and non-climacteric parentals ('Piel de sapo' or PS; PI 161375) can serve to establish these basis. The NILs exhibited differences in flesh color (light white-yellow to light orange for the NILs), while the flesh of PS was light white-yellow and PI 161375 showed green-flesh. This variability was used for carotenoid profile studies. About 12 carotenoid compounds were detected in the population, though only four constituted the profile of the lines studied (trans-violaxanthin, cis-violaxanthin, lutein and trans  $\beta$ -carotene). Five carotenoid compounds were good discriminant among NILS and PS (cis-neoxanthin only present in PS and neoxanthin, phytoene and  $\alpha$ - and  $\beta$ -cryptoxanthin only present in the NILs). Zeaxanthin was only present in one NIL and in PS. The information is discussed in terms of carotenoid biosynthesis, mapping QTLs responsible of carotenoid metabolism and aroma, climacteric or non-climacteric pattern, nutritional implications as a source of pro vitamin A, and possible implications in future design of melon varieties with predictable carotenoid composition depending on the human needs.

## **Agricultural tramline system - A lift and link to upland vegetable supply chain in the Philippines: Alimodian experience**

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The drudgery of hauling and the limited number of haulers are among the major problems in highland vegetable production in the Philippines. An agricultural tramline system was introduced as a hauling facility which aims to improve transportation of commodities in hard-to-reach and inherently rugged production areas within the supply chain. The present study examined the influence of this agricultural tramline system as a hauling facility for farm inputs and vegetables to improve the supply chain of upland vegetables in Alimodian. The analysis focused on the farmers as the target group of the study. The introduction of the agricultural tramline facility in the traditional supply chain was found to have the following direct positive results: (a) substantial reduction in working hours and the required number of haulers from 18 to 1.0 man-days/ha; (b) reduced hauling cost by P2.57 per bag, and (c) 29.8% increase in utilization of production inputs. The cultivated area, the range of crops grown, the number of cropping seasons, and the yield also tended to increase with the operation of the facility. For the farmers, the tramline facility offers the following socio-economic advantages: (a) improving productivity by providing the opportunity to apply the recommended rates of production inputs at the proper time, (b) increasing profit by directly reducing hauling cost and providing opportunity of increasing yield and better quality of marketable produce, and (c) providing better quality of life by reducing drudgery and releasing more time for other productive activities.

## **Callus hair growth within the outer cortex of mature apples of Fuji and Fuji sports: its relevance to post-harvest storage and the distribution of phytonutrients and allergens**

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Mature apples of Fuji and Fuji sports sourced from around the world have recently been found to develop unusual clumps of callus hairs between the parenchyma cells of the outer cortex. The clumps were particularly well developed in Fuji Suprema from Brazil, moderately developed in Fuji grown in Europe, New Zealand, South Africa, Chile and the USA, and least developed in Fuji imported from China. They are also found in fruit of close relatives of Fuji and a small number of unrelated cultivars. Callus hairs, present in both organically-grown and conventionally-grown fruit, proliferate in the network of intercellular air spaces between cells and also in larger cavities or lacunae which often have poor connectivity with other airspaces. In these locations they have the potential to restrict or modify the flow of oxygen and carbon dioxide in the outer part of apples, and thus may be one of the factors contributing to internal browning, a post-harvest disorder to which large or late-picked Fuji are known to be vulnerable. The individual callus hairs are found within 17 mm of the skin, are approximately 20 µm in diameter and are multicellular and branched. When callus growth is extensive, air spaces become filled with a tangle of hairs covered with characteristic pectin-rich globular protuberances which adhere to the surface of the neighbouring cells. The hairs frequently contain starch even when it has been metabolised from the surrounding parenchyma, and are rich in auto-fluorescent compounds. Hairs close to the skin sometimes accumulate anthocyanins, particularly in very red Fuji. Our initial observations suggest that the callus hairs may also accumulate the allergen Mal d 3 which is thought to be confined to the peel, and be associated with some corking disorders.

## Determination of pathogen viability in fruit and vegetable processing by means of flow cytometry

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Fresh products require fast handling steps and a short and efficient production chain to ensure product freshness from harvest to consumer. These handling constraints conflict directly with the time required for conventional microbiological loading analyses. Consequently it is often not possible to determine the microbial hygiene status along a fresh produce production line that also allows for timely and appropriate related contamination control measures. To ensure the safety of fruit and vegetables new short-time microbiological analyses have to be developed and established in fresh food production. Important food safety factors are the presence of bacteria on the surface of fruits and vegetables and within the wash water, as well as the viability of the bacteria. Flow cytometry is able to detect viable, non-viable and viable-but-not culturable bacteria. Preliminary results from an analysis of spinach and carrot wash water showed a microbial contamination of 107 cfu/ml and 106 cfu/ml, respectively, dominated by gram-negative bacteria. Therefore the aim of this study was to detect viable gram-negative bacteria by flow cytometry. A new protocol was developed to determine the viability rate of bacteria based on a combination of carboxyfluorescein diacetate (CFDA) and propidium iodide (PI) staining. CFDA is an indicator of intact microbial cell membranes and metabolic activity. PI is an indicator of permeabilized cell membranes. By using both dyes in combination it was possible to differentiate between viable, non-viable and viable-but-not-culturable bacteria. *Pectobacterium carotovorum* and *E. coli* were chosen as representatives for common phytopathogenic and human pathogenic bacteria. Optimal staining parameters were developed and applied in order to verify the success of certain inactivation protocols on the chosen model microorganisms.

## Postharvest photobiological treatment: an approach to simultaneously improve nutritional value, keeping quality and food safety of fruits and vegetables

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The objective of this work was to check the possibility of enhancing flavonoid biosynthesis in peeled bulb onion (*Allium cepa*) and trimmed green onion (*A. fistulosum*) in response to postharvest ultraviolet irradiation. We also wanted to take advantage of the process for means of reducing decay incidence and ensuring microbial safety of the product. UV-C irradiation ( $3 \text{ kJ m}^{-2}$ ) elevated the quercetin content in external edible scales of peeled onion by 100 to 150% compared with the non-treated control. The increase was also observed in total content of phenolic compounds and in the activity of hydrophilic antioxidants. UV-B treatment of  $6 \text{ kJ m}^{-2}$  enhanced quercetin content by 150%. Similar trends were present in green onion. Enhanced production of secondary metabolites in irradiated onions was accompanied by an increase in respiration rate. At the same time, the UV-C irradiation decreased *E. coli* counts on inoculated bulb and spring onions by  $1.5^{-3}$  log. It also inhibited the disease development in *Penicillium*-inoculated onions and increased the percentage of healthy bulbs. Photobiological treatments are relatively convenient for implementation, accurately measurable and leave no undesirable toxic residues on food products. We propose that they may have a potential for enhancing health value of harvested produce with simultaneous improvement of keeping quality and food safety. The industry of minimally-processed (fresh-cut) fruits and vegetables may be a suitable area for applying this approach.

## PeaPle - a decision support system of new generation

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In the last decade, a new generation of decision support systems (DSS) has emerged in horticulture. These new decision support systems are not in the form of a decision tree, but simulate the changes (i.e. loss) in product quality, and therefore help finding optimal treatment conditions. Two examples of such DSS are "Q-Apple" and "CoolMate". The first one was created in 1996 to support the export of 'Elstar' apples from the Netherlands to United Kingdom. The second one was made around 2001 for KLM airlines "to guarantee the quality of perishables during transport". The main commodities simulated by CoolMate were flowers. The "PeaPle" is a DSS created within the framework of the FP6 European Integrated Project "ISAFRUIT", with the objective to simulate quality changes of apples and peaches along different supply chains, to meet the demands of consumers, and consequently stimulate the increase of fresh fruit consumption. The "PeaPle" is planned as a multi-cultivar system which allows the design of various supply chains from harvest to the retail, with technological parameters (e.g. duration, temperature, atmosphere etc.) set by the user. The first quality parameter modelled for this DSS is fruit firmness, but more quality indices will be modelled (e.g. soluble solids content, acidity or colour). Since the level of quality decay depends on the maturity of the fruits at harvest, the user is first asked for information on the initial fruit status. Then the stages of the supply chain have to be defined, including (CA) storage, transport and shelf life, and planned technological parameters for each chain stage typed in. Once the development of the supply chain has been finished, the user can generate the graph presenting quality changes along the whole supply chain, or create the report presenting the status of the fruit batch at the end of each stage (and the description of the designed supply chain). The graph and report can be printed or saved as files. Also the sequence of supply stages (with their technological parameters) can be saved for future use in the DSS. For better planning of the optimal supply chain, several chains can be simulated in one run and presented in a series of adjacent graphs or in one report. Although the original "PeaPle" is in English, the software will be translated into several languages for the convenience of DSS users in different countries.

## Water condensation in plastic film packages during handling of stone fruit in the postharvest chain

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Fluctuating temperatures during storage, transport, and marketing of open handled fruit can cause condensation of water vapour on the produce surface. In packed fruit, water droplets on the inner film layer are often visible, and the appearance of these packages is reduced. Furthermore, the wet produce surface offers ideal growing conditions for microorganisms, affecting produce quality in the postharvest chain. The objective of the present study was to investigate condensation processes of water vapour in film wrapped packages of fruit under changing ambient conditions. In a first step varying air temperatures between 2°C and 8°C and natural convection against and around the packaging unit were investigated. Japanese plums (*Prunus salicina* L. 'Sapphire') of average 100 g per fruit were cooled down, placed in a plastic container (foodtainer) and wrapped with a plastic film of low water vapour permeability. Per packaging unit temperatures were measured at the surface of a plum unaffected by other plums, at the surface of a plum in the boundary layer between two plums, in the air unaffected by both plums and film, at the inside/outside of the film, and at the inside of the container using very small thermistors. The relative air humidity also unaffected by both plums and film was measured with a capacitive humidity sensor. Results of the experiments show, that during one temperature fluctuating cycle condensation/evaporation processes take place at different locations in different time intervals. In a short time after decreasing the outside air temperature the inside film temperature falls below the dew point of the internal air indicating the beginning of a condensation process at the inner film surface. Some minutes later the inside container temperature falls below the dew point also displaying condensed water at this location. With rising outside air temperatures evaporation processes from both surfaces begin followed by a short phase in which no condensed water is existent. Some times later the slightly decreasing temperature in the boundary layer between two plums is lower than the now more rapid rising dew point temperature of the air. The same process can be observed later at the produce surface which is unaffected by other plums. The detailed knowledge about the interaction between produce and environment can be helpful in design and selection of packaging material to avoid free water in modified atmosphere packages.

## **A novel active packaging to maintain quality and increase shelf life and safety of table grapes**

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Consumers demand new means of preservation with absence of chemicals. Table grape is an important fruit typical of the Mediterranean diet which is consumed almost all over the year. However, grape fruits are considered highly perishable due to important quality losses from harvesting to retailing mainly due to weight loss, color changes and accelerated softening and ripening. The weight loss not only affects the berry but also the rachis inducing browning and then being considered as unmarketable. In addition, table grape is very sensitive to decay during prolonged storage, the main important disease being caused by *Botrytis cinerea*. This work presents an innovative technological development by using an active packaging based in the combination of modified atmosphere packaging (MAP) with natural essential oils with antimicrobial and antioxidant activity. The effect of this active packaging on the delay of fruit ripening and the extension of shelf-life based on safety and the preservation of sensory attributes and bioactive compounds with functional properties were studied.



## Effect of acetic acid vapour on sensory quality of strawberries

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Gray mold caused by *Botrytis cinerea* is the main reason for decay in harvested strawberries. The application of specific fungicides resulted in resistances of some *B. cinerea* strains and the development of effective, hazard free alternative methods was requested. A couple of reports have shown that a treatment of fresh fruits (apple, pear, apricot, plum) with acetic acid (AA) vapour was effective for suppressing fungal decay including gray mold of strawberries. An important requirement for the use of a sanitizer is the quality guarantee of the produce (freshness, odour, taste). AA vapour treatment of strawberries resulted in no apparent phytotoxic effects up to 6 mg/l AA concentration (t = 30 min), followed by a storage at 10°C. The optimal treatment concentration was found at 4 mg/l. The objective of this study was to determine if an AA vapour treatment affect the taste and the odour of strawberries. For this, fresh fruit were fumigated with AA vapour in a closed 22.4 l perspex box with ventilator (c(AA) = 0, 2 and 4 mg/l box volume, t = 30 min). The strawberries were stored at 7°C and 20°C for 1, 4 and 24 hours and were inspected by a taste panel. AA treatment in a concentration of up to 6 mg/l did not affect the appearance and the taste of fruit. The odour was affected at an AA concentration of 2 mg/l and resulted in the rejection of the panel. The extension of storage time up to 24 hours resulted not in an abatement of the typical AA smell.

## Supply chain management and post-harvest technology for fruit and vegetables (DOCUMAP) – a joint european-asian project (EU-Asia-Link Programme)

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A dense network of partner universities is created for the advance of specialist know-how in supply chain management and postharvest technology in Asia and Europe: the Humboldt University of Berlin and the Leibniz-Institute of Vegetable and Ornamental Crops Großbeeren/Erfurt e.V., Germany; Hanoi Agricultural University, Vietnam; China Agricultural University, China; Syiah Kuala University, Indonesia; Swedish Agricultural University, Sweden; Copenhagen University, Denmark; Katholieke Universiteit Leuven, Belgium. Aim of the project is the amplification of the linkage between European and Asian partner universities and industry for the applied and problem-oriented education in supply chain management and post-harvest technology in horticulture. Learning methods which have to be translated to the Asian university terms are problem-based learning, multidisciplinary team work and networking within an university/industry collaboration. Asian staff and students are trained in summer schools and a sandwich programme, European students work together with their Asian counterparts in case studies in Asia and Europe, European and Asian lecturers jointly establish new modules, study projects, internships, a mentoring programme and a curriculum evaluation system at the Asian partner universities. Outputs: These new elements and activities (sandwich programme, summer schools, module development, development of university-industry network operations, establishment of a curriculum evaluation system, design of an internet platform) are supported with coordination desks for university-industry cooperation as well as an internet platform and a virtual learning environment. As a first step four modules are designed with special emphasis on “Quality Oriented Production in Horticulture”, “Advanced Postharvest Biology and Biotechnology”, “Advanced Postharvest Technology”, and “Food Supply Chain Management and Food Marketing” aiming at the development of a curriculum in supply chain management and post-harvest technology and for the promotion of higher education networking between Asia and Europe.

## UV-B-induced changes of volatile metabolites in blueberries (*Vaccinium corymbosum* L.)

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UV-radiation induces stress and activates plant defence systems, and often leads to an accumulation of bioactive compounds in plant tissue. Besides their contribution to the aroma profile in food, volatile metabolites (primarily terpenes) offer bioactive properties (antimicrobial, anticarcinogen, antioxidative). In general, volatile metabolites interact in the ecological network between plants and their environment and respond to stress conditions (e.g. pest attack or drought). Stress conditions might be also indicated by an increase of proteins as they are precursors of numerous biosynthetic pathways and often being one of the first stress mediated reaction in plants. Recently, it was hypothesized that volatiles have a plant protective function revealing antioxidant activity. In the present experiment the influence of UV-B radiation on changes in volatile compounds of blueberries was studied. Eight year old *Vaccinium corymbosum* L. cv. 'Blue-crop' were cultivated on formerly used farmland. After harvest, one part of the fruit samples was subjected to UV-B radiation for 60 or 120 min using an UV-B fluorescence light source (FL 20SE, 305-310 nm) with an average fluency rate of 8.2 J m<sup>-2</sup> at a distance of 30 cm. After an adaptation time of 2 and 24 h fruits were analysed for volatile patterns and proteins. Results showed an UV-B stress mediated increase of proteins. With regard to volatile metabolites (C6-aldehyds, terpenes) an increase of the relative peak area was observed after both UV-B treatments (60 and 120 min). However, there was a strong influence of the adaptation time. The highest relative peak area was found after an adaptation period of 2 h, while it declined after 24 h. The influence of UV-B on changes in protein and volatile metabolites will be discussed in detail and also as a possible tool to improve postharvest quality.

## Investigations of flow conditions in a Cooled display cabinet with air humidification during simulated retail display

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Climatic conditions are very unsatisfactory for fruit and vegetables in retail. The temperatures are too high, the relative humidity is too low. Since several years cooled display cabinets with air humidification are available. To raise the moisture content of display cabinet air to higher levels is one way to maintain freshness of horticultural produce. The machine cooled dry air is humidified by an ultrasonic fogging system, which dispense a fine cold water fog over the displayed fruit and vegetables. The objective of this experiment was to investigate the cold air and the fog distribution respectively the air humidity distribution in the cabinet. The study was carried out using a 2.5 m long and 1.8 m high multi-deck produce display cabinet Mirado-80NCH (Carrier/Linde, Mainz, Germany). 12 crates can be loaded inside the cabinet. The temperature distribution was detected with a thermographic camera. The temperatures were calculated using the software program IRBIS (Fa. InfraTec, Dresden, Germany). The air humidity respectively the air state were determined by weighing real product and by evaporation spheres. After reducing the fan size and fan revolution and after optimising the cold air distribution in a hyperbolic manner over the width of the cabinet the air velocity close to the produce surface could be limited to  $0.7 \text{ ms}^{-1}$  at every position in the cabinet. Air velocity against and around the produce in combination with air humidity is responsible for transpiration loss of the presented fruit and vegetables. The use of the fogging system was found to reduce evaporative weight loss from fruit and vegetables during simulated retail display. Compared to free convective conditions and to cooled conditions without humidification and depending on the position in the cabinet, weight loss of different vegetables in crates (radish, carrot or leek) could be reduced clearly.

## Comparison between two tomato cultivars based on quality and functional properties

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Tomato fruit is one of the most important crops in the world, and Spain is one of the main producers in Europe. In Spain, several traditional tomato cultivars exist, which are very popular in their own local zones, but these cultivars have as the main problem the lack of resistance to some particular viruses that decrease their productivity. The aim of the present work was to compare the plant development and ripening in a greenhouse of two types of tomatoes 'De la Pera': one traditional cultivar and other genetically modified. We have studied the growth pattern on plant of these products and we have harvested the tomatoes at five maturity stages to measure different maturity parameters (respiration rate and ethylene, fruit firmness, total soluble solids, titratable acidity, total antioxidant activity (TAA), total polyphenols (TPH) and lycopene content. The traditional tomatoes studied had higher levels of functional compounds, measured as lycopene content, and TPH as well as TAA than genetically modified tomatoes. On the other hand these tomatoes reached higher values of weight and volume than traditional types, and higher levels of fruit firmness. For both types of tomatoes, the best stage to harvest was stage 4.

## Effect of postharvest application of 1-MCP on mango fruit ripening and quality

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Mango fruit is a subtropical climacteric fruit that produces small quantities of ethylene, but its ripening depends on ethylene, which influences color development and fruit softening. In the present study we examined the effect of 1-methylcyclopropene (1-MCP) treatment before cold storage on mango quality. Fruit ripening was slowed down by reduction in softening, delay in color development and acidity breakdown, which extended the storability at 12°C and shelf life at 20°C. In addition, 1-MCP reduced chilling injury symptoms, expressed as internal breakdown, leading to improved pulp texture. We checked the influence of 1-MCP on several mango cultivars: 'Keitt', 'Kent', and 'Tommy Atkins'. The most effective treatment in all tested cultivars was achieved using low concentrations of 1-MCP (100-300 ppb) at a high temperature of 25°C for 24 h. The inhibition in fruit ripening was more pronounced when the treatment was applied at 25°C instead of 20°C. In mango cv. 'Kent', 1-MCP treatment delayed chlorophyll breakdown, however, storing 'Kent' at a lower temperature of 12°C induced color change from green to red. Treating waxed mango cv. 'Keitt' with 1-MCP showed a synergistic effect between the wax and the 1-MCP. The waxed fruit treated with 1-MCP was firmer and maintained better membrane integrity compared to all other treatments. 1-MCP treated mango cv. 'Tommy Atkins' maintained higher level of acidity which was correlated to better taste. We will discuss the advantage of using 1-MCP in mango fruit in order to extend its ability to stand cold storage.

## Inhibiting effects of organic matter on sanitation during root vegetable washing

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To prevent cross-contamination with human pathogens as well as with plant pathogens wash water sanitation is recommended for carrot processing. In recent studies limits in bactericidal effects of chlorinated water and aqueous ozone were presented. Usually wash and rinsing water in washing plants are loaded with organic substances (chemical oxygen demand (COD)) up to 10 000 mg l<sup>-1</sup> of COD, which limit the sanitation effect of oxidizing agents. For example 1 g of carrot per litre water represents already about 100 mg COD. The task of this experimental study was therefore to investigate the remaining inactivation potential of chlorine and ozone when applied to *Pectobacterium carotovorum* and *Escherichia coli* suspended in tap water and loaded with different concentrations of COD. Fresh carrots were mashed (0.1 to 10 g l<sup>-1</sup>, 70 mg g<sup>-1</sup> COD) and then mixed with *P. carotovorum* or *E. coli* suspension (10<sup>4</sup> to 10<sup>6</sup> cfu ml<sup>-1</sup>) and added to chlorinated (1000 ppm free Chlorine) or ozonated (up to 4 ppm ozone) water. After dilution the suspensions were stirred for 5 minutes. Then aliquots of the mixtures were plated. *E. coli* was determined on McConkey agar after 48 h incubation at 37°C and *P. carotovorum* were plated on McConkey agar and incubated for 48 h at 30°C. The threshold for inactivation of *P. carotovorum* was about 2 g l<sup>-1</sup> mashed carrots for the chlorinated water and 0.7 g l<sup>-1</sup> for ozonated water. The threshold for *E. coli* in chlorinated water was about 1 g l<sup>-1</sup> and ozonated water about 0.5 g l<sup>-1</sup>. For higher concentrations of COD the effect was negligible. The results show that already little concentrations of organic matter in washing or rinsing water in vegetable processing plants inhibit the effect of sanitation treatments. It is assumed that the oxidizing agents first react with the organic matter without influencing bacterial growth. Consequently, the application of high hygienic standards, i.e. closed cool chain, fixed cleaning cycles and frequent water change is recommended to effectively prevent unwanted bacterial growth.

## **Routine quality control for blackcurrant fruit is poorly correlated with the real biochemical composition of the samples**

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The taste of blackcurrant fruit is fundamentally based, in part, on the ratio between concentration of sugars and acids. Sugars and organic acids are the main soluble components present in blackcurrant berries and are often used as an indicator of fruit ripeness and quality. Currently in the blackcurrant industry, total soluble solids (TSS) and to a lesser extent total titrable acidity (TTA) are commonly used in routine quality control (QC) as a measure of sugar and acid content, respectively. In the present study the concentration of non-structural carbohydrates (viz. fructose, glucose, sucrose) and non-volatile organic acids (viz. ascorbic, citric, malic, oxalic, and tartaric acid) of 17 blackcurrant cultivars was quantified using standard high performance liquid chromatography and the results were compared against TSS and TTA. Poor correlations were found between TSS and total sugar concentration ( $R^2 = 0.53$ ) and between TTA and organic acid composition of the samples ( $R^2 = 0.46$ ). Results suggest that the blackcurrant industry does not have a means of measuring taste-related target analytes sufficiently well enough, and, therefore, special emphasis should be given to the development of new cost effective analytical techniques that can readily replace TSS and TTA for standard QC.



## Seasonal variation in the sugar content and firmness of strawberries retailed in the UK

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Strawberries are available in UK supermarkets throughout the year. The period of UK outdoor strawberry production is short and so the outdoor season is extended by protected cropping. During this period, UK supermarkets may also supplement the home-grown supply with crops produced in Holland. Outside the strawberry growing season of N. Europe, the supply to UK supermarkets is maintained with imports from S. Europe, the Middle East and the USA. Strawberries were purchased from each of six leading UK supermarkets on 35 dates, spread throughout the year. The sugar content and the firmness of the fruit were assessed on the 'best before' date specified on the label. Data are presented for each of the dates. The mean sugar content of all strawberries through the year was 8.0° Brix. The means for all six supermarkets in a given week ranged between 6.2° and 10.0°. The mean firmness, as assessed by Shore reading was 46.7, with a range between 18.9 and 76.1 for specific weeks. The highest sugar content and highest firmness were obtained from crops produced in the Middle East. Crops grown in the USA and Spain generally had higher sugar contents and firmness than the UK and Dutch crops. The UK and Dutch produced crops were dominated by the variety 'Elsanta'. In general the UK-produced 'Elsanta' had both higher sugar content and higher firmness than the imported Dutch crop.

## Extending shelf life and maintaining quality of Royal Z plums with 1-MCP

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Royal Z plums are an early season Japanese type plum with excellent taste and a short shelf life, due to rapid softening. They develop internal flesh disorders if stored for longer than three weeks. 1-methylcyclopropene (1-MCP) is an ethylene action inhibitor which has been found to slow ripening processes in many fruits and vegetables. Royal Z plums were treated with  $0.5 \mu\text{l l}^{-1}$  overnight at  $18^{\circ}\text{C}$  before being stored for 2 weeks at  $0^{\circ}\text{C}$ . After storage the plums were held at  $18^{\circ}\text{C}$  for 4 and 8 days and then evaluated for ripeness and quality parameters as well as organoleptic quality. 1-MCP increased the shelf life of the plums from 4 to 8 days by slowing the fruit softening and the decrease in titratable acidity. Taste tests after 4 days found the control fruits tasty with a good sugar: acid balance, while the 1-MCP treated fruits were too firm and acidic. However, after 8 days the control fruits were bland and too soft, while the 1-MCP treated fruit received ratings better than the control fruits after 4 days. Antioxidant components such as anthocyanin, total phenols, flavonoids and antioxidant activity using 2,2 diphenyl-1-picrylhydrazyl (DPPH) were determined. All components increased during shelf life after harvest, with anthocyanins increasing the most. During storage at  $0^{\circ}\text{C}$  was also an increase in anthocyanin and flavonoid content and in antioxidant activity. During ripening after storage, however, anthocyanin, flavonoid and antioxidant activity decreased in control fruit, while they increased in 1-MCP treated fruit. In conclusion, 1-MCP increases shelf life of Royal Z fruits and also maintains the antioxidant compounds of the fruit.

## Optimization of the duration of deastringency treatment depending on persimmon maturity

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Persimmon cv. 'Rojo Brillante' is astringent at harvest. Treatment with 95% CO<sub>2</sub> for 24 h at 20°C has been adopted by the industry as the standard deastringency method since it had been demonstrated to be effective at different maturity stages of the fruit. The aim of the present work was to study the effectiveness of shorter exposition to 95% of CO<sub>2</sub> on the removal of astringency when applied at different maturity stages of the fruit. Fruits at early, middle and late maturity stages were exposed to 95% CO<sub>2</sub> at 20°C for 12, 18 or 24 h. The level of astringency of the fruit was evaluated at 0, 1, 2, 3 and 6 days after treatment. Sensory evaluation as well as measurements of soluble tannin content and acetaldehyde production were carried out. Results showed that the astringency remained after CO<sub>2</sub> treatments, progressively decreases with the time. Only the 24-h treatment ensured complete deastringency of the fruits irrespective of the maturity stage; fruits at middle maturity stage lost completely the astringency just after the treatment, while in early and late mature fruit, a period of 2 days after treatment was necessary to achieve absence of astringency. Treatment for 18 h was not effective when applied to early mature fruit; however, when applied to fruit at middle and late stages of maturity, the treatment was effective immediately and 6 days after its application, respectively. Treatment for 12 h was ineffective, resulting in remaining astringent fruit irrespective of the maturity stage, even 6 days after treatment. Response of the different maturity stages to the treatment is discussed.

## Effects of package atmosphere and temperature on phenolics, total antioxidant capacity and colour in kernels of 'Franquette' walnuts during 8-month storage

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The effects of package atmosphere and temperature on phenolic compounds, total antioxidant capacity and colour were investigated in kernels of 'Franquette' walnuts stored for 8 months. Dried walnuts were sealed under air or 100% N<sub>2</sub> in Rovac A packages (80 µm thickness, CASFIL, Portugal) and stored at 1°C or 20°C for 4 and 8 months. The highest total phenolic concentration (25.41 mg gallic acid/g), total antioxidant capacity (1856 mM trolox equivalents/g and 1724 mM trolox equivalents/g according to FRAP and DPPH method, respectively) and *h<sub>o</sub>* value (78.18) were observed in samples before storage. The above parameters decreased progressively during storage time in all samples. Concentration of O<sub>2</sub> inside the N<sub>2</sub>-atmospheres increased to approximately 6.2% (v/v) and 8.3% after 4 and 8 months storage, respectively, at both temperatures. Low temperature and N<sub>2</sub>-atmosphere prevented the decreases, whereas their combination resulted in the best prevention of losses. However, walnuts stored in air at 1°C showed similar changes to those stored in N<sub>2</sub>-atmosphere at 20°C during the whole storage period. Indicatively, after 8 months storage the total phenolic concentration decreased by 7.5% in N<sub>2</sub>-atmosphere and 16% in air at 1°C, while at 20°C the decrease was about 16% and 35% in N<sub>2</sub>-atmosphere and air, respectively. Additive positive effects of low temperature and N<sub>2</sub>-atmosphere were also observed on prevention of decreases in L\* parameter, whereas changes in C\* did not follow a pattern similar to L\*, but were affected only by temperature. Before storage, among the major phenolic compounds detected the ellagic, protocatechuic, vanillic, and syringic acids were found at 822.4 ng/g, 581.8 ng/g, 581.6 ng/g, and 310.2 ng/g, respectively. After 8 months storage all phenolic compounds decreased in all samples. The decreases were reduced in N<sub>2</sub>-atmosphere at 1°C and pronounced in air at 20°C.

## Parameters of storage process influencing vegetable quality

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Keeping quality is one of the main problems of every vegetable storage stage. The important problem is to describe cooling of vegetables by air ventilation. Using basic laws of physics, we assembled the mathematical model of the process. Natural losses characterize losses of moisture which unfavourable influence the storage ability of live organisms. If duration of cooling vegetables was shorter, less losses of mass are observed in production, but larger air expenditure is necessary which in its turn causes additional expenses. On the basis of the functional analysis of the storage model, it is possible to optimize regulation of heat-moisture processes for a particular kind of production. Considering the heat transfer maintained from the product, it will be possible to carry out successful storage of vegetables. It enables to improve technological process of storage. Optimized and experimentally verified model will help to explain and predict physical processes in vegetables during storage.

## Consumer preferences of 'Elstar' apples at differing ripeness treated with 1-MCP

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1-MCP is a valuable tool to improve the postharvest quality of apples during commercialisation. The sensory quality of MCP treated apples is very strongly influenced by their ripeness status, storage conditions and storage duration. This investigation evaluates the consumer preference for MCP treated 'Elstar' apples with differing ripeness and storage durations. In 2007 "in-store" consumer preference tests were carried out with 'Elstar' apples: with and without MCP treatment and two different stages of ripeness. The apples were commercially stored for 4 months (January 2007 test) in CA plus 8 days shelf life at 20°C and 8 months CA (May 2007 test) plus 8 days shelf life. The supermarket shoppers tasted an apple slice from each treatment category and their preference for fruit texture (firmness), overall taste and overall liking was recorded. From the remaining cut apple segments the flesh firmness, total solid solids, titratable acidity, and background colour was determined the following day and the results related to the sensory data. In January, shoppers preferred the less-ripe untreated and ripe MCP-treated 'Elstar' apples while less-ripe MCP treated and ripe untreated fruit were rejected. By May, the consumer preference pattern had changed and less-ripe MCP treated fruit were now clearly preferred while ripe untreated fruit showed very low preference scores. The results from these consumer preference tests show that MCP treated 'Elstar' under some circumstances (e.g. short CA storage time) can be non-preferred. Optimal post-harvest management and storage now requires producers to have a very thorough understanding of fruit ripening to best match fruit with storage conditions and consumer marketing windows.

## Effect of atmospheric pressure plasma treatment on the stability of flavonoids

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Flavonoids are an important constituent of the human diet. In recent years, they have gained much attention in research on cancer prevention and reduction of cardiovascular diseases due to their naturally high antioxidative and anticarcinogenic properties. Thermal processes such as boiling, frying, and microwave cooking are able to reduce the flavonoid content of vegetables and a decrease in the antioxidant activity after heat treatment in aqueous solution has been observed. These limitations have fostered the development of gentle food process techniques that do not affect the bioactivity of the flavonoids. In this context, non-thermal atmospheric pressure plasma is an innovative and emerging technology that seems to be a promising alternative to thermal treatments, since an efficient inactivation of microorganisms comes along with a moderate heating of the treated surface. Yet, energetic electrons from the plasma can interact directly with the tissue surface, causing a.o. fragmentation. As well the respective roles of UV photons and reactive oxygen species and radicals and their influence on dietary bioactive compounds are not well understood. The aim of this study was to investigate the stability of selected model quercetin glycosides using a cold discharge (plasma jet) with varying gas mixtures. Plasma treatment was performed using a non-thermal plasma jet operated in argon at atmospheric pressure and driven by radio frequency of 27.12 MHz. The reaction of the Ar plasma with quercetin glycosides has been studied at various radio-frequencies driven voltage, gas flow rate and at different positions from the jet nozzle outlet. The degradation of quercetin and its derivatives was followed by high performance liquid chromatography/diode-array detection (HPLC/DAD) and UV/VIS spectroscopy. First results show that the quercetin glycosides are degraded by interaction with the plasma depending on increasing plasma voltage and exposure time. Depending on the working conditions, different plasma intermediate species have been observed by optical emission spectra. From the results on the type of intermediate species, different processes for the plasma-induced decomposition are proposed. The experiments provide useful insights about the plasma-induced physical and chemical reactions in view of future industrial adaptations in food processing technology.

## Quality of fresh-cut 'Khake Dam' and 'Red Maradol' papayas as affected by low temperature storage

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The changes in physico-chemical and microbiological quality of fresh-cut 'Khake Dam' and 'Red Maradol' papayas were measured during storage at 4, 10, and 13°C. Total soluble solid, titratable acidity, total ascorbic acid, texture and microbial counts were determined after slicing and after stored for 2 days at low temperatures. Total soluble solid content slightly decrease in both cultivars stored at all temperatures, whereas titratable acidity, total ascorbic acid and texture were increased regardless of low temperature storage. Respiration rate and ethylene production of both cultivars varies to about 1.1-4.2 mg CO<sub>2</sub>/kg•h and 0.07-1.3 µl C<sub>2</sub>H<sub>4</sub>/kg•h, respectively. Water-soaked appearance occurred on both cultivars and reached to the threshold of marketability on day 2 at all storage temperatures. Mesophilic aerobic bacteria, coliforms, and fungi counts of fresh-cut 'Red Maradol' cultivar just after slicing were lesser than those of fresh-cut 'Khake Dam' cultivar. All microbial counts were increased in both cultivars during storage. A storage temperature of 4°C did inhibit ethylene production and delay microbial growth of both cultivars, whereas it did affect adversely water-soaked appearance of 'Red Maradol' cultivar. Therefore, the optimum storage temperature for fresh-cut papaya is dependent with cultivar.



## Skin yellowing and discolouration in stored carambola treated with 1-methylcyclopropene

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Carambola cv. B10 at colour index (CI) 3 were exposed to 1-methylcyclopropene (1-MCP) at concentrations of 0 (control), 400, 800 and 1200 nI/l for 8 hours at 25°C. The fruits were then stored at 8°C for 4, 5 and 7 weeks. After each storage period at low temperature, the fruits were removed and held further for another 1 week at ambient (25°C). The study showed that exposure to 1-MCP did not affect the yellowing of the skin colour during and after low temperature storage. 1-MCP reduced skin browning and controlled blackening of the fruit ribs. L\* values showed a declining trend during storage at low temperature in the control and 1-MCP treated fruits. However, there were no significant differences in L\* values between the control and 1-MCP treated fruits on the respective period of storage either on the time of removal or after being held further for 1 week at ambient. The a\* values increased during storage at low temperature which indicated the reduction in the greenness of the fruits. The a\* values decreased further when the stored fruits were held at ambient for a week. There was no clear difference between the control and the 1-MCP treated fruits both during storage and after being held for another week at ambient. The b\* values increased during storage with the highest values were found in fruits stored for up to 4 weeks at 8°C and declined from then onwards. Holding further of the stored fruits for another week at ambient following low temperature storage resulted in the decline of b\* values where the control fruits stored for 5 weeks had b\* value at even a lower level than the fresh fruits on day 0. The 1-MCP treated fruits at this storage period had higher b\* values which indicated that the 1-MCP treated fruits were less affected by chilling injury than the control.

## Treatments applied to some minimally processed horticultural products to preserve their quality during shelf life

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Minimally processed fruits and vegetables have continuously increased in the past years due to consumer life style. These products need more care to preserve their quality during shelf-life. The present work had the objective to evaluate the effects of some treatments, applied after cutting, on the quality preservation of fresh-cut kiwi, pear, strawberry, tomato and pepper fruits. Fruits were washed in tap water, cut longitudinally into quarters and dipped in solutions of 2% citric acid, 2% ascorbic acid or 2% calcium lactate. Control fruits had no treatments. After, fruits were placed in plastic trays, covered with 15µm thick polyethylene film and stored at 2°C for 9 days. At days 0, 3, 6 and 9 of the experiment flesh colour ( $a^*$ ,  $b^*$ ,  $L^*$ ), firmness, soluble solids content (°Brix) and total phenol content were measured. The most marked effect of treatments on the quality preservation of fruits was on the flesh firmness which was higher in kiwifruit and strawberry treated with citric acid mainly in the last days. In tomato and pepper, treatment with ascorbic acid retained firmness better. In pear firmness increased after treatment. Except kiwifruit, at the end of the shelf-life period fruits treated with citric acid showed higher values of  $a^*$  when compared to the other treatments. After 9 days at 2°C, total phenol content was lower in kiwifruit and strawberry treated with citric acid than in the other treatments, while in tomato ascorbic acid showed the best results. Overall, it seems that the beneficial effect of the various applied treatments on quality preservation in shelf-life depends on the fruit species and possibly of the variety.



## **Section 2**

# **Postharvest physiology and metabolomics: the interaction of postharvest scenarios with biochemical and physiological aspects and processes**

## Ripening regulation and postharvest fruit quality

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By the regulation of fruit ripening we ensure consumers have a year-round supply of fruit with acceptable eating quality and health promoting components. Fruit ripening is a highly regulated process with coordinated genetic and metabolic events, leading to essential changes in gene expression, physiology, biochemistry and anatomy. These complex regulatory events transform a physiologically mature but inedible fruit into an edible, tasty product. Molecular and genetic analysis of fruit development and especially of ripening, have resulted in confirmed gains in knowledge about ethylene biosynthesis and responses, cell wall metabolism and environmental factors. Innovations in CA technology like dynamic controlled atmospheres (DCA) and/or the use of the chemical ethylene inhibitor (1-MCP) are new tools for the enhancement and preservation of quality and health promoting components in climacteric fruit. Dynamic CA, with non destructive monitoring systems based either on ethanol concentration or chlorophyll fluorescence allows the use of oxygen atmospheres during storage that are close to the lowest tolerance limits for fruit without inducing excessive anaerobic metabolism. In contrast to other available technologies, 1-MCP has the potential to control ethylene action by blocking the ethylene receptors and thereby maintaining fruit quality, and avoiding specific storage disorders not only in storage but also during marketing and shelf-life. Postharvest physiological disorders may result from oxidative stress influencing fruit physiology during fruit maturation and ripening when active oxygen species exceed the capacity of an organism to maintain redox homeostasis and exhaust the internal defence systems. Many postharvest researchers are involved in evaluating antioxidant activities as affected by cultivar, production practices and postharvest handling procedures. Sensory investigations and consumer expectation surveys have confirmed that the aroma, firmness, crispiness and juiciness are the most relevant sensory traits. Ripening regulation by modern storage technology shows great benefits in terms of texture, TSS and acidity but often hampers aroma formation mainly depending on the at-harvest ripening stage of the fruit. In future, postharvest researchers will be challenged to meet consumer requirements with fruit that is well flavoured and nutritious.

## Effect of postharvest conditions and treatments on health-related quality of vegetables and fruits

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There is convincing evidence that a large intake of vegetables and fruits reduces the risk of several chronic diseases. The health-promoting effects could be due to physiologically active constituents among the thousands of phytochemicals, in addition to nutrients, that are present. Experiments with cell cultures, animal models and humans have revealed specific bioactivities. A direct antioxidant effect in the body may be insignificant for phytochemicals that are antioxidants in vitro. Instead, health-promoting phytochemicals can act by other mechanisms, e.g. induce phase II enzymes in drug metabolism, modulate intracellular signalling pathways, inhibit tumour growth or initiate apoptosis in cancer cells. It is not yet known what intake levels of various phytochemicals are beneficial for health. For intake calculations and dietary recommendations, it is important to know the effect of pre- and postharvest conditions and treatments on the final levels in the product before ingestion. In general vegetables and fruits lose their content of vitamin C postharvest, and more so during suboptimum conditions. Glucosinolates and dietary fibre are relatively stable, whereas phenolic constituents and carotenoids vary in behaviour depending upon species, ripening stage and the specific compound. Atmospheres with lowered O<sub>2</sub> and elevated CO<sub>2</sub> concentration reduce the loss rate of vitamin C and can change the storage behaviour of several constituents such as flavonols and anthocyanins. The effect of incident light postharvest is little investigated, but increases in phenolics are possible. Non-bruising mechanical stress could also be of significance, but very few results are available. Furthermore, the properties at harvest can have an impact later. For instance, apple varieties with the lowest levels of vitamin C had the largest storage losses of vitamin C, and pak choi with a high initial level of flavonoids showed an increase after controlled atmosphere storage, whereas a low start level of flavonoids failed to increase. It is usually not possible to assess health-related quality of fruits and vegetables by our senses. Therefore, rapid and non-destructive methods to measure health-related properties are needed. Only a few such methods have been developed so far.

## Variation of fructo-oligosaccharides in asparagus spears during storage under different temperature regimes

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Fresh spears of asparagus were stored in the dark at 4, 10 or 20°C for two weeks. During storage, contents of glucose, fructose, sucrose, 1-kestose, neokestose and nystose, and activities of invertase, 1-kestose hydrolyzing enzyme (1-KHE), sucrose:sucrose 1-fructosyltransferase (1-SST), fructan:fructan: 1-fructosyltransferase (1-FFT) and fructan:fructan: 6G-fructosyltransferase (6G-FFT) were determined. Glucose and fructose varied significantly during storage, while sucrose was stable. 1-Kestose and nystose increased at the end of the storage period and this increase was more apparent at 20°C. Invertase activity showed similar variation at 4 and 10°C but increased sharply after two days, before decreasing abruptly after one week of storage, and 1-kestose hydrolyzing activity showed a pattern similar to that of invertase activity. 1-SST did not vary in the bottom portion but initially increased in the middle and top portions. 1-FFT was high and decreased during storage and 6G-FFT activity showed a pattern similar to 1-FFT but was higher. The 6G-FFT to 1-FFT activity ratio was temperature independent. These results suggest that short fructooligosaccharides and their metabolizing enzymes could play a role of balance between the hydrolysis and synthesis activities of carbohydrates. The high content of sugars may also extend the rapid decline of sugars in the top portion of the spears.

## Isolation and characterization of the monodehydroascorbate reductase gene from *Vaccinium corymbosum* cv. Bluecrop and the impact of CA-storage on its expression and on the level of ascorbic acid

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Ascorbic acid (AA) is a major antioxidant in plants that is involved in the ascorbate-glutathione cycle, in which monodehydroascorbate reductase (MDAR) regenerates reduced ascorbate. Blueberry is considered a fruit species with high AA content. Using Differential Display Reverse Transcription-PCR, a cDNA fragment was isolated from blueberry that showed sequence homology to other plant MDAR genes. Subsequently, the 5' RACE-PCR technique was employed to obtain the full-length cDNA sequence. The cDNA is 1551 bp in length and encodes a protein of 433 amino acids. The deduced blueberry MDAR protein showed highest sequence identities to MDARs of *Pisum sativum* and *Vitis vinifera*. RNA gel blot analysis of the blueberry MDAR gene revealed a differential expression pattern in freshly-harvested and stored fruit as well as in fruit stored under various controlled atmosphere conditions. Changes in the level of ascorbic acid associated with these treatments were also assessed. A dramatic loss in ascorbic acid occurred under all storage conditions, even after three weeks in store. However, it was obvious that storing fruit under low O<sub>2</sub>, combined with high CO<sub>2</sub> level (up to 18%) resulted in better preservation of ascorbic acid, although a high CO<sub>2</sub> level (24%) reduced fruit quality and taste.



## Response of 1-methylcyclopropene treatment on quality preservation and shelf life extension in plum fruits (*Prunus domestica* and *P. salicina*) under multiple temperature regimes

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The prime objectives of the study was to assess the impact of 1-MCP on physical, physiological and biochemical changes in plum fruits during storage at different storage temperatures (2°C, 15 °C and 20°C). European plum (cv. Hauszwetschge) fruits were treated with 0.5 µl l<sup>-1</sup> 1-MCP and 100 ppm ethylene, alone or in combination (i.e. 1-MCP+ethylene) at 2°C for 24 h. At 15 day intervals (i.e. 15, 30, 45, 60 days at 2°C) fruits were transferred to 20°C for 6 days. 1-MCP treated European plum fruits exhibited lower physiological loss in weight, retained better firmness and higher L values (brightness), b\* values (blue-yellow axis), showed minimum change in total soluble solids, sucrose, glucose and fructose as compared to other treatments and untreated fruits. Fruits lost nearly 16% of their physiological weight during 56 days of storage at 2°C and more than 30% of their weight by the end of storage period of 60 days at 2°C plus 6 days at 20°C. PPO activity was lowest (3.01 units g<sup>-1</sup> min<sup>-1</sup>) in 1-MCP treated fruits. Fruits treated with 1-MCP have lowest carbon dioxide (3.14±0.98 ml kg<sup>-1</sup> h<sup>-1</sup>) and ethylene (17.59 µl kg<sup>-1</sup> h<sup>-1</sup>) production rates as compared to other treatments. Japanese plum (cv. Santa Rosa) treated with 1-MCP (0.5 µl l<sup>-1</sup>) and stored at 15°C for 9 days showed lower weight loss, decay loss and higher specific gravity, higher total soluble solids, acidity, ascorbic acid content as compared to control fruits. The study has shown that 1-MCP has the potential to control the ripening of plum fruit and extend the storage period by more than 15 days at 2°C and by approximately 5 days at 15°C.

## Spatial and temporal profile of non-structural carbohydrates in pre-climacteric Sri Lankan mango (*Mangifera indica* L.) fruit

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No published information is available on the genotypic variation of major biochemical constituents in mango fruit endemic to Sri Lanka. Accordingly, non-structural carbohydrates were determined from the peel and pulp of pre-climacteric Sri Lankan mango cultivars (viz. Willard, Karutha Colomban and Malgovala) at three different maturity stages. Sugars and starch were quantified using standard HPLC and a total starch assay kit, respectively. Sugar concentrations of both pulp and peel were reduced with maturity in cvs. Malgovala and Karutha Colomban, yet increased in cv. Willard. Total sugars were significantly higher in the pulp and peel ( $300.67 \text{ mg g}^{-1}$  and  $177.05 \text{ mg g}^{-1}$  dry weight (DW), respectively) of cv. Malgovala than that of cvs. Willard ( $236.47 \text{ mg g}^{-1}$  and  $143.21 \text{ mg g}^{-1}$  DW) and Karutha Colomban ( $128.1 \text{ mg g}^{-1}$  and  $85.37 \text{ mg g}^{-1}$  DW). Reducing sugars contributed to ca. 80% of total sugars, whereby fructose was dominant in both pulp ( $67.43 - 141.34 \text{ mg g}^{-1}$  DW) and peel ( $56.23 - 106.1 \text{ mg g}^{-1}$  DW) followed by glucose and sucrose. Sucrose ( $5.18 - 29.77 \text{ mg g}^{-1}$  DW) was significantly lower in peel samples. Although no noticeable variation in starch content between pulp and peel was found at the immature stage, starch increased with maturity and was significantly higher in pulp ( $25.99 - 55.00\%$  DW) than peel ( $18.17 - 38.92\%$  DW) at full mature stage. The mean starch content was higher in both pulp ( $36.75 \text{ mg g}^{-1}$  DW) and peel ( $31.14 \text{ mg g}^{-1}$  DW) of cv. Malgovala followed by Karutha Colomban and Willard. Implications of these biochemical changes on subsequent postharvest quality are discussed.

## The role of ethylene response-pathway components in avocado ripening

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To elucidate the role of ethylene response pathway components during avocado ripening and storage, we have isolated avocado (*Persea americana* cv. Arad) cDNA homologues of two ethylene receptors: PaETR, PaERS1 and a mitogen-activating protein kinase (MAPKKK), PaCTR1. The basal levels of PaETR, PaERS1 and PaCTR1 mRNA in avocado mesocarp were very low at harvest and were hyper-induced by exogenous ethylene treatment. The expression of both ethylene receptors and PaCTR1 genes also increased in parallel to the onset of climacteric ethylene peak, suggesting that an endogenous increase in ethylene leads to increase in these genes' expression. Application of the ethylene inhibitor, 1-methylcyclopropene (1-MCP), at harvest delayed ethylene production and down-regulated expression of PaETR, PaERS1 and PaCTR1 genes. PaETR mRNA expression in tissues taken from various distances from the seed revealed that the expression level was the highest close to the base of the seed and was reduced gradually toward the distal end. This pattern was correlated with ethylene evolution levels. We suggest that ethylene receptors and PaCTR1 are involved in regulation of ethylene responsiveness during avocado ripening.

## Comparative study of techniques to restore the ripening process in 1-MCP treated 'Blanquilla' and 'Conference' pears

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'Blanquilla' and 'Conference' pears represent important produce for Spain and the rest of Europe. Although their storage life can be prolonged substantially with refrigeration, they ripen very quickly. These pears are also very sensitive to physiological disorders during cold storage. 1-MCP treatments have been tested by various research groups already. Very often, 1-MCP treated fruit remain 'evergreen' and their ripening process is blocked and does not resume after removal from cold storage. To solve this problem, 1-MCP treatments were combined with external ethylene or temperature manipulation treatments to re-induce ripening. The first strategy was to treat fruit with 1-MCP (300 ppb), then hold them at 15°C for 5 to 15 days and subsequently store them at 0°C in regular air. The second strategy involved treatment with 1-MCP (300 ppb), followed by air storage at 0°C and progressive re-warming to 6°C one month before removal. For the third strategy, two different doses (300 ppb and 600 ppb) of 1-MCP treatment were used combined with two different doses (300 ppb and 600 ppb) of exogenous ethylene. Ethylene production, quality (firmness, soluble solids content, acidity) and physiological disorders were measured after 3 - 4 months of air storage. 1-MCP treatment clearly inhibited ethylene production in all experiments but the sensitivity to 1-MCP and the capability to restore ethylene production were cultivar related. The first strategy was successful in restoring ethylene production and softening depending on the duration of the temperature manipulation, while maintaining the beneficial effect of 1-MCP on physiological disorders. The second strategy was less satisfactory. For the third strategy with exogenous ethylene, the high dose of 1-MCP combined with the high dose of ethylene allowed partial restoration of ethylene production and softening whereas the combined low doses resulted in higher ethylene production and significant softening.

## Biochemical and textural ripeness assessment of avocado fruit from different origins

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Defining stage of ripeness and quality of avocado is notoriously difficult to assess by conventional methods. Texture is a very important determinant of avocado fruit quality, and can change radically during storage. The difficulties to determine avocado quality are related, in part, to the spatial heterogeneity of fruit characteristics during ripening. The aim of this study was, therefore, to assess the discriminatory capabilities of physiochemical spatial profiles to determine ripeness of avocado cv. 'Hass' fruit originating from Spain, Peru and Chile. Fruit were stored at 12°C and sampled at regular intervals. The texture of different horizontally-cut slices from individual fruit during ripening was measured using a previously unreported method. Maximum load, elasticity and viscosity of fruit tissue was measured using an Instron 5542 universal testing machine fitted with a 500 N or 5 N load cell. The same tissue slice was then further processed prior to subsequent quantification of non-structural carbohydrates (NSC) and fatty acid methyl esters (FAME) using standard high performance liquid chromatography coupled to evaporative light scattering detection and gas chromatography coupled to flame ionisation detection, respectively. Significant spatio-temporal differences in maximum load, elasticity, viscosity, NSC, and FAME profiles were found in avocados from different origins. Differences in texture and target analytes measured were used to differentiate avocado fruit into definable groups using principle component analysis.

## Mechanical properties of artificial cell walls

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Cell walls are considered as the main structural component affecting the mechanical properties of fruit and vegetables. Fruit mechanical properties depend largely on the conditions of their storage and on the technological process parameters, such as temperature and relative humidity. In order to examine and to simulate the effect of various polysaccharides on the mechanical properties of cell walls, model cell walls with chemical composition and structure that would be equivalent to those of natural cell walls may be used. The objective of this study was to construct a model cell wall that would be characterized by a structure and chemical composition similar to those of natural cell walls and that would be of dimensions sufficient for the performance of mechanical testing. Mechanical properties were tested in different relative humidity of storage conditions. Artificial plant cell walls were produced from bacterial cellulose and cell wall constituents of apple parenchyma. The artificial cell walls were stored at low, medium and high relative humidity, and then subjected to micro-mechanical tests. Uniaxial tensile tests were carried out and revealed that the different cell wall materials differed in their mechanical properties. Depending on the composition of artificial cell walls mechanical properties differed significantly, addition of hemicelluloses and pectin to native cellulose caused decrease of secant modulus in high humidity. Increasing the humidity during storage resulted in a decrease in the value of the secant modulus in all materials. The artificial cell wall materials can be used for the simulation of the effect of external factors on the physical and chemical properties of cell walls and for the simulation of processes taking place in the plant tissue.

## Developing protocol for exporting quality mangoes to China

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Under a recently signed protocol between Pakistan and China, Pakistani mango industry has got access to Chinese market. However, the mangoes need to undergo a hot water treatment (HWT) for quarantine (fruit fly disinfestation) purposes. Further, skin blemishes due to sapburn injuries are also an industry concern for improving visual fruit quality. During these studies, mature mango fruit cv 'Chaunsa' were harvested with 4-5 cm attached pedicel. Fruit were treated with potential anti-sap chemicals [1% Ca(OH)<sub>2</sub>, destemming under lime solution; 1% KAl(SO<sub>4</sub>)<sub>2</sub>O<sub>12</sub>(H<sub>2</sub>O), destem and dip; 1% Tween-80 C<sub>64</sub>H<sub>124</sub>O<sub>26</sub> (Avg.), destem and dip; control] and then half lot was subjected to HWT (48°C for 60 min) as per protocol, while the other half was kept untreated. Both fruit lots were stored (13± 1°C, 85% RH) for 21 days. Sapburn injuries were scored before and after 24, 48 and 72 hrs storage. After storage fruit were ripened at ambient temperature (25°C) and assessed for incidence of chilling injuries and diseases as well as various quality parameters including fruit firmness, peel colour, total sugars, reducing and non-reducing sugars, acidity, total carotenoids, ascorbic acid contents and organoleptic characteristics (taste, pulp colour and texture etc). Sapburn injury score showed significant differences for chemicals and chemical-HWT interactions. Destemming in lime followed by HWT resulted in least sapburn injury with firmer fruit. HW treated fruit generally showed significantly lower anthracnose incidence, while higher level of sugars (total and reducing) compared to non-treated fruit. Total carotenoids were significantly higher in fruits without HWT. Organoleptic evaluation revealed smoother pulp texture in fruit without HWT compared to HWT. This paper provides detailed account of the study and suggestions for sapburn management and HWT usage for mango export purposes.

## A search for both 1. Volatile and 2. New non-volatile and water soluble cyclopropene antagonists of ethylene action

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The use of the most promising antagonist of ethylene presently available, 1-methylcyclopropene (1-MCP), is limited mainly due to its insolubility in water and is used, therefore, in a volatile form only in sealed chambers. It cannot be used for dip loading of cut flowers or application as a spray in the field. In addition, a greater selection of ethylene antagonist is commercially desired to meet the market demand for inhibitors that block the ethylene receptor for various lengths of time. Seventeen cyclopropene putative inhibitors of ethylene action were synthesized by Sisler and screened for their potency as ethylene antagonists. The most promising one was selected in order to further synthesize the novel water and stable cyclopropene derivative (\*WS-CPD), that was found to be an effective inhibitor of ethylene-induced responses in agricultural crops, like delaying banana peel de-greening at least by 12 days, and color change of 'Hass' avocado fruit at least by 5 days, prolonging the vase-life of carnation and petunia cut flowers at least by 14 days, as well as delaying abscission of citrus leaf explants by at least 7 days. Further research is conducted to improve peel penetration of the inhibitor into certain fruits, like avocado and banana. Some positive effects on delaying fruit softening were nevertheless already achieved.

\* Patent pending

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## Abscission of bunch tomatoes during storage

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Cherry tomatoes harvested as bunches are sensitive to abscission during storage, which is a significant commercial problem for this produce. Abscission can result from detachment of the fruit from the stem without the calyx or from the 'joint' abscission zone within the pedicel. We have shown that high levels of exogenous ethylene are required to trigger abscission and that application of methyl jasmonate can enhance the abscission as well induction of tomato endo-glucanases. Abscission during storage can be significantly reduced by application of the inhibitor of ethylene action, 1-methylcyclopropene (1-MCP) and auxin in various application methods. Abscission through the joint was dominant during the winter season while bunch tomatoes grown in the summer suffered from abscission from the stem-end. The effect of relative humidity during storage or shelf-life was elucidated. Expression of endo-glucanases and polygalacturonases during storage was investigated in both abscission zones and the kinetics of expression during storage were influenced by the application of the growth regulators and their antagonists. These results offer a wide perspective over the environmental and molecular processes controlling abscission of bunch cherry tomatoes.

## Effects of polyethylene thickness, photoperiod and initial stage at harvest on ripening of two varieties of tomato (*Lycopersicon esculentum* Mill) fruits

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The effects of thickness of polyethylene (PE) packaging material, photoperiod and initial stage of ripening at harvest before storage at 28°C on further ripening of two varieties of tomatoes were studied. Fruits at the first four stages of ripening—green, breaker, turning and pink—were separately packed in PE of 2.5, 5.0, 10.0 and 20 µm thickness. They were sealed and stored either under 12 h alternating light and darkness or complete darkness. Daily observation for progressive red colour development showed that photoperiod, packaging material and initial stage of ripening before packing and storage affected ripening. The ripening of stage 1 (green) fruits of both 'Roma' and local 'Beske' varieties was independent of photoperiod, but decreased with increase in thickness of PE packaging material. Ripening progressed more in total darkness than in 12 h alternating light and dark in fruits that were initially at stage 2 (breaker) before storage. However, the difference was more pronounced in 'Roma' than in the local variety. The least ripening in 'Roma' was observed in 20 µm PE in alternating light and dark while the greatest colour development was observed in 2.5 µm PE also initially at the breaker stage. There was no significant difference between effect of 10 µm and 20 µm PE material on the local variety. Fruits initially at stage 3 (turning) did not show a significant effect of photoperiod in 'Roma' but the local variety. Further ripening of stage 4 (pink) fruits seemed to be unaffected by thickness of PE in 'Roma' fruit stored in complete darkness but had significant effect in alternating light and dark with the extent decreasing as PE thickness increased. The same trend was observed in local fruits. Generally, both photoperiod and thickness of packaging material had more significant effect at the early stages (green and breaker) than the later stages (turning and pink).

## Kinetic modelling for optimal packaging and storage of sweet cherries

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This paper discusses the relationships between storage environment, respiration rate and storage life using sweet cherries as a case study. Cherries are a highly perishable crop and good temperature control is vital to maximise retention of quality and ensure adequate storage life. Hydrocooling to rapidly remove field heat is recommended and the optimal storage temperature is 0°C. Slow or delayed cooling and temperature abuse during transport or marketing will accelerate deterioration, increasing the risk of losses through poor product appearance or rots. Modified or controlled atmosphere storage can also be employed to advantage in prolonging cherry storage life. To design and analyse MAP systems it is necessary to quantify the dependence of respiration rate on temperature and gas composition. These relationships may also have utility in characterising changes in fruit quality due to temperature variation in the cool chain. Using data drawn from the literature and experimental studies of sweet cherry physiology and storage, the dependence of cherry respiration rate on temperature for normal air storage is shown to be adequately described by a generic Arrhenius relationship. Different cultivars do exhibit some differences in their physiological responses and opportunities for further development of the model to incorporate cultivar-specific temperature and gas atmosphere responses are demonstrated. The application of the derived models is illustrated through typical supply chain data to highlight the importance of the cold chain in maintaining cherry fruit quality.

## Conjugated trienes, a-farnesene and storage disorders in 'Abbé Fétel' pears treated with 1-MCP

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'Abbé Fétel' pears are very prized in Italy, due to their non-melting, juicy texture and excellent flavour when ripe. However they cannot be stored for long term in normal atmosphere (NA), because after 3-4 months they lose the ripening ability, while in controlled atmosphere (CA) they can be subject to senescent (soft) scald. Pears cv 'Abbé Fétel' picked at two times were cooled (-0.5°C) at different speeds, while monitored with fluorescence sensors. Cooled fruit were treated with 300 ppb 1-MCP and stored in normal air or in controlled atmosphere (2% O<sub>2</sub>, 0.7% CO<sub>2</sub> at -0.5°C). After 4 and 6 months of storage, fruit were analyzed immediately after storage and after 9 days of shelf life at 20°C. Weight, skin colour and firmness were measured on fruit samples. Fruit skin was extracted with hexane for analysis of a-farnesene and conjugated trienes (CT) by spectrophotometric method. Cooling speed affected fruit fluorescence and the effect was maintained throughout the storage. Among storage disorders, pears showed superficial scald, senescent scald, internal breakdown and decay. Superficial scald was remarkably influenced by storage atmosphere, being almost fully controlled in CA; the effect of 1-MCP on superficial scald was not clear. Senescent scald was induced especially in CA, and aggravated by slow cooling, but it was controlled by the treatment with 1-MCP. CT and a-farnesene generally were higher after 4 than 6 months storage in NA, compared with CA, and decreased with shelf life. The interactions between storage treatments are discussed in relation to the incidence of disorders and to the contents of a-farnesene and CT in the skin.

## Metabolomic evaluation of 'Braeburn' browning

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'Braeburn' browning is an internal storage disorder sometimes associated with elevated storage CO<sub>2</sub> concentrations. Incidence of the disorder can be reduced using pre-storage diphenylamine (DPA) drenches indicating a relationship between reactive chemical species and disorder occurrence. 'Braeburn' apples were sampled at commercial harvest. Accordingly, apples were treated with 2000 µL·L<sup>-1</sup> DPA and stored at 1°C in air or in 1.5 kPa O<sub>2</sub> and 1, 2, or 3 kPa CO<sub>2</sub> for 1 or 2 months. The metabolic profile of damaged and healthy cortex samples was evaluated after harvest and following storage using GC-MS analysis of trimethylsilyl (oxime) derivatives. Principal component analysis of the metabolic profile revealed metabolomic shifts resulting from differing tissue integrity, diphenylamine treatment, hypoxic storage, CO<sub>2</sub> concentration, and storage duration. This demonstrates that this subset of the metabolome is representative of metabolic perturbations associated with browning.

## Hormonal control of sprouting of sweetpotatoes in storage

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An understanding of the control of sprouting of sweetpotatoes is important, both for marketing of sweetpotatoes in the developed world and for the role of the crop for food security in the developing world. Longterm storage of sweetpotatoes requires inhibition of sprouting, while stimulation of sprouting is necessary for the production of planting material. Many studies have been conducted on the control of sprouting/dormancy of potatoes whereas sprouting in sweetpotatoes is rarely studied. Recently, exposure to ethylene has been introduced as a commercial method for controlling sprouting in potatoes. Data presented here shows that 20 ppm ethylene is effective in controlling sprouting in sweetpotato over 4 weeks of storage at 25°C. Trials using gibberellins and gibberellin synthesis inhibitors showed that the gibberellins are implicated in the stimulation of sprouting in sweetpotatoes. The results are discussed within the context of hormonal control of sprouting in root crops.

## Effect of ethylene and 1-MCP treatment on the biochemistry and physiology of onion bulbs (*Allium cepa* L.) during storage

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The storability of onion bulbs is dependent on the rate of sprout growth. Maleic hydrazide is a sprout suppressant commonly applied pre-harvest to extend storage life of onions. However, growing public concern over chemical residues has led to alternative methods to be developed. When applied exogenously, ethylene causes varying symptoms in a range of fruits and vegetables and has been demonstrated to act as a sprout suppressant in onion, despite consensus defining onion bulbs as non-climacteric. However, a dichotomy exists whereby the ethylene binding inhibitor, 1-methylcyclopropene (1-MCP), also acts as a sprout suppressant in onion. The aim of this study was to understand the mechanisms by which exogenously applied ethylene and 1-MCP affect onion biochemistry and physiology during storage. Onion cvs. Wellington and Sherpa were treated with 0 (control), 10  $\mu\text{l l}^{-1}$  ethylene or 1  $\mu\text{l l}^{-1}$  1-MCP for 24 h at 20°C. Replicated outturns were sampled thereafter during prolonged storage at 0°C. Following treatment and at each outturn, onion bulbs were placed in hermetically sealed jars and gas samples taken for gas chromatography analysis. Data suggest that both ethylene and 1-MCP initially increase respiration rate in both cultivars. Further biochemical and physiological analysis will be conducted towards the end of storage.

## Effect of individual shrink wrapping and modified atmosphere packaging of 'Bhagwa' pomegranate fruit on long term storage and quality maintenance

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Pomegranates are considered the exotic treasures of the fruit world for their highly prized ruby-red arils hidden beneath a thick peel. They contain powerful antioxidants which may help the body fight diseases, lower blood pressure and reduce the risk of heart disease. The major postharvest problem of pomegranate is desiccation of fruit resulting in dullness, toughness, deformation and discolouration of peel leading to unmarketability. Modified atmosphere packaging (MAP) and Individual shrink wrapping (ISW) are important postharvest packing techniques to extend the storage life of many perishables fruits and vegetables. In the present study, the feasibility of exploiting these techniques for extending the storage life of high value fruits like pomegranates was investigated. Freshly-harvested mature 'Bhagwa' pomegranate fruit were either individually shrink wrapped or MA-packed with three different types of polymeric films, i.e. BDF-2001, D-955 and LDPE and stored at low temperature (80-85% rH) and ambient conditions (25-30°C & 60-70% rH). The effects of MAP and ISW on extension of storage life and quality attributes like antioxidants (ascorbic acid, total phenols, total flavonoids and anthocyanins), total antioxidant capacity, acidity, sugars and organoleptic quality were studied at regular intervals. At ambient conditions, pomegranates could be stored in harvest fresh condition for 3 weeks by MAP and 1 month by ISW with < 1.0% weight loss, compared with > 20% weight loss in non-wrapped fruits. At 8°C, the fruit could be stored for 3 months either by ISW or MAP with least weight loss of < 1%, compared with > 15% weight loss in non-wrapped fruit. Shrink wrapping and MA packaging significantly maintained peel moisture content, peel thickness and helped in retention of vitamin C, total phenols, anthocyanins and had better organoleptic quality, compared with non-wrapped fruit. Among the different films, D-955 film followed by LDPE film was best for maintaining the fruit quality. Shrink wrapping proved to be a very useful technique in greatly reducing the weight loss and extending the storage life of pomegranates both at ambient and low temperature storage conditions.



## Variation in vase life of cut rose cultivars and soluble carbohydrates content

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Postharvest characteristics of 10 cultivars of *Rosa hybrida* were investigated. The way of flower opening varied among cultivars and the cut flowers of some cultivars did not open completely. The vase life markedly varied among cultivars. It was the shortest in 'Black Magic' (5.6 days) and the longest in 'Maroussia' (14.3 days). There was no correlation between vase life and transpiration rate of cut roses. Treatment with sucrose plus 8-hydroxyquinoline (HQC) markedly promoted petal reflection and inhibited bluing. Concentrations of glucose, fructose and sucrose in petals of some cultivars that had better longevity were much higher than others. No difference was found among cultivars in soluble carbohydrate concentrations in stems and leaves. Ethylene production among cultivars was different and long-lived cultivars produced lower ethylene amounts than short-lived cultivars. The results suggest that the longer vase life of some cultivars versus others may be attributed to higher soluble carbohydrate concentrations in petals and low ethylene production of the flowers.

## Composition of bioactive substances in tomato fruits as affected by moderate UV-B radiation

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Tomato fruits are a rich source of bioactive compounds such as carotenoids, phenols, and hydrocolloids. In order to increase health-promoting compounds in fruits we studied whether the application of moderate UV-B radiation can have an elicitor effect on secondary plant metabolism and thus subsequently change bioactive compound concentrations and composition in tomato fruits without morphological defects. Tomato fruits cv. *Liberto* were subjected to UV-B radiation before and after harvest with an UV-B dosage of 0.075 and 0.15 Wh m<sup>-2</sup>, using an UV-B fluorescence light source (FL 20SE) at a distance of 40 cm from plants with fruits (preharvest) and harvested fruits (postharvest). After different adaptation times up to 66 h the concentrations of carotenoids, total phenols, flavonoids and hydrocolloids in ripe tomato fruits were determined. UV-exposure before and after harvest caused an accumulation of lycopene, water-soluble pectin and  $\beta$ -carotene. The highest increase in lycopene was induced with a preharvest UV-B dosage of 0.075 Wh m<sup>-2</sup> after 22 h of adaptation and a postharvest UV-B dosage of 0.15 Wh m<sup>-2</sup> after 48 h adaptation time. In contrast,  $\beta$ -carotene concentration was mainly affected by postharvest UV-B applications of 0.075 and 0.015 Wh m<sup>-2</sup> with increasing concentrations up to an adaptation time of 48 h. The present results indicated that the synthesis of bioactive plant compounds was promoted by moderate UV-B radiation before and after harvest. However, it was demonstrated that time and duration of the UV-exposure led to a plant compound-specific response, which has to be investigated in further experiments. In general, it is concluded that moderate UV exposure might have beneficial effects on the accumulation of bioactive compounds and thus, might be a suitable tool to increase health-promoting components by appropriate pre- and postharvest treatment.

## Physical postharvest elicitors UV and ozone as mediators for changes in textural properties of white asparagus (*Asparagus officinalis* L.)

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Spears of white *Asparagus officinalis*. are developmentally immature and rapidly growing shoots. After harvest they retain their physiological activity and even continue growth at high rates. As asparagus spears are purchased as a fresh commodity but also increasingly as convenience product (i.e. sliced, fresh-cut), quality assurance has to focus on the retardation of metabolic processes after harvest on the one hand and on the other hand has to meet hygienic requirements. Due to new food safety regulations (HACCP, traceability), the optimization of postharvest treatments and storage requirements is an essential tool for the food supply chain management of asparagus. The application of short-term UV radiation and ozonated wash water is known for disinfection of pathogenic organisms in numerous food products. Hence, the aim of our investigation was to evaluate the stress-mediated plant responses of physical elicitors such as UV and ozone on textural properties and on the storability of asparagus spears. After harvest, 'Gijlim' asparagus spears were subjected to a) short-term UV-B application (UV dosage:  $8.2 \text{ J m}^{-2}$ ) for 60, 90 or 120 min using an UV-B fluorescence light source (FL 20SE, 305-310 nm) or b) additionally submerged in ozonated water (4 ppm) for 2 min. After an adaptation time of 2 and 22 h cell wall composition (mono- and disaccharides, pectic substances, cellulose, hemicellulose, lignin, protein) were analysed and mechanical properties (dynamic stiffness coefficient, tissue strength) and water status were determined. Non-treated spears were used as control. An aliquot of postharvest treated spears were stored at 2°C and 20°C for up to seven days. UV and ozone treatment revealed a pronounced effect on the synthesis of cell wall composition and mechanical properties of asparagus spears. Results will be discussed and outlined in terms of possibilities and constraints for the application and transfer in food chain systems.

## Impacts of different maturity stages and storage on nutritional changes in raw and cooked tubers of orange-fleshed sweet potato (*Ipomoea batatas* L. Lam) cultivars

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Sweet potato (*Ipomoea batatas* L. Lam), the seventh most important food crop of the world is an important member of the root and tuber crops which are also considered as the most important food crops after cereals and grain legumes. Being rich in  $\beta$ -carotene, a precursor of vitamin A, orange-fleshed sweet potatoes have emerged as an important biofortified crop in many developing countries to alleviating Vitamin A malnutrition and thereby combating night blindness of children. But the stage of harvest maturity with optimum yield and nutritive value differs among the cultivars. In addition, consumer acceptability, cooking quality and storability of the tubers should be taken into account for selecting new cultivars of orange-fleshed sweet potato. The present study evaluated fifteen orange-fleshed sweet potato cultivars harvested at 75, 90, 105 and 120 days after planting (DAP). A linear increase in dry matter (17.21-26.52%), starch (4.97-17.38%) and total sugar content (1.74-2.79%) of the tubers of different cultivars were found throughout the harvesting periods starting from 75 to 120 DAP, while  $\beta$ -carotene content showed an increasing trend (2.75-11.57 mg/100g) only up to 105 DAP and a declining trend in ascorbic acid content (32.34-13.75 mg/100g) was observed with maturity of the tubers. Although some of the cultivars were found to be early maturing types, it is worthwhile to harvest the tubers of most of the cultivars at around 105 DAP considering the productivity, nutritional quality and consumer acceptability. During cooking a slight reduction in  $\beta$ -carotene content of the tubers was found along with the significant differences among the cultivars in nutrient composition of the cooked tubers. Thus, consumption of some of the orange-fleshed sweet potato cultivars like ST-14, 372-7, Kamala Sundari, CIPSWA-2 and 440038 with high retinol equivalents can make a significant contribution in alleviating vitamin A malnutrition and combating night blindness.

## The effect of packaging materials and technologies on storability of fresh black currants

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Black currants have been classified as a non-climacteric fruit, exhibiting no increase in respiration rate or ethylene production during ripening. As a typical soft fruit they have a high physiological post-harvest activity, and a short ripening and senescence period. The objective of this study was to determine the possibility of prolonging black currant storage time, reducing moisture loss and texture changes by packaging in different materials. The effect of packaging material for prolongation of storage time were determined by using ready-made PET/adhesive/PP containers; PP (polypropylene) trays coated with biodegradable PLA films with a thickness of 25 or 40  $\mu$  OPP (oriented polypropylene) material with film thickness 40  $\mu$  carton boxes placed in PLA films, with thickness 25 and 40  $\mu$  and PP boxes with holes, and carton boxes as a control. The samples were stored in light "Commercial Freezer/Cooler ELCOLD" at +4°C. The moisture losses, changes of pH value and texture as well as composition of gasses were analysed for all samples during the period of three weeks.

## Cell wall-modifying enzyme activities after controlled atmosphere storage of calcium-treated 'Fuji' apples

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Refrigeration of apple (*Malus x domestica* Borkh.) fruit, both under air or hypoxic conditions, is a widespread technology used to delay many ripening-related modifications, and thus to extend commercial life of produce. These changes include modifications in the cell wall structure, which are believed to underlie changes in fruit firmness and texture, and are largely driven by different related enzyme activities. A number of post-harvest procedures, including treatment with calcium solutions, has been tested to delay fruit softening as well as the incidence of some apple-specific physiological disorders. In this work, fruit of the apple cultivar 'Fuji Kiku-8' were picked at commercial maturity, treated with 2% (w/v) CaCl<sub>2</sub> for 5 minutes, and stored for 7 months at 1°C and 92% rH under either air or two different controlled atmosphere (CA) regimes (3 kPa O<sub>2</sub> : 2 kPa CO<sub>2</sub> and 1 kPa O<sub>2</sub> : 2 kPa CO<sub>2</sub>). Different cell wall-modifying enzyme activities were determined 7 days after removal from storage in order to assess relationships, if any, to changes in fruit firmness induced by calcium treatment and/or storage atmosphere. Applied calcium was effective in preserving firmness of air-treated fruit, but no significant differences in this attribute were found for samples kept under CA regardless of treatment. In contrast, applied calcium enhanced polygalacturonase (PG) and pectin methyltransferase (PME) activities in CA but not in air-stored samples. As regards storage atmosphere, hypoxic conditions led to increased PG, endo-1,4-β-D-glucanase (EGase) and pectate lyase (PL) activities after cold storage, whereas β-xylosidase β-Xyl) activity was inhibited by low oxygen concentrations.

## Effect of chitosan applied as coating on mandarin clementine 'Oronules'

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Citrus fruit are coated during postharvest handling to improve their appearance and extend their shelf life. Chitosan, a bioactive polysaccharide with antimicrobial and biostimulant activities as well as film forming properties, could be used as coating of fruits and vegetables. In the present study a commercial solution of chitosan was applied on mandarins 'Oronules' to investigate its effect when applied as coating at different solid content (0.6, 1.2 and 1.8%). Additionally, one group of mandarins was coated with a commercial wax, and another group remained uncoated. Mandarins were stored at 5°C up to 30 days followed by 7 days at 20°C simulating retail conditions. All coatings applied restricted gas exchange and modified internal atmosphere of the fruits compared with uncoated mandarins, with a greater effect at higher chitosan concentration. Chitosan-coated mandarins at higher solid content had the highest CO<sub>2</sub> internal atmosphere content and the highest ethanol content. Even though chitosan applied at 0.6% increased the internal level of CO<sub>2</sub> of the mandarins, this coating did not increase the amount of ethanol compared with uncoated mandarins. Chitosan application did not decrease weight loss of mandarins during storage whereas the commercial wax decreased weight loss of mandarins compared to control. The internal quality of mandarins was not affected by coating application. All coatings applied increased the gloss of the fruit. In order to improve the water barrier properties of the chitosan coating it would be necessary to add hydrophobic components to the formulation.

## Modifications in cell wall composition after storage of 1-MCP-treated peach fruit

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Softening of peach (*Prunus persica* L. Batsch) fruit is usually rapid at ambient temperature, and limits considerably commercial life of the produce. The decline in fruit firmness during ripening and storage is largely the result of a coordinated series of modifications to the polysaccharide components of the primary cell wall and middle lamella, leading to disassembly and weakening of the structure. In this work, suitability of controlled atmosphere (CA) storage and 1-methylcyclopropene (1-MCP) treatment to delay these changes and thus to extend storage potential of peach was tested. Fruit of 'Tardibelle', a late-harvesting cultivar, were picked at commercial maturity, treated with  $1 \mu\text{l l}^{-1}$  1-MCP at 1°C for 24 h, and stored for 21 days at 0°C under either air or CA (3 kPa O<sub>2</sub> : 10 kPa CO<sub>2</sub>). Cell wall materials were extracted in phenol : acetic acid : water (PAW) and fractionated immediately after storage and 7 days thereafter, in order to assess a possible relationship to changes in fruit firmness. Yield of both PAW- and water-soluble fractions increased during the post-storage period, indicating solubilisation of cell wall during the shelf life of fruit. Accordingly, yields of cell wall materials and of pectin-containing fractions (CDTA- and Na<sub>2</sub>CO<sub>3</sub>-soluble) declined, possibly in relation to the decrease in flesh firmness. The increase in yield of PAW- and water-soluble fractions along post-storage at 20°C was attenuated by 1-MCP treatment, which proved more effective than CA storage in delaying solubilisation of cell wall polymers. The effects of both post-harvest handling procedures on the distribution of cell wall polysaccharides among the different fractions assessed will be discussed.



## Aroma volatile compounds influencing sensory acceptability of 'Golden Reinders' apples after ULO storage

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Although current commercial practices usually disregard fruit aroma, this attribute is an important aspect influencing the sensory quality of produce. The aroma profile of a fruit is complex and depends on the combination of all volatile compounds emitted, as well as on the concentration and odour threshold of each individual compound. The aim of this work was to find out those aroma compounds having most influence on consumer's acceptance of 'Golden Reinders' apples during shelf life after CA storage. Immediately after harvest, 'Golden Reinders' apples were stored at 1°C and 92-93% relative humidity in ultra-low oxygen (ULO: 1% O<sub>2</sub> + 1% CO<sub>2</sub>). One batch of ULO-stored fruit remained under this atmosphere for 19 or 30 weeks, a second batch was kept during 17 or 28 weeks in ULO followed by 2 weeks in refrigerated air, and a third batch of fruit was maintained 15 or 26 weeks in ULO followed by 4 weeks in refrigerated air. After storage, volatile compounds and consumer's acceptance of fruit were analyzed after 1 and 7 days at 20°C. Data were subjected to principal component analysis (PCA) in order to characterise fruit after storage. PC1 and PC2 accounted for 64% of total variance. The biplot of PC1 vs. PC2 for this model showed that acceptability was correlated to some aroma compounds, namely hexyloctanoate, ethylacetate and ethyl 2methylbutanoate. Moreover, samples receiving the highest scores in acceptability were those stored for 19 weeks, apparently in relation to higher emission of hexyloctanoate, ethylacetate and ethyl 2methylbutanoate, whose odour descriptors include "fruity" and "ripe apple".

## Relationship between non-structural carbohydrate concentrations and total soluble solids in litchi cv. Mauritius fruit stored at low temperature

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Although total soluble solids (TSS) are routinely used to assess “sweetness” in litchi fruit, the relationship between sugars and TSS has not been fully defined. The aim of this study was to compare changes in TSS vs. non-structural carbohydrate concentrations in litchi fruit. Litchi cv. Mauritius fruit ( $n = 432$ ) were stored at low temperature (5, 8, 10 and 13°C) for 13 days. Juice from fresh aril tissue was measured for TSS [%]. Aril tissue was subsequently extracted and non-structural carbohydrates (viz. fructose, glucose and sucrose) quantified using standard HPLC. The main sugars in aril tissue were glucose (275.5 mg g<sup>-1</sup> dry weight (DW)), fructose (270.5 mg g<sup>-1</sup> DW) and sucrose (170.2 mg g<sup>-1</sup> DW). TSS and sucrose concentrations were significantly higher in fruit stored at 5°C than at 8, 10 or 13°C, whereas the highest glucose and fructose levels were found at 13°C. Total sugar concentrations fluctuated between 516.8 and 844.8 mg g<sup>-1</sup> DW and did not correlate to TSS ( $R^2 = 0.003$ ). It is, thus, recommended that alternative methods to TSS be used to assess ‘sweetness’ in litchi fruit.

## Antioxidant capacity and total phenolics in peel and pulp of two Pakistani mango cultivars during high temperature storage

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The increased consumption of fresh produce, naturally rich in antioxidant products, has been associated with reduction in the incidence of cardiovascular diseases and cancer, and also with the prevention of degenerative diseases. There is, however, a lack of published data on profiling antioxidant capacity in mango fruit. A study was designed to determine the total antioxidant capacity (ferric reducing antioxidant power; FRAP) and total phenolics (TP; Folin-Ciocalteu) contents from peel and pulp of two important Pakistani mango cultivars (viz. Faiz Kareem and Chaunsa) during high (32°C) temperature storage. On a dry weight (DW) basis mean FRAP values for mango pulp were 8.08 mM Fe<sup>+2</sup> g<sup>-1</sup> (cv. Faiz Kareem) and 9.15 mM Fe<sup>+2</sup> g<sup>-1</sup> (cv. Chaunsa) whilst TP levels ranged between 1.05 to 1.28 mg gallic acid equivalents (GAE) g<sup>-1</sup>. In contrast, peel extracts for both cvs. Faiz Kareem and Chaunsa exhibited significantly higher mean values for FRAP (181.36 and 328.10 mM Fe<sup>+2</sup> g<sup>-1</sup>) and TP levels (30.55 and 50.69 mg GAE g<sup>-1</sup>), respectively. Health implications of the differences in antioxidant capacity between mango peel and pulp tissue are discussed.

## Cultivar variation in apple fruit firmness and texture during maturation, ripening, and storage

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Firmness and texture dynamics of apple cultivars ('Delicious', 'Fuji', 'Gala', 'Golden Delicious', 'Honeycrisp', and 'Pink Lady') with a range of maturation and ripening characteristics were instrumentally assessed. Apples were harvested on multiple dates during maturation, and fruit from a harvest at or near physiological maturity were stored in air or a controlled atmosphere. The influence of ethylene action on firmness and texture was assessed by treating some fruit with 1-MCP prior to storage. Parameters measured using whole fruit with a section of peel removed included firmness in the outer and inner cortex, creep (deformation under constant load), and viscoelasticity. Signal processing was used to generate an estimate for fruit crispness. Cultivar-specific patterns were identified indicating that changes in inner cortex firmness, creep, crispness and/or viscoelasticity occur in the absence of outer cortex softening. The reverse pattern, decreased outer cortex firmness without change in one or more of the other parameters measured, also was observed. Postharvest treatment with 1-MCP and/or storage in a controlled atmosphere also differentially impact these firmness and texture parameters. The results indicate that a range of firmness and texture patterns is discernable during ripening of the cultivars evaluated and that additional measurements of apple physical properties may identify changes during ripening that are not apparent with a measurement of outer cortex firmness alone.

## Effect of fruit maturity indices and hot water treatment on mango fruit quality

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Maturity index is of paramount importance as storage life and quality of the mango fruit depends on the stage of harvest maturity. In Pakistan, maturity indices for mangoes have not yet been standardized. The objective of this study was to assess fruit maturity indices for commercial mango cv. Samar, Bahisht, Chaunsa and Sindhri in order to develop a reliable maturity index. Mango fruit were harvested at different times within conventional harvesting season and categorized into possible range of specific gravities. Three classes were designed as 1.00-1.02, 1.02-1.04 and >1.04. After categorization of fruit, fruit were further divided into two sets. One set was considered as control (without hot water treatment) while the other set was subjected to hot water treatment (HWT), as per import requirement of China (48°C for 60 minutes). Percentages of other maturity indices, including skin colour, pulp colour (RGB colour scheme), TSS, shoulder position, skin roughness and dry matter contents were also recorded for each class and treatment. After HWT application, fruit were packed in wooden crates and kept at ambient temperature (30°C and 60-65% rH) for ripening. At ripe stage, quality analysis (TSS, total titrable acidity, ascorbic acid and sugar contents) and organoleptic evaluation was done. In cv. Chaunsa fruit with specific gravity 1.02-1.04 was found to be better due to higher TSS (23.91°Brix) and total sugar content (7.72%). Skin roughness was prominent in fruit with 1.00-1.02, while absent in fruit with higher specific gravities i.e. >1.02. Fruit ripening pattern and initially recorded RGB values of fruit pulp colour (Red: 200-250; Green: 195-247; Blue: 85-170) under different specific gravities were reproduced to be included in mango field guide for farmers and extension workers. Manuscript further explains methodology and detailed discussion of two cvs and important issues resolved during these studies.

## Preliminary results on some constitutional changes in 1-MCP treated quince (*Cydonia oblonga* Mill.) fruits during cold storage period

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In this research, the effect of 1-methylcyclopropene (1-MCP) treatments on compositional parameters was investigated in quince cv. Ekmek and Esme fruits during cold storage period. Following commercial harvest, at the beginning of October, fruits were treated with 1-MCP at 300 nl l<sup>-1</sup> and 1000 nl l<sup>-1</sup> doses at 12°C temperature in air for 24 h and then stored at 0±1°C and 85-90 relative humidity conditions for six months. During the cold storage period, some compositional components such as sugars, organic acids, vitamin C, phenolic compounds were determined by using high pressure liquid chromatography in fruit flesh taken from samples at monthly intervals. The amounts of different compounds were calculated according to external standards. The results show that the amount of various nutritional components was affected by the cultivar, storage period and 1-MCP treatment. At the end of cold storage period of six months, while Esme fruits treated with 1-MCP at 1000 nl l<sup>-1</sup> had higher fructose (4596 mg kg<sup>-1</sup>), galactose (198 mg kg<sup>-1</sup>), sucrose (693 mg kg<sup>-1</sup>), malic acid (4010 mg kg<sup>-1</sup>) and 3 caffeoylquinic acid (229 mg kg<sup>-1</sup>) levels, while Ekmek fruits having the same treatment had higher vitamin C content in addition to the other components. Based on these results, 1-MCP treatment at 1000 nl l<sup>-1</sup> could be taken into consideration as a promise postharvest application for decreasing loss of compositional substances in the fruits of Ekmek and also Esme quince cultivars.

## Reducing enzymatic browning of fresh-cut eggplants by antioxidant application

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Fresh-cut eggplants, as other vegetables, have a very short shelf-life due to tissue disruption and increased metabolism. Enzymatic browning is a major problem reducing shelf-life due to the reaction of phenolic compounds with the release of endogenous polyphenol oxidase and the diffusion of atmospheric oxygen into the tissue. The main approach to inhibit browning is the use of antibrowning agents based on citric acid or ascorbic acid. In this work, the objective was to study the effect of a wide range of antioxidants reducing enzymatic browning of fresh-cut eggplants. Fresh-cut eggplants were dipped in ascorbic acid (AA), citric acid (CA), peracetic acid (PA), cysteine (Cys) and 4-hexylresorcinol (4-HR) at different concentrations. Color and sensory evaluation were performed during storage at 5°C. Among the antioxidants studied, AA and Cys were the most effective reducing browning, whereas the rest of the antioxidants caused tissue damage, which translated into higher browning than control samples. AA was effective in a range of concentrations of 0.35% and 0.88%, whereas concentrations above 1.5% induced higher browning than control samples. Cys was effective in a range of concentrations of 0.1% to 1%, and the effectiveness of preventing browning increased as concentration increased. The loss of effectiveness was faster in AA than in Cys treatments. The limit of marketability for samples dipped in 0.88% AA and in 0.5% Cys and stored at 5°C was 2 and 9 days, respectively. After 9 days of storage at 5°C, samples dipped in 1% Cys were still evaluated as very good. These results show the potential of Cys as antioxidant to control enzymatic browning of fresh-cut eggplants.

## Changes in colour and antioxidants during vine and postharvest ripening process of tomato fruits

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Tomato fruit ripening is a complex, genetically programmed process that culminates in dramatic changes in texture, colour, flavour, and aroma of the fruit flesh. The characteristic pigmentation of red ripe tomato fruit is due to the deposition of lycopene, the predominant carotenoid found in tomato fruit, and  $\beta$ -carotene, which are associated with the change from green to red as chloroplasts are transformed to chromoplasts. Detached tomato fruits stored at 15°C and 30°C, and those vine ripened on the plant were studied, to characterize ripening process by Hue° index of CIELab colour system, which was strongly influenced by circumstances of ripening. Changes in colour of fruits stored at 15°C and vine ripened fruits showed significant differences versus fruits at 30°C. Polyphenols, vitamin C and lycopene content of tomato fruits were analysed at the end of the experiment. Storage temperature influenced vitamin C and lycopene content, while polyphenols did not show significant differences among the different storage conditions.



## 1-Methylcyclopropene application suppresses lipid peroxidation and increases antioxidant enzyme activity in cold-stored Sekaki papayas

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The effects of postharvest application of 1-methylcyclopropene (1-MCP) at 270 ppb for 12 hours on lipid peroxidation and activities of superoxide dismutase (SOD), ascorbate peroxidase (APX) and catalase (CAT) in papayas (*Carica papaya* cv. Sekaki) stored at 10°C for four weeks were studied. Papaya fruits treated with 1-MCP exhibited lower malondialdehyde (MDA) content when transferred to ambient temperatures for ripening as compared to the non-MCP treated fruits suggesting that lipid peroxidation was suppressed by the 1-MCP. In addition, the activities of SOD, APX and CAT were also elevated by the treatment. Chilling injury incidence was slightly alleviated; however loss of tissue firmness was decreased. These results suggest that 1-MCP, being an antagonist of ethylene action, may reduce cellular disintegration that involves development of oxidative stress through the enhancement of some antioxidant enzyme activity and prevent ethylene-associated degradation of cell wall components that leads to tissue softening.

## The role of carbohydrate metabolism during wound-healing of sweetpotato roots at low humidity

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Sweetpotato cultivars differ in the efficiency by which their roots can heal wounds at low humidity, although this does not appear to relate to rate of wound-healing at high humidity. A negative relationship occurs between cultivar root dry matter (DM) content and efficiency of root wound-healing at low humidity assessed by a lignification score (LS). Root dry matter content tends to be negatively related to root sugar levels. The study presented here was undertaken to examine further the role of carbohydrate metabolism in root response and ability to heal wounds in the presence of water stress. Data from 17 cultivars confirmed the negative correlation between LS and DM and the positive correlation between LS and root sugar levels. Measurement of sugar levels at the root surface both at the time of wounding and after complete healing (5 days) for 10 cultivars indicated a stronger relationship of LS with final sugar levels than initial DM content. This was confirmed in experiments using a system of adjacent tissue cuboids cut from the parenchyma which were able to exhibit lignification almost as efficiently as whole roots. With this system it was also possible to demonstrate a relatively rapid accumulation of sugars within 24 hours of healing. The data was examined by the development of linear regression models of LS. Comparison of the levels of variance accounted for by the models indicates that LS is strongly cultivar dependent, and most of the cultivar effect is related to cultivar differences in sugar levels during wound-healing. Differences in sugar levels between roots/cuboids of each cultivar also have an effect. Further, the similarity of the models for the whole roots and cuboids gives us confidence in the validity of using the cuboids to investigate wound healing of whole roots. The hypothesis is put forward that sugar accumulation provides osmotic protection of water stressed tissues.

## Growth conditions affect the turgor of flower buds of cut roses

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Keeping quality of summer and winter-grown cut roses can greatly differ. In general, summer-grown roses show a longer vase life than those produced in winter. In central and northern Europe greenhouses cultivation of roses in winter is only possible with supplementary lighting. Vapour pressure deficit (VPD) and temperature sum were lower in winter than in summer. One important factor influencing the vase life of cut roses is the water regime during growth and in postharvest. In this study, the water status of flower bulbs and peduncles was investigated at the point of harvest to identify the parameters that determine postharvest life. Turgor ( $\Psi_p$ ) was calculated as the difference of tissue water potential ( $\Psi$ ), determined either by pressure bomb measurements (flower buds) or psychrometrically (peduncle tissue) and osmotic potential ( $\Psi_{sPi}$ ), psychrometrically obtained from cell sap extracts. Out of four cultivars investigated in the presented study three ('Akito', 'Aloha' and 'Red Giant') followed the above given generalisation. In contrast, flowers of the cultivar 'Milva' exhibited a longer vase life in winter than in summer. Winter-grown roses of all cultivars reveal a significantly lower mean flower bud turgor ( $\Psi_p$ -flower). However, only in winter grown 'Aloha' roses the turgor of the tissue in the upper third peduncle part ( $\Psi_p$ -peduncle) was significantly different from  $\Psi_p$ -flower. The water potential of peduncles did not significantly differ between summer and winter-grown flowers. In 'Akito', 'Aloha' and 'Red Giant' we found no significant differences in  $\Psi$ -flower between summer and winter. However, summer-grown flowers of the cultivar 'Milva' exhibited significantly lower water potentials. The generally lower  $\Psi_p$ -flower in winter can be explained by the significantly less negative  $\Psi_{sPi}$  in flowers of all cultivars. It can be concluded that the osmotic potential is the decisive factor enabling plants to control water flow into the flower buds under normal vase life conditions. The lower content of osmotic active substances in winter-grown roses may result from the reduced assimilation under the low light conditions of supplementary lighting. However, vase life and  $\Psi_{sPi}$ -flower did not correlate for the four investigated rose cultivars.

## Evaluation of rutin of murta extracts on the permeability of carboxymethylcellulose edible films

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Leave extracts of the Chilean native plant murta (*Ugni molinae* Turcz) show, through HPLC analysis, rutin (C<sub>27</sub>H<sub>30</sub>O<sub>16</sub>) peaks of different areas for different ecotypes, as was shown before for other flavonol glycosides. The rutin is known as antioxidant, but in the present work, the interest is focused on its polyphenolic structure, and its effect on permeability properties of films, when prepared at rutin concentrations approximately similar as found in three different murta ecotypes. Films were prepared with carboxymethylcellulose (CMC), sunflower oil, glycerol as plasticizer and: water for control treatment (CMC-H<sub>2</sub>O), or different rutin aqueous solutions (CMC-rutin concentration), or murta extract of one of the three different ecotypes (CMC-ecotype extract). The film forming solution was poured and spread onto an acrylic plate level fitted with rims, was allowed to dry at room temperature, peeled off and kept conditioned at 25°C in NaBr (58% relative humidity). For gas permeability measurements, samples of films were cut (7 x 7 cm) and thickness measurements were done at seven random positions with a micrometer of sensitivity 0.001 mm. HPLC chromatogram analysis of rutin of Sigma-Aldrich, showed a retention time of 44.51 min, and the murta ecotypes, retention times of 43.45-45.67 min. Then the area was estimated for the rutin peak of each ecotype and thereafter, the rutin was incorporated in three different concentrations, 16, 22, 55 µg/g, according to the rutin content of the three murta ecotype extracts selected for films called CMC-rutin. Results show a slightly higher permeability to CO<sub>2</sub> at lower rutin concentration in the film, which are higher than CO<sub>2</sub> permeability values of the films with CMC-ecotype. The H<sub>2</sub>O permeability analysis did not show significant differences among the samples. Comparing to previous results there can be said that rutin is one of the extract components affecting water and gas permeability of CMC-murta extract films. We acknowledge projects DIUFRO N° 120617 and INNOVA N° 06CN12PAT-57

## Comparison of susceptibility to postharvest rots of Conference pears produced organically and conventionally

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Given the increasing importance of organic produce, a study was carried out to find out how organic production methods affect the post-harvest and storage quality of 'Conference' pears (*Pyrus communis*). When fruit were taken out of cold storage and artificially-infected with either *Monilinia fructigena* or *Penicillium expansum* disease development was significantly slower in organic pears than in conventional pears. The effects were more marked for *M. fructigena* which is the more aggressive pathogen (about 20% inhibition of lesion growth rate), compared with a smaller, but significant, effect on *P. expansum* (5-10% inhibition of lesion growth rate). Organic pears had a higher dry matter content (15.6% compared with 14.7%) and were firmer than conventionally-produced fruit (e.g. 6.9 kg compared with 5.8 kg after 6 months storage), which may affect the rate of pathogen growth. In addition, it has been postulated that organic produce has a higher phytochemical content produced naturally by plants to protect themselves against bacteria, viruses, and fungal infection. Analysis of total phenols indicated an increase induced by infection by either pathogen, but no significant differences either before or after infection between organically- and conventionally-produced pears. Profiles of phenolic content in organically- and conventionally-produced pears provide no clear explanation of the differences in resistance.

## Role of oxidative stress in chilling injury incidence of Satsuma mandarin fruits

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Susceptibility of Satsuma mandarin fruit to chilling injury limits its fresh marketability. In this study, the effect of various heat treatments (hot water washing and dipping) on chilling tolerance based on antioxidant enzymes in fruits peel of Satsuma mandarin were investigated. All treatments applied in this study suppressed chilling injury symptoms development in mandarin fruits but none of them could prevent it completely. The major reduction of chilling injury incidence and severity was found for fruits that were previously immersed at 50°C for 30 seconds or 2 min. The higher hot water temperatures not only couldn't reduce chilling injury development, but also increased heat damage. One day after treatments, CAT and POX activity in fruits exposed to hot water treatments was slightly higher than the non-heated fruits. At the end of 8 weeks storage at 2°C a slight change was found for CAT, while POX activity increased significantly. A rapid increase in POX activity was associated with increased peel damage from both chilling injury and heat treatments. Overall, decreasing chilling injury symptoms in 'Satsuma' mandarin after exposure to various heat treatments was due to suppression of the increase in POX activity and preventing the decline of CAT activity during storage periods.

## Physico-chemical characteristics of 'Bellezza' a new hybrid of mandarin

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'Bellezza' is a hybrid of *Okitsu satsuma* x *Carvalhais mandarin* released in 1996 by the DOFATA of the University of Catania (Italy). The fruit has a quite large size with a weight normally higher than 120 g, is oblate in shape, seedless in absence of cross-pollination and ripens in December. The overall aspect of 'Bellezza' mandarin is very attractive (in Italy "Belezza" stands for beauty) with the deep orange colour of the peel and the aromatic juicy flesh. Objective of this trial was to compare the physico-chemical and nutritional characteristics of 'Bellezza' mandarins with the two parents *Okitsu* and *Carvalhais*. In particular, the juice pH, titratable acidity, soluble solids, ascorbic acid, total phenols, sucrose glucose, fructose, and flavonoids together with its antioxidant activity were periodically monitored. The results indicate that 'Belezza' mandarins ripen later than the two parents and hold well on the three until the end of December. Titratable acidity was slightly higher than both parents as were sugars and ascorbic acid content. 'Bellezza' mandarins also had a higher level of total phenols and of narirutin and dydimin flavonoids. The overall positive characteristics of 'Bellezza' mandarins (pleasant taste, attractiveness of the fruit, high content of nutritional compounds) superior to the parents, make this new hybrid of mandarin worth of introduction in commercial orchards.

## Changes in starch degradation patterns in apple cultivars held on-tree and off-tree at different temperatures

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The rate of deterioration of apples in storage and the sensory quality after storage is influenced by their maturity and ripening status at harvest. One important harvest parameter is the starch degradation pattern, typical for each apple variety. Starch hydrolysis continues during apple ripening on the tree and in storage, however, the speed of starch degradation in fruit on-tree and in fruit off-tree stored at different temperatures is not known. This research evaluates the changes in starch pattern of the following four apple cultivars 'Gala', 'Elstar', 'Jonagold' and 'Golden Delicious' held both on-tree and off-tree at different storage temperatures (1°C, 10°C, and 20°C) in air. Every two or three days over a 4 week harvest window appropriate for each cultivar, the starch pattern and the flesh firmness in the stored samples were measured. Fruit held at 1°C showed no significant change in starch degradation with the exception of the final 'Golden Delicious' storage sample. The starch degradation pattern of fruit stored at 10°C was similar to the fruit remaining on-tree and fruit stored at 20°C had higher starch degradation after 2 weeks when compared with the fruit held at the other temperatures, while 'Golden Delicious' held at 20°C showed clear differences after 3 weeks. 'Gala' flesh firmness only changed significantly after 3 weeks storage at 20°C while 'Elstar' flesh firmness was lower after 2 weeks at 20°C and lower after 4 weeks at 10°C when compared with the 1°C storage treatment. 'Golden Delicious' and 'Jonagold' stored at 1°C softened slower than fruit remaining on-tree.



## **Distribution of sugar components within the KOB heritage apple cultivar collection**

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Sugars and organic acids contribute greatly to the eating experience of fruit. Much of the variation in taste, texture and appearance of apples can be explained by changes in the amounts and ratio of organic acids and sugars. The traditional extensive cultivation of apples is an ecologically valuable component of the Lake of Constance region, in South-Western Germany. Over centuries numerous heritage apple cultivars with a particularly extensive genetic diversity have been selected and optimally adapted to the region and a range of end users. Since April 2004, the Kompetenzzentrum Obstbau-Bodensee (KOB), within the scope of the "INTERREG IIIA Bodensee-Alpenrhein-Hochrhein" project, has maintained a collection of heritage apple cultivars grown in the Bodensee region. The individual sugar components (glucose, fructose, sucrose and sorbitol) and acidity content have been characterized from subset of the approx. 250 heritage apple cultivars. The distribution pattern of individual sugars will be discussed in relation to the cultivar attributes with possible suggestions for processing ability and consumer health.

## Relationship between blackspot susceptibility, turgor and elasticity of potato tubers during storage

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The aim of this study was to build a model that reliably predicts the risk of blackspot development in potato tubers in response to mechanical load during the postharvest processing chain exactly measured with a triaxial impact sensor. The micro technical device with length of 42 mm includes an autonomous data logger for measurement of impact acceleration with a sampling rate of 3200 Hz. It can be implanted in real produces like apples, carrots or potato tubers. In contrast to current artificial measuring spheres this new device considers the mechanical and geometrical parameters of the produces. For determination of the relation between produce specific parameters and blackspot susceptibility hand harvested potato tubers were used. The floury cultivar 'Afra' with high starch content and the waxy cultivar 'Milva' with low starch content from regional production in Brandenburg was chosen. Turgor was calculated from water potential measured with a dew point hygrometer and osmotic potential measured with a vapour pressure osmometer. Elasticity was evaluated with a quasi static compression test and starch content by determination of specific gravity. These parameters are related to blackspot formation inside the tubers on the bud end induced by a controlled drop from a height of 50 cm onto steel using a custom-built apparatus fitted with an impact force sensor. The percentage of damaged 'Afra' tubers increased from 10% to 40%, for 'Milva' from 15% to 38% during the first 3 month of storage time. In contrast to general notion no higher blackspot susceptibility was observed for 'Afra'. During the same period the mean starch content of 'Afra' increased from 17.0% to 18.7%, that of 'Milva' from 14.7% to 15.6%. Turgor changes were less pronounced than those of tissue elasticity. A mass loss of 1.5% reflects a decline in tissue turgor of less than 0.1 MPa between November and January. In earlier studies similar turgor changes were found in potato tubers during storage but an almost stable susceptibility for blackspot bruise. In our experiments, 'Afra' tubers had lower water content than 'Milva', but higher water potential, turgor and elastic modulus which indicates a higher stiffness of 'Afra' tubers. According to the presented results turgor seems to be a less appropriate parameter for prediction of blackspot susceptibility than the elastic modulus.

## Antioxidant capacity and pungency of horcal onion under refrigeration storage

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Onions (*Allium cepa* L.) are beneficial to health; they are attributed to polyphenols and sulphur containing compounds and are one of the major sources of dietary flavonoids. The aim of this study was to determine and evaluate the evolution of pungency, total polyphenols and antioxidant capacity of Horcal onion under refrigeration. Horcal is a typical variety of onion grown in Castilla y León, a region in the north of Spain. Three areas were investigated: a) the different layers of the onion (inner, outer and a mixture); b) the influence of nutrients present; c) the effect of soil type. In all areas of investigation, the parameters were evaluated at the beginning and the end of refrigeration. Onion pungency was measured by pyruvic acid levels. It was observed that: a) Antioxidant capacity, total polyphenols and pyruvic acid content were higher in the outer layers of the onion. During storage, Horcal onion presented a decrease in antioxidant capacity and total polyphenols content but an increase in pyruvic acid content. b) The pyruvic acid content was increased in the presence of a higher nitrogen concentration. The antioxidant capacity and the total polyphenols content were not affected. c) the soil type affected all area studied. In conclusion, the pungency is affected by nutrient level and soil type. The antioxidant capacity and total polyphenols content were solely affected by soil type. At the end of storage, in all areas studied, the pungency increased. The antioxidant capacity and the total polyphenols content sometimes increased, sometimes decreased or stayed the same.

## Effect of ethephon and 1-MCP on peel colour development of banana

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Effect of ethylene-released compound (ethephon) and 1-MCP on ripening of 'Hom Thong' (*Musa acuminata*, AAA Group, non-Cavendish) and 'Grand Nain' (*Musa acuminata*, AAA Group, Cavendish) bananas were studied in relation to color development, chlorophyllase activity, and ethylene production. Fruits with and without ethephon treatment were kept at 25°C. The results showed that peel colour of 'Hom Thong' fruit developed normally, whereas peel colour of 'Grand Nain' fruit did not. Ethephon treatment accelerated chlorophyll degradation as well as chlorophyllase activity in both cultivars and colour development of 'Grand Nain' was still poorer than that of 'Hom Thong'. Chlorophyllase activity in 'Hom Thong' banana peel was higher than that of 'Grand Nain' banana peel resulting more rapid chlorophyll degradation in 'Hom Thong' banana. In contrast, 1-MCP treatment retarded chlorophyll degradation and ethylene production in both cultivars. However, rate of endogenous ethylene production had no correlation with chlorophyllase activity in both cultivars.

## Carbohydrate metabolism in *Dendrobium* flowers after harvest

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Inflorescences of *Dendrobium* 'Pompadour', *Dendrobium* 'Misteen', *Dendrobium* 'Sakura', *Dendrobium* 'Caesar' and *Dendrobium* 'Intuwong' with removal of 0, 50 and 100% open florets were held in the distilled water at 25°C for 15 days. The results showed inflorescences without removal of open florets had less dropping of flower buds and more opening of flower buds than those with removal of 50 and 100% open florets. Inflorescences of *Dendrobium* 'Pompadour' with removal of 0, 50 and 100% open florets had the highest dropping rate of the flower buds compared to other cultivars. *Dendrobium* 'Pompadour' open florets had higher reducing sugars (RS), total sugars (TS) and total non-structural carbohydrates (TNC) contents than flower buds, while large flower buds (old buds) had more RS, TS, TNC contents than small flower buds (young buds). But small flower buds had more non-reducing sugars (NRS) contents than large flower buds. As the holding time advanced, flower buds of inflorescences without removal of open florets had more NRS, RS, TS, TNC contents than those with removal of all open florets. Flower buds in inflorescences with removal of 50% open florets had more NRS, RS, TS, TNC contents than those with removal of all open florets. In final day both large and small flower buds had almost the same NRS, RS, TS, TNC contents. Flower buds had more NRS content than open flowers right after harvest and during holding time. Data showed sugar translocation between open florets and flower buds in flower buds of *Dendrobium* after harvest.

## Prevention of enzymatic browning of Asian pear (*Pyrus serotina* Rehd.) by some anti browning agents

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Fruit harvested at the standard maturity level from a commercial mature Asian pear (*Pyrus serotina* Rehd.) trees cultivar 'KS13' grown on European pear seedling rootstocks at Tarbiat Modares University (TMU) research orchard were used in the present study. Onion and garlic extracts were prepared by extracting onion and garlic with water, and the effects of the extract on Asian pear polyphenol oxidase activity and browning of Asian pear fruit juice were investigated. The polyphenol oxidase of Asian pear was inhibited by onion and garlic extracts, and the inhibitory effect of onion and garlic extracts on Asian pear polyphenol oxidase was increased with the heated extracts treatments. The inhibitory effect of the extracts was increased with increasing heating temperature and time. In addition, results indicated that the inhibitory effect of garlic extract was enhanced in comparison to onion extract. The browning of Asian pear juice was retarded by addition of both fresh and heated onion and garlic extracts. The extracts inhibited the Asian pear polyphenol oxidase activity non-competitively. Therefore, the inhibitory effect of onion and garlic extracts against Asian pear browning seems to be due to the inhibitory effect of onion and garlic extracts against Asian pear polyphenol oxidase activity.

## **Pre-cooling: the key for successful storage of horticulture products in tropical countries**

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Field heat was found to be responsible in stimulating the biochemical changes in the fruit after harvest. The high fruit temperatures measured in the field have been strongly associated with direct exposure to the sunlight. Therefore, in tropical country like Malaysia, where average day temperature is 33°C, the recommended harvesting operation hours were limited. Pre-cooling by hydrocooling methods was introduced during post-harvest handling before storage of selected commercial tropical fruits and compared with non-precooled. This study concluded that pre-cooling is the key for successful storage of the selected commercial tropical fruits.

## **Effect of controlled atmosphere storage on the antioxidant capacity, total phenolics and flavonoids of 'Hayward' kiwifruit**

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Phenolic compounds are broadly distributed in the plant kingdom and are the most abundant secondary metabolites found in plants. These compounds have many favorable effects on human health such as the lowering of human low-density lipoprotein reduction of heart disease and cancer. In this study, the effect controlled atmosphere storage (CA) on the antioxidant capacity, flavonoids and total phenolic compounds content of 'Hayward' kiwifruit was evaluated. 'Hayward' kiwifruits were CA-stored (2 kPa O<sub>2</sub>/5 kPa CO<sub>2</sub>) at 0°C for 5 months. The total flavonoid content remained constant during storage in both air and controlled atmosphere, while total phenolics was better preserved in CA stored kiwifruits. A decrease in the total antioxidant activity was observed during storage in all treatments. The results showed that a significant correlation of total phenolic compounds content and antiradical activity exists.

## **Section 3**

### **Alternative methods for increasing shelf life and safety**



## How do alternative storage methods affect the storage potential of carrots?

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A high storage potential of carrots (*Daucus carota* L.) is necessary to ensure a year-round supply. In Denmark, carrots are stored under straw or in cold rooms. Fungal attack occurring during cold storage can lead to severe economical losses. Several pathogens reduce the storage potential of carrots in Northern Europe e.g. Sclerotinia rot (*Sclerotinia sclerotiorum*), crater rot (*Rhizoctonia carotae*) and black spots caused by *Rhexocercosporidium carotae*. The storage potential of carrots is mainly determined during the growing season in which a carrot develops into a storage root. The storage conditions can only help to maintain quality as long as possible. Cold temperature storage (0-1°C), controlled atmosphere storage, ozone treatment and application of natural substances have been suggested to maintain the quality of carrots and reduce fungal attack during long time storage. The effect of alternative storage methods (18% O<sub>2</sub> and 3% CO<sub>2</sub>; 1 ppm ozone) on postharvest losses, dry matter content and secondary plant metabolites were determined during 4-6 months storage at 1°C. The content of terpenes in the chambers originating from the carrots was analysed to determine the levels of natural substances surrounding the carrots during long term storage. The dry matter content of the root periderm decreased slightly during storage. A similar tendency was seen in the content of secondary plant metabolites, e.g., polyacetylenes and terpenes in ambient air. The relations between storage potential, biochemical transformations within the carrot rot, fungal attack, levels of natural substances in the storage atmosphere are discussed in relation to storage method.

## Spatial distribution, attachment and growth of bacteria on fruit and vegetable tissues

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We have identified the colonisation of fruit and vegetable tissues as a three-stage process:

- initial attachment
- a consolidation stage, sometimes involving production of extracellular polymer by the attached bacteria
- growth.

We have investigated the spatial distribution of bacteria on broccoli, carrot and tomatoes, and found a differential distribution depending on the plant part. The initial attachment of bacteria has been measured and occurs rapidly. We have defined an attachment and detachment coefficient, and these can be used to model the attachment phase of colonisation. Furthermore, the rate of attachment to specific parts of the tissues varies with the differential distribution. We have also measured the change in numbers of bacteria within and on tissues during storage. This equates to the consolidation and growth phase of colonisation, and provides information about the potential for decontamination of tissues for subsequent use. The work described here has received funding from the European Community's Sixth Framework Programme under grant agreement FOOD-023115.

## Low oxygen pretreatment inhibited ripening and reduced superficial scald in Bartlett pear

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Californian Bartlett pears suffer from superficial scald symptoms after cold storage at -1°C for 4 months. In order to avoid the scald, we tested various pretreatments prior to cold storage, including: 5 min dip in the antioxidant chemical, diphenylamine (DPA) (1750 ppm), or physical treatments of flushing low-O<sub>2</sub> for 4 or 7 days at 20°C in 300L chambers. In addition, fruits were conditioned at 20°C for 4 or 7 days in regular air. Control fruits were placed one day after harvest at -1°C. During treatments, the Bartlett fruit produced high levels of the anaerobic metabolites acetaldehyde, ethanol and ethyl acetate, which affected fruit ripening later in cold storage. After 3 to 4 months at -1°C plus 5 days at 20°C, the low-O<sub>2</sub>-7d-treated pears had the highest firmness and greener color as expressed in Hue angle. The low-O<sub>2</sub> treatment induced various volatile esters in addition to the anaerobic metabolites, but reduced ethylene production during cold storage which, in turn, decreased scald development. The control fruit after 4 months at -1°C exhibited superficial scald symptoms upon transfer to normal conditions, while the DPA and the low-O<sub>2</sub>-treated fruit did not show scald symptoms. Using GC-MS and SPME technique to check the headspace volatiles from the pear peel revealed that the DPA and low-O<sub>2</sub>-7d-treated fruit produced lower levels of alpha-farnesene and its degradation product, 6-methyl-5-hepten-2-one (MHO), after 3 and 4 months in cold storage. In addition, DPA and low-O<sub>2</sub>-treated fruits after 4 months at -1°C exhibited much higher levels of 2-hexenal, and reduced levels of 1-hexanol than the control fruit. We will discuss the use of environmentally friendly low-O<sub>2</sub> pretreatment, which can be suitable as an organic treatment, inhibited ripening and reduced superficial scald in Bartlett pear.

## Comparison of a palladium-promoted ethylene scavenger to 1-methylcyclopropene in manipulating ethylene-induced ripening in avocado cv. Hass fruit

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Increased ethylene production is associated with development of quality characteristics of climacteric fruit and also with loss of storage potential. The removal of ethylene and/or inhibition of the effect of ethylene in stored environments is fundamental to maintaining postharvest quality of climacteric produce. A wide range of approaches have been used to minimise the effect of ethylene on fruit. A former study by demonstrated that a newly developed palladium (Pd)-promoted material was capable of removing ethylene at cool temperatures to sub-physiologically active levels. Whilst 1-methylcyclopropene (1-MCP) acts by blocking the perception of ethylene, the Pd-promoted material rapidly removes ethylene from an environment. The aim of this study was, thus, to compare the efficacy of 1-MCP vs. Pd-promoted material on subsequent ripening of avocado (*Persea americana* Mill.) cv. Hass fruit at 12°C. Pd-promoted material effectively scavenged both exogenously administered and endogenously produced ethylene by avocado fruit to sub-physiologically active levels within 24 h and as a consequence a delay in ethylene-induced ripening was observed. Crucially, Pd-promoted material did not disrupt subsequent ripening. Inhibition of ethylene-induced ripening was also observed for 1-MCP, despite the presence of ethylene being well above physiologically active levels. This study suggests that Pd-promoted material has the potential to be used commercially and possibly to overcome problems associated with disruption of normal ripening, which are often observed when using 1-MCP.

## Potential non-chemical methods for use against thrips (*Thrips tabaci*) in green asparagus

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Alternative methods for disinfestation of asparagus against Thrips (*Thrips Tabaci*) need to be developed for the Thai export trade, ensuring efficient thrips' mortality, while maintaining quality and environmental safety. Hot air / water using temperatures of 40 - 60°C and high CO<sub>2</sub> treatments were studied at laboratory level. An appropriate treatment involving hot water at 45°C for 15 minutes, with or without high CO<sub>2</sub> treatment, followed by hydro-cooling with water at ambient temperature (~ 20°C) was identified. Methods to assess quality, such as objective tests (% weight loss, force measurement, colour measurement) and subjective tests (appearance, decay, off-odour, texture: snap-test) gave no indication of significant quality deterioration. Chlorophyll fluorescence, ion leakage measurements and scanning electron microscopy (SEM) were used to assess physiological stress. The Fv/Fm ratio, which indicates the health of photosystem II, was shown to decrease immediately after all heat treatments tested, but recovered over 24 h for non-damaging heat treatments (42.5 and 45°C). An increase of percentage K<sup>+</sup> leakage was observed that increased with treatment temperature but recovered over 24 h following treatment at 45°C. SEM cross-sections from parenchyma tissue showed that cell walls became denser and thinner in heat treated asparagus. High CO<sub>2</sub> treatments showed neither significant detrimental effect nor indication of physiological stress, and could kill thrips although not at a sufficiently high rate to satisfy probit 9. Confirmatory trials to demonstrate the efficacy of these treatments in Thailand, using naturally infested asparagus were carried out, as well as a feasibility study conducted by interviewing companies in Thailand. The mortality rate of thrips was not as high as when this method was tested in the UK. Application of the selected disinfestation method in Thailand would be possible because it is not too complicated to adapt into existing process lines.

## Post harvest quality of mango (*Mangifera indica* L.) fruits as affected by irradiated chitosan coating

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The effect of coating with irradiated CRAB chitosan (CHlirr,  $M_v = 5.14 \times 10^4$ ), control CRAB chitosan (CHlun,  $M_v = 2.61 \times 10^5$ ) as well as radiated Shrimp chitosan (CHlirr,  $M_v = 5.14 \times 10^4$ ) on postharvest preservation of mango (*Mangifera indica* L.) was studied. Irradiation at 100 kGy and 200 kGy of both CRAB chitosan and Shrimp chitosan were used and the fruits were stored at  $15^\circ\text{C} \pm 1^\circ\text{C}$  and 85% relative humidity for 6 weeks. The effect of chitosan coatings on fruit ripening behaviour, biochemical and organoleptic characteristics were evaluated during storage. The data regarding incidence of disease attack was also noted. The overall results showed the superiority of irradiated CRAB chitosan (200 kGy) in extending the shelf-life of mango fruit as compared to control. The irradiated CRAB chitosan (200 kGy) treated fruits also maintained their eating quality up to 4 weeks of storage. Only 6.0% disease incidence was observed in irradiated CRAB chitosan (200 kGy) as compared to control (25.0%) after 4 weeks of storage while after 6 weeks all control fruits were spoiled. The results of this study showed that irradiated chitosan coatings can be an excellent potential to be used on fresh produce to maintain quality and extending shelf-life.

## Eliciting the endogenous resistance mechanism of phytoalexins production against pathogens in citrus fruits by mediation of limonene hydroperoxides or by wounding oil glands

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Limonene released of injured oil glands in mature green lemons affected host - pathogen relations in two different ways: a direct fungicidal effect against the spores of the postharvest wound pathogen *Penicillium digitatum* Sacc. and elicitation of the endogenous mechanisms of resistance against pathogens, as exemplified by the induced de novo production of the phytoalexins scoparone and scopoletin. Wounding of the oil glands in mature green lemon fruit induced first rapid generation of hydroperoxides or reactive oxygen species (ROS) and later also the production of scoparone and scopoletin. The hydroperoxides produced after this injury were identified as limonene hydroperoxides. Their production was shown to be the result of photooxidation of the limonene exuded from the punctured oil glands with chlorophyll (in particular, chlorophyll b) serving as photosensitizer. Both UV irradiation as well as sun exposure to limonene resulted in the generation of these limonene hydroperoxides. The production of the hydroperoxides and the phytoalexin depended on the physiological maturity of the fruit. Only a low concentration of limonene hydroperoxides was induced by puncturing the oil glands of older yellow lemon and scoparone accumulation was half of that in green fruit, and was insufficient to inhibit the pathogen. Injury of the peel between the oil glands, which avoided the release of the essential oil induced only negligible production of hydroperoxides and scoparone.

## The use of 2,6-dichloroisonicotinic acid and chitosan for the control of postharvest rots in pears

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Given the increasing importance of organic produce, a study was carried out to identify novel treatments to control postharvest rots in 'Conference' pears (*Pyrus communis*) appropriate for the organic production system. In this study the effects of 2,6-dichloroisonicotinic acid (INA) and chitosan to control fungal infection in pears were studied. Both chemicals are elicitors; hence they have been used to induce natural resistance in several fruits such as apples. INA at the concentrations of 0.3 and 0.5 mM controlled the growth of both *Monilinia fructigena* and *Penicillium expansum* when pears were inoculated 24 hrs after INA treatment (98 – 99% inhibition compared to control), but not after 48 hrs. Treatment with chitosan (0.5 or 1.0%) dramatically controlled the growth of *M. fructigena* (100%), but interestingly had no effect on *Penicillium expansum*. Preliminary data on the profile of phenolics content before and after inoculation with and without INA and chitosan treatment are presented.



## Qualitative and microbiological changes in fresh-cut broccoli raab during cold storage

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Broccoli raab (*Brassica rapa* L.) is a vegetable similar to Broccoli (*Brassica oleracea* L. var. *Italica* Plenck) traditionally grown in southern Italy. It is low in calories and sodium, but rich in calcium, phosphorous, vitamins and also a good source of protein, fiber and pholate. The growing interest in nutrition and healthy eating has contributed to increase the demand for fruits and vegetables. Broccoli raab is already high appreciated for their known organoleptic traits and can be used as fresh-cut products to increase their distribution and value. The aim of this study was to evaluate the microbiological and qualitative changes during the cold storage of fresh-cut broccoli raab in self controlled atmosphere (SCA). Broccoli raab inflorescences and young leaves were selected (no longer than 10 cm) and set in plastic trays packaged in sealed plastic films; each package contained about 250 g of product. Polyvinyl chloride (PVC, 50 µm thickness) and a polyamide/polyethylene laminated film (PA/PE, ratio 20/70 - 90 µm thickness) were used as packaging materials. The samples were stored for 20 days at 4°C in SCA. Changes in respiratory activity, colour, browning, microbial growth and sensorial attributes were measured during the cold storage. The predominant microbial load was characterized by bacteria, following by yeast and enterobacteriaceae. Moulds were not found during the trial. Fresh-cut broccoli raab packaged in PA/PE bags showed a viable cell count lower than legal limit for safe consumption until the 11th day in storage, while in PVC the microbial count was about 2 cfu g<sup>-1</sup> higher. A significative browning (P < 0.05) was observed only in samples packaged in PA/PE bags, probably due to high CO<sub>2</sub> level inside the package. The results of this study showed that it is possible to process broccoli raab as fresh-cut vegetable and to extend its shelf-life until 11 days. Anyway, other experiments are in progress in order to detect the optimal processing condition to improve fresh-cut broccoli raab shelf-life.

## In vitro antifungal activity of some plant essential oils on postharvest pathogens of strawberry fruits

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The essential oils produced by different genera are, in many cases, biologically active, endowed with antifungal, antimicrobial and antioxidant activity. To evaluate the antifungal activity of 7 plant species essential oils against four postharvest pathogenic fungi (*Rhizopus stolonifer*, *Penicillium digitatum*, *Aspergillus niger*, *Botrytis cinerea*) that decrease longevity of strawberry fruits, we planned this experiment. Chemical composition of plant oils was determined by capillary gas chromatography and mass spectrometry. Antifungal assays were carried out in vitro using Petri dishes containing PDA. Results showed that all of essential oils had different potential of antifungal activity. Oils of *Salvia officinalis* and *Artemisia aucheri* had low antifungal activity whereas *Satureja sp.* oils showed promising inhibitory activity even at low concentration against *A. niger*. *Thymus sp.* and *Satureja sp.* oils showed inhibitory activity on other fungi. None of these oils exhibited fungicidal activity even at high concentration against *A. niger* whereas exhibited fungicidal activity against *B. cinerea*.

## Control of post harvest diseases of peach by microwave treatments

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Postharvest decay is the major factor limiting the storage life of peaches. Grey and blue mold caused by *Botrytis cinerea* and *Penicillium expansum* respectively, are the major cause of postharvest diseases of peaches. In order to study the effects of microwave on storage life and control of post harvest diseases of peach, this research was carried out in Khorasan Agricultural and Natural resources research center, during 2003-2006. The peaches Alberta, Red and White and Green of Mashhad were harvested at the commercial maturity and after sorting were stored at 40°C for 12 hours. Then the fruits were treated with microwave with frequency 2450 MHz and two intensities (200 w, 800 w) for 0, 30, 60 and 120 seconds. The treated fruits were laid on plastic trays, packed in perforated polyethylene bags and kept in cold storage (0°C and 90-95% r.H.) for 2 months. The qualitative characteristics including (fungal contamination, soluble solids content, titratable acidity, weight loss, firmness and color) were done after 0, 15, 30, 45 and 60 days and sensory attributes were measured after 60 days' storage. Experimental design was 4 factorial adopted completely randomized design and multiple range test (Duncan) were used to compare the means. The results showed that fruit treatments with microwave decreased the fungal contamination of peach fruits in cold storage and increased pH, flesh firmness, total soluble solids. Treatment with microwave (800 w, 60 s), maintained the quality characteristics of fruits. Panel tests confirmed these results.

## Determination of the best picking time of pear 'Spadona' and 'Coscia' and effect of CaCl<sub>2</sub> on their storing properties

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This research was conducted in Khorasan Agriculture and Natural Resources Research centre in 2005 and 2006 in order to determine the best harvesting date of pear 'Spadona' and 'Coscia' and the effect of different CaCl<sub>2</sub> treatments on fruit quality. The statistical design was 4 factors factorial adopted completely randomized design with 3 replicates. Factor A was cultivar ('Coscia' and 'Spadona'), Factor B was picking time (first, second and third), factor C was CaCl<sub>2</sub> solution concentration (0, 4% and 6%) and factor D was storage life (0, 30, 60, 90, 120, and 135, 150, 165 and 180 days). Pear 'Coscia' was picked in (July 24<sup>th</sup>, July 31<sup>st</sup> and August 6<sup>th</sup>) and 'Spadona' in (August 7<sup>th</sup>, August 14<sup>th</sup> and August 21<sup>st</sup>). After treatment with CaCl<sub>2</sub> solutions, the fruits were transferred to cold storage (0 - 1°C, relative humidity 85-90%) and stored for 6 months. The qualitative and quantitative characteristics of fruits (flesh firmness, total soluble solids, titratable acidity, TSS/TA, pH, weight loss, decay, calcium, ascorbic acid and reduced sugar) and sensory attributes (texture, color, taste, odor and overall quality) were registered after picking and after 30, 60, 90, 120, 135, 150, 165 and 180 days of cold storage. Results revealed that pear 'Spadona' that was picked in August 21<sup>st</sup> (heat unit=1986/8, full bloom=140 days) and treated with 6% CaCl<sub>2</sub>, maintained the best qualitative and quantitative characteristics and sensory attributes after 180 days in cold storage.

## Postharvest shelf life of parsley affected by pre-cooling, hydration and temperature of storage

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In this study the influence of pre-cooling and hydration treatments on the shelf life of parsley leaves stored at 5 and 24°C was determined. Immediately after harvest the leaves were immersed or sprayed with water at temperature of 5 or 26°C. Loss of fresh weight during storage followed a positive linear model for the control leaves and for those pre-cooled for 15 minutes with water at 5°C, immersed in water at room temperature for 15 minutes, sprayed once with cold water or sprayed every six hours with cold water and stored at 5°C. No loss of fresh weight was detected for leaves sprayed at every two hours with cold water and stored at 24°C. By spraying the leaves stored at 5°C with cold water every six hours, a 3.6-fold reduction on the rate of fresh weight loss was detected, resulting in the longest shelf life among all treatments. Chlorophyll content dropped linearly through the storage period at 24°C, however in a lower rate when the leaves were sprayed with cold water every two hours. In all treatments, a linear negative correlation for the relative water content was determined for leaves stored at 5°C, with lower rate for the parsley sprayed every six hours with cold water. Similar trend was observed for leaves stored at 24°C, except for the parsley sprayed every two hours with cold water, where the relative water content was kept unchanged during the storage.

## Effect of eugenol, thymol, and menthol on decay and antioxidant activity in blueberries

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Three naturally occurring antimicrobial compounds derived from essential oils of plants were examined for their effectiveness in retarding decay and maintaining the postharvest quality of blueberries (*Vaccinium corymbosum*). All three compounds, including eugenol, thymol, and menthol inhibited fruit decay development as compared to the control. Treatment with eugenol was the most effective in suppressing the fungal growth during storage at 10°C. Treatment with thymol or menthol also significantly inhibited the mold growth, but to a lesser extent. In addition to reducing the decay, all three essential oils tested showed the capability to promote total anthocyanins and total phenolics and enhance antioxidant activity in blueberry fruit tissues expressed as oxygen radical absorbance capacity. The free radical scavenging properties of blueberry fruit were evaluated against 2,2-diphenyl-1-picrylhydrazyl (DPPH•), hydroxyl (HO•), and superoxide radicals (O<sub>2</sub>•<sup>-</sup>) using electron spin resonance (ESR) measurements. Higher radical scavenging capacities were found against DPPH• and HO• in all treated fruit, particularly in berries treated with eugenol, than those in control samples. Results from this study indicate that these and other essential oils deserve to be evaluated further for their effects on storage life of other fruits and vegetables as well as on organoleptic quality of these commodities.

## Efficacy of different natural and synthetic silicas against two stored grain pests: *Sitophilus granarius* (L.) and *Sitophilus oryzae* (L.)

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The development of non-chemical pesticides, e.g. physically active substances such as diatomaceous earth (DE) is advancing. The purpose of the present study was to compare the efficacy of different silica products against the two stored insect pests granary weevil (*Sitophilus granarius* L.) and rice weevil (*Sitophilus oryzae* L.) under different environmental conditions. Different AL-06-formulations, a silica product developed in our group for greenhouses were compared with the commercial DE products Fossil Shield® FS100, FS90.0s, FS80p, and three synthetic amorphous silica's (SAK). The experiments were conducted in petri dishes with and without food at different ambient climate conditions. Mortality and weight of the beetles were recorded over time. The mortality rate was determined after 1, 2, 4, 7, 14, and 28 days. The highest mortality in *S. granarius* trials was achieved with a commercially available SAK (92%) after 48 hours. The results of this study indicate that SAK can effectively control *S. granarius*. Apparently, the hydrophilic DE FS100 and one of the SAK's failed to control the beetles sufficiently, after 48 hours 20% to 47% mortality. At higher dosages all materials resulted in a higher beetle mortality rate. Feeding material increased survival time significantly. Four of the DE products reduced the beetle population within 14 days to less than 50% and within 28 days to 15%, respectively. The poor performance of some substances supports the fact, that hydrophilic substances saturate with water from the surrounding air and lose their insecticidal efficacy quickly. Generally, the application products consisting of smaller particles resulted in a higher mortality rate than the use of DEs with larger particles. Further studies are planned to identify water saturation effects in order to select silica products for greenhouse trials under humid conditions.

## Effect of ozonated and chlorinated water on quality of fresh-cut cauliflower and basil

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Food safety is ultimately an important issue for consumers. Vegetables have been found a source of contamination from pathogenic microorganisms. The best method to reduce pathogens from vegetable is to prevent contamination. Therefore, washing process is one alternative solution to decrease the microbial load in vegetable and provide consumer safety. The objectives of this study were to determine the effect of washing methods with ozonated and chlorinated water comparing with tap water and unwashed on the reduction of microbial load and the shelf life of fresh-cut cauliflower and fresh-cut basil and to analyze the effect of these treatments on sensory evaluation such as color, smell, texture and overall acceptance. It was found that washing fresh-cut cauliflower with ozonated water reduced the total plate count (TPC) and *E. coli* count (EC) to 1.8 and 1.88 log CFU/ml, respectively. Ozonated water was more effective than chlorinated water to reduce the microbial load at the same concentration (0.31-0.35 ppm) and 15 min washing time. Chlorinated water washing showed a reduction to 0.6 and 0.99 log CFU/ml for TPC and EC, respectively. Basil washed with ozonated water reduced TPC and EC to 0.39 and 0.66 log CFU/ml, respectively. This reduction of microbial load was similar to the result by chlorinated water washing (0.23 and 0.37 log CFU/ml for TPC and EC, respectively). Fresh-cut cauliflower and basil were stored at 3 and 8°C and kept for 18 and 5 days, respectively. The overall acceptance of fresh-cut cauliflower from ozonated washing had a higher score than from chlorinated washing. However, the overall acceptance of fresh-cut basil from ozonated washing was similar to chlorinated washing. This result shows the potential of ozonated washing method to substitute traditional chlorinated washing to prolong the shelf-life of fresh-cut vegetable.



## **Efficacy of 1-MCP on 'Holly' tomatoes treated at pre-grading and post-grading operations**

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Skin colour of tomatoes is an indicator of ripeness which advances significantly over time during postharvest life, until the full red colour is reached and it is important at the grower/packer level to maintain the harvest colour stage to avoid losses. Grading operations and the number of impacts the fruits accelerate visual colour stages due to ethylene-related factors. If, at grading, colour advancement can be lessened or halted, this could be an advantage in the supply chain by allowing a more advanced colour stage at harvest, thereby maintaining improved aroma and taste. 'Holly' classic round tomatoes were treated at the pink-orange colour stage with 625 ppb 1-methylcyclo-propene (1-MCP) for 8 hours prior to grading operations; and a further sample was treated post grading operations. 1-MCP was able to maintain the fruits at the pink-orange colour stage for a longer period after operations when treated pre-grading than for untreated fruits; it was also more effective when applied pre-grading than post-grading. The results are significant for tomatoes and for other ethylene-influenced fruits when 1-MCP is used and which may be exposed to relatively high-impact grading and handling operations. They also suggest that it may be necessary to re-examine the impact of grading operations on fruits in the absence of 1-MCP use.

## Modified atmosphere and humidity packaging for fresh mushrooms

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Mushrooms (*Agaricus bisporus* L.) are one of the most perishable products. Mushrooms are conventionally packed in plastic punnets and over-wrapped with perforated PVC film and stored under refrigeration temperature. But high humidity levels, created due to the high transpiration rate of mushrooms and poor water vapor permeability of the film, causes condensation inside the package as clearly seen underneath the film of the punnets being sold in the supermarket. A possible solution to control humidity would be to use desiccants in conjunction with modified atmosphere packaging. The objectives of the present study were to optimize the number of micro-perforations for achieving optimum levels of O<sub>2</sub> and CO<sub>2</sub>. A mixed type of moisture absorber was prepared containing bentonite, sorbitol, and CaCl<sub>2</sub> in the proportion of 0.55, 0.25 and 0.2 g per g, respectively. Each package containing 250 grams of whole mushrooms was placed with a desiccant bag containing 0, 5, 10 and 15 g of moisture absorber and covered with a PVC polymeric film, perforated with 0, 3 and 6 holes of diameter 0.25 mm. After five days in the controlled temperature room at 10°C the quality parameters such as weight loss by mushrooms, weight gain by the moisture absorber and color were evaluated. According to the results, the optimum number of holes was found to be 6 at 10°C yielding 7-9% O<sub>2</sub> concentration and 9-10% CO<sub>2</sub> concentration. The weight loss of mushrooms in the control package (MAP without moisture absorber) was found to be 2.2%, which increased to 3.6, 5.0 and 6.2% when 5, 10 and 15 g of the moisture absorber, respectively, when packed with 250 g of mushrooms. For each pack the desiccant absorbed around 40 and 70% of its own weight after 3 and 5 days, respectively. In control packages, water condensation accumulated on the film, forming drops and making poor visibility through the film whereas; very little condensation was observed on the packages containing any amount of the moisture absorber. The Browning index of all mushrooms increased from an initial value of 8.6 during the five storage days to a maximum level of 18.0. Packs containing 5 g of desiccant were better than those without moisture absorber as the browning index was lowest (14.8 after 5 days). Mushrooms packed with 5 g of desiccant and perforated with 6 holes were still usable and could still be presented on the market and be sold.

## Conservation of the postharvest quality in Habanero pepper (*Capsicum chinense* Jacq.) by means of modified atmosphere

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In Mexico the chili is of traditional value and a cultural identity, since it has contributed to a special characterization of the kitchen and Mexican culture for the last eight centuries. The Habanero pepper (*Capsicum chinense* Jacq.) constitutes one of the products of importance in the agriculture of Yucatan. Generally, its fruit is commercialized fresh for direct consumption or as raw material for industrial processing. Due to the increase of the international demand for Habanero Pepper, the necessity to apply techniques of handling that increase the shelf life of the product appeared. Modified atmosphere has been applied with good results to different agricultural products, and were tested with different conditions in the present study. Established fruit quality indicators were measured. Obtained results in the treatment with modified atmosphere and refrigeration (AR) led to significant differences up to 75% of the time of conservation in comparison with the chili peppers that were stored without modified atmosphere at room temperature with 27°C (SART). In AR in comparison with the treatment without modified atmospheres but under refrigeration (10°C) the numbers of storage days was similar but differences were measured between the quality parameters. No significant differences appeared between the treatment SART and the treatment with modified atmospheres at room temperature (ART). Differences in quality and conservation between chili peppers watered by the method of furrows in comparison with those of irrigation by dripping exist. In conclusion, the use of modified atmosphere with refrigeration, for the chili peppers that were watered under the system of furrows during their stage of growth I provided the best method for storage.

## Combined effects of gaseous O<sub>3</sub> and modified atmosphere packaging on quality and shelf-life of fresh-cut red bell pepper

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Bell peppers consumption and demand have increased during the last years, especially for use as an ingredient of ready-to-eat products. Fresh-cut red peppers were treated with 0.7 ppm ozone for 1, 3 and 5 minutes. Untreated fruits were used as a control. Pepper strips were packaged and sealed in polypropylene trays in air and stored at 10°C for 14 days. Weight loss, gas composition, pH and firmness were evaluated and microbial analyses were performed. Colour was measured before and immediately after O<sub>3</sub> treatment and at the end of the storage period. No differences were observed between the control and the ozonated samples regarding the physicochemical parameters studied, except colour. Weight loss was negligible during storage. O<sub>2</sub> concentration decreased and CO<sub>2</sub> levels increased continuously, mainly on day 14, associated to fungal development. By day 14<sup>th</sup>, pH values increased and a significant softening was observed in all the fruits. Regardless of O<sub>3</sub> exposure time, no differences in colour were found in the samples before and after the treatment. Even more, O<sub>3</sub> did not cause surface discoloration or damage to the peppers. However, °hue and chroma values were lower in these samples with respect to the control. After 14 days of storage, lower values of L and an increase in °hue and chroma values were observed in all the fruits. The initial counts of aerobic mesophilic bacteria were similar for all the treatments. However by day 14<sup>th</sup>, regardless of the exposure time to O<sub>3</sub>, a reduction of approximately 2,56 log units was observed for treated samples. On every evaluation date, an important reduction in the counts was observed for psychrotrophic bacteria and also for yeasts and moulds. Our results indicated that O<sub>3</sub> combined with modified atmosphere could be used to reduce microbial counts and extend the shelf-life of minimally processed red bell peppers.

## Effects of aqueous ozone on quality of minimally processed red bell pepper

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One of the main causes of bell pepper decay during storage is microbial contamination. Ozone may be an alternative to traditional sanitizers due to its high reactivity and spontaneous breakdown to non-toxic products. Fresh-cut red peppers were immersed in 1 ppm ozonated water for 1, 3 and 5 minutes. Tap water was used as a control. Pepper strips were packaged and sealed in polypropylene trays in air and stored at 10°C for 14 days. Weight loss, gas composition, pH, colour, firmness and microbial quality were evaluated. Weight loss was negligible during storage in all the treatments. Regardless of the treatment and the immersion time, the final concentrations of O<sub>2</sub> and CO<sub>2</sub> were close to 4.5 and 16.2%, respectively. By day 14<sup>th</sup>, pH values increased and a significant softening was observed in all the fruits, with lower firmness values in the fruits washed for 3 and 5 minutes. At the beginning and the end of the experiment, the ozonated samples were darker than the control ones with almost no changes during the shelf-life. Even more, O<sub>3</sub> did not cause surface discoloration or damage to the peppers. All the treatments showed similar initial counts of aerobic mesophilic bacteria. After 14 days of storage, an increase in the counts was observed in all the treatments with only slight reductions when washing lasted 3 minutes. Similar results were observed for yeasts and moulds but, in this case, the highest counts were found when the immersion time in ozonated water was 5 minutes. However, O<sub>3</sub> was effective to reduce the counts of psychrotrophic bacteria and this reduction was kept during the shelf-life, when the fruits were washed for 3 and 5 minutes. Our results showed that washing with ozonated water may be an alternative to traditional sanitizers, but further studies are needed regarding O<sub>3</sub> concentration and washing times.

## Effect of high CO<sub>2</sub> pre-treatment on the individual anthocyanin content and their antioxidant activity in table grapes during storage at low temperature

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Our interest lies in the application of high CO<sub>2</sub> pre-treatments that prevent any adverse reactions that lead to a higher susceptibility to fungal attack. In this context, we reported the beneficial effect of high CO<sub>2</sub> to control fungal growth in highly perishable fruits such as table grapes. However, we have observed that this beneficial effect in table grapes is not related to the induction of defence mechanisms such as phytoalexins or pathogenesis-related proteins. It is therefore essential to study the reactions induced by low temperatures that are prevented by the gaseous treatment. The influence of environmental conditions on anthocyanin content is well known. Specifically, low temperatures induce anthocyanin production and activate the expression of genes related to their biosynthesis. We have studied the effect of low temperatures and high CO<sub>2</sub> on total anthocyanin content and on the profiles of individual anthocyanins in 'Cardinal' table grapes, as identified by HPLC-DAD-MS. Given that the antioxidant activity response to environment is less uniform than the anthocyanin response and that not always an increase in anthocyanins is associated with a proportional increase in antioxidant capacity, we decided to analyze the contribution of individual anthocyanins to the total antioxidant capacity in response to low temperature (0°C) and high CO<sub>2</sub> levels (20% for 3 days). Our results prove a causal relationship between the increase in the content of a specific anthocyanin and total antioxidant capacity. We show that the content of anthocyanins between low temperature and high CO<sub>2</sub> response differ substantially. Low temperature has an increasing transient effect on the concentration of each of the identified anthocyanins and high CO<sub>2</sub> has an important effect for specific anthocyanins. Data provide new insights about the effect of low temperature and high CO<sub>2</sub> levels on anthocyanins pathway.

## Changes in antioxidant activity and physical-chemical parameters in minimally processed 'Primosole' mandarins

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The potential of 'Primosole' (*Miho x carvalhais*) mandarins as minimally processed products prepared either by mechanical peeling and slicing or by manual peeling and separation of the fruit in segments was studied. Slices or segments were placed in rigid polypropylen trays, sealed with a polyolefinic film and stored for 3, 7 or 10 days at 5°C. Over the storage periods several physical-chemical parameters (texture, flavonoids, antioxidant activity, pH, titratable acidity, total soluble solids, ascorbic acid, total phenols, sugar content) as well taste characteristics and in-package atmosphere composition were monitored. 'Primosole' mandarins showed an interesting potential as minimally processed fruit regardless the way they were prepared. However some juice components, such as ascorbic acid and sugars (glucose, fructose and sucrose) over the storage periods in mechanically prepared fruit decreased at a higher rate than in those manually prepared. Conversely, significant differences were not detected in changes of antioxidant activity and flavonoids level. In particular, antioxidant activity was fairly constant in both treatments during storage as well as hesperidin and dydimin, while narirutin exhibited a significant general increase. The taste analysis revealed a better maintenance of the sensory quality in fruit manually prepared with respect to those mechanically processed, with the first having at least three more days (10 days) of shelf-life than the latter.

## Effectiveness of fludioxonil against penicillium decay in citrus fruit

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Fludioxonil (FDL) is a 'Reduced risk' fungicide recently registered for postharvest treatments of different horticultural crops in the USA. FDL is a broad spectrum fungicide with a different mechanism of action with respect to other fungicides currently in use for prior postharvest treatments of selected fruit crops, including citrus fruits in the United States. The effectiveness of postharvest 30-s-dip treatments in aqueous mixtures of FDL or imazalil (IMZ) containing 300 or 600 mg/L (active ingredient, a.i.) at 20°C was compared for controlling green mold caused by *Penicillium digitatum*. In fruit treated 24 h after artificial wounding or inoculated with *Penicillium digitatum* (106 conidia/mL) the effectiveness of FDL was similar or inferior to IMZ, respectively in condition of pathogen low or high pressure. In experiments aimed at assessing the protective activity of FDL with fruit subjected to the fungicidal treatments 24 hours before inoculation with *P. digitatum*, the effectiveness of FDL was found to be dependent by the mode of fungal inoculation, being remarkably higher in fruit wounded and inoculated by spray than in fruit inoculated by dipping a steel rod into the conidia suspension before puncturing. The lower performance of FDL in fruit inoculated by puncturing was ascribed to the lack of systemic properties of the fungicide. However, during storage it is unrealistic that fruits reports wounds: re-infections may take place mainly through old wounds caused before or at the time of fungicide treatments. In similar contests FDL can be highly effective as a curative as well as a protective agent against penicillium decay and can successfully be used in place or in combination/rotation of/with IMZ or thiabendazole to overcome the risk of selection of resistant strains of pathogens.



## Effect of superatmospheric oxygen levels on physiological and qualitative aspects of cold stored pomegranate fruits

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Exposure to high levels of O<sub>2</sub> can positively affect the quality of different commodities during the postharvest life. Objective of this experiment was to assess the physiological and qualitative response of 'Primosole' pomegranates exposed to normal atmosphere (NA) (21 kPa O<sub>2</sub> and 79 kPa N<sub>2</sub>) or to atmospheres with high levels of O<sub>2</sub> (SAO) (50 kPa O<sub>2</sub> and 50 kPa N<sub>2</sub> or 97 kPa O<sub>2</sub> and 3 kPa N<sub>2</sub>). Fruit were kept for a 4-week-storage period at 2°C in NA or SAO plus 1 week at 20°C in NA to simulate the marketing conditions (SMC). At the end of cold storage significant differences were detected in respiration between fruit exposed to NA and 50 kPa O<sub>2</sub>, while significantly lower values were detected in those held at 97 kPa O<sub>2</sub>. However, upon transfer to SMC, respiration in fruit held at 97 kPa O<sub>2</sub> increased at a higher rate than the other treatments. The exposure to SAO had no significant effect on total anthocyanins and the main chemical parameters (pH, titratable acidity, total soluble solids) of the juice, although at the end of the SMC the levels of °Brix and titratable acidity were slightly lower in fruit stored at 97 kPa O<sub>2</sub>. Chilling injury appeared only sporadically, regardless the treatments, but browning of the husk was more severe at 97 kPa O<sub>2</sub> than the other treatments, especially after SMC. The exposure to SAO seemed to inhibit decay development, since at the end of cold storage only in fruit exposed to NA some decay developed, but at the end of SMC the highest incidence of decay was detected in fruit stored at 97 kPa O<sub>2</sub>. The results of this experiment indicate no important effect on the overall quality of fruit cold stored in superatmospheric oxygen levels, especially at 97 kPa O<sub>2</sub>.

## GRAS methods as a possible control of postharvest diseases in sweet cherry

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Sweet Cherry fruit has a very limited storability and shelf-life due to its high respiration and its susceptibility to bruising and rotting. In this work the influence of different GRAS (generally recognized as safe) methods were tested to control *Penicillium expansum* (blue mold), *Botrytis cinerea* (gray mold) and *Monilinia fructicola* (brown rot) in different sweet cherry varieties. After disinfection with sodium hypochlorite cherry fruit were bruised and artificially infected by dipping them into a spore solution of known concentration (10<sup>4</sup>). After 6 h the infected cherries were dipped in a GRAS solution for 1, 2, or 3 min. and then stored at 20°C and high humidity. After 5 to 10 days the decay incidence with blue mold, gray mold and brown rot was scored. Comparing different GRAS methods, sodium bicarbonate tested in three different concentration, 2, 3 and 4%, in combination with a 0.06% yeast solution (*Aurebasidium pullulans*), showed good results in reducing fungal diseases. In most cases, the addition of yeast and increasing concentrations of NaHCO<sub>3</sub> enhanced the effect of sodium bicarbonate against the growth of the pathogen. Although a concentration of 4% NaHCO<sub>3</sub> cannot be recommended for use in practice, because of excessive foaming and white residues on the fruit surface. Chitosan, a derivative from the outer shell of crustaceans, has promising antifungal activity, although more experience is necessary. Other tested GRAS methods, such as citric acid, calcium formiate, Na-metasilicate or yeast alone did not show adequate effects against the tested fungi *Penicillium expansum*, *Botrytis cinerea* and *Monilinia fructicola*. In addition, fruit treated with citric acid had a excessive percentage of cracked cherries.

## Study on plasma chemistry of oxygen radicals in cold atmospheric pressure plasma with respect to fresh produce processing

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Sensitivity of food products can hinder the application of conventional thermal food preservation methods. Fresh fruit and vegetables are physiological active food systems and temperatures above 45°C can result in unwanted deterioration. Utilising cold atmospheric plasma to achieve sterilisation is an alternative to conventional sterilisation means. Non-thermal plasma shows antimicrobial effects due to various reactive species. Three basic mechanisms are discussed in the plasma inactivation of microorganisms, involving a direct destruction and/or an intrinsic photodesorption by UV irradiation (the latter forming volatile compounds) and a slow combustion using reactive oxygen species or radicals emanating from the plasma. The presence of O-atoms and OH-radicals in Rf-driven argon plasma generated in air has recently been proven by optical emission spectroscopy (OES). Yet depending on the gas mixtures used and the plasma working conditions different intermediate species and products are expected. To better understand the basic processes of plasma-induced radical chemistry and its effect on bioactive compounds, we studied the formation of radicals in different low-temperature plasmas by means of electron paramagnetic resonance (EPR). Plasma was generated using a non-thermal plasma jet operated in argon at atmospheric pressure and driven by radio frequency (27.12 MHz). The obtained plasma was applied to testing material. In order to measure the relatively short-lived radicals, various nitron species, such as N-tert-butyl- $\alpha$ -phenylnitron (PBN) or  $\alpha$ -(4-Pyridyl N-oxide)-N-tert-butylnitron (POBN) as well as 5,5-Dimethyl-1-pyrroline N-oxide (DMPO), were used as free-radical spin trapping agent. The selection of suitable spin traps was based on the solubility, stability and spectra complexity of the radical adducts. The spin trap agents react with a free electron, giving rise to a relatively stable EPR-observable radical. In this study we report on the characterisation of the reactive species in Ar plasma generated in air with different process gas mixtures. The formation of plasma radicals have been analysed at various radio-frequency driven voltage, gas flow rate and at different positions from the jet nozzle outlet. Depending on the working conditions, different plasma intermediate species have been observed and compared to optical emission spectra. From the analysis of both the reaction products and the type of intermediate species detected by OES, different plasma reactions and processes are proposed to describe the plasma chemistry of ROS in each particular mixture of gas.

## Patulin accumulation in pears infected by *Penicillium expansum*

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Blue mould caused by *Penicillium expansum* Link is one of the most destructive rot of pome fruit worldwide, during storage. Under favourable conditions, for pathogen development, the disease can produce heavy losses. A relevant aspect of *P. expansum* infections, correlated to public health, is fruit contamination by patulin a mycotoxins produced by the fungus. The mycotoxin accumulates in processed apple fruit: juice, puree and baby food. About 50 different secondary metabolites has been identified in pure culture. The aims of the present study were to characterize the isolates causing blue mold on pear in Italy by physiological and genotypic parameters and detect patulin and other secondary metabolites (ochratoxin A, ochratoxin B, citrinin) produced. Secondary metabolite analysis revealed intra-specific differences, patulin was found in all isolates, but a significant reduction was observed between isolates cultivated in agar substrates and fruit. There was no correlation between the concentration of patulin and the percentage of infected fruits, but sample with a lower infection severity showed a significantly reduction of mycotoxin. The HPLC-UV analysis of infected tissues evidenced the presence of secondary metabolites, but none of the peaks found had a retention index and/or UV spectrum corresponding to ochratoxin A, ochratoxin B, and citrinin.

## The effect of postharvest hot air treatments on ripening and soluble sugars in banana fruits

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Postharvest hot air treatments have the potential to alleviate chilling injury in banana fruits and other chilling sensitive commodities of the tropical and sub tropical origins. In the present study, two hot air treatments (50°C for 10 minutes and 40°C for 60 minutes) significantly improved tolerance to chilling temperature (8°C) in banana fruits through an enhanced antioxidant defense system. However, these treatments had significant effects on ripening related changes and soluble sugars. Immediately after the hot air treatments, respiration rate was approximately 30% higher in the treated fruits, relative to the untreated controls. On the contrary, ethylene evolution in the treated fruits was greatly depressed by as much as 5 times in the treated fruits, relative to the untreated controls. This trend was however reversed during cold storage and at the end of cold storage when the fruits were transferred to ambient room conditions. At this point, the treated fruits had respiration rates comparable to the untreated fruits, while ethylene levels were higher in the treated fruits. Compared to the untreated fruits, which were stored at ambient room conditions throughout, treated fruits and untreated fruits stored at 8°C failed to achieve a hue angle low enough to give them the characteristic bright yellow color of well-ripened bananas. Similarly, the treated fruits did not soften sufficiently, thereby maintaining greater pulp and peel firmness compared to the untreated control fruits which were stored at ambient room conditions throughout. The fruits treated with hot air at 50°C for 10 minutes had significantly higher levels of the hexose sugars (glucose and fructose) compared to the untreated cold-stored control fruits. At the end of the 3-week cold storage period followed by a ripening period of 5 days, fruits from both hot air treatments had significantly higher levels of all the soluble sugars compared to the untreated cold-stored control fruits. However, these sugars levels were significantly lower compared to the control fruits that were stored at ambient room conditions throughout. These findings show that although hot air treatments are effective in alleviating chilling injury in banana fruits, fine tuning with respect to effective but non-injurious time versus temperature combinations is necessary to ensure that fruit quality is maintained.

## Controlling postharvest decays of lemons by some prestorage physical treatments

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The use of hot water, UV-C and combination treatments (hot water+UV-C) on 'Interdonato' lemon fruit are found to be a promising alternative for postharvest decay controlling. Harvested fruit were divided into four treatment groups. First group was dipped into 53°C hot water for 3 minutes duration time. The second group was subjected to UV-C irradiation at 1.5 kJ m<sup>-2</sup>. The third group was first dipped into hot water (53°C, 3 min.) and followed by UV-C irradiation (1.5 kJ m<sup>-2</sup>). And the nontreated fourth group was served as control. After treatments fruit were stored at 10°C and 90-95% relative humidity (rH) for 5 months. By taking samples at monthly intervals, the parameters weight loss [%], juice percentage, titratable acidity [%], total soluble solids [%], ascorbic acid [mg/100 ml] were analyzed. And decay incidence [%] was monitored at the same intervals. During storage, there were no significant differences found about weight loss and juice percentage between treatments while higher levels of titratable acidity and total soluble solids were observed in all treated fruit. Also the highest level of ascorbic acid was obtained from the combination treatment during storage. All treatments reduced significantly decay incidence of lemon fruit. But the most effective treatment for controlling decay was found to be hot water treatment.

## The effect of the combination biocontrol and UV-C light against postharvest diseases of apple fruit

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Blue mould caused by *Penicillium expansum* is the most important postharvest disease of pome fruit worldwide. However, the continuous use of fungicides in commercial pack-houses has led to increase the number of resistant strains of pathogens. Furthermore, there is a growing concern of consumers about the possible harmful effect of these substances or their residual metabolites on the environment. Therefore there is a clear need to develop new alternative methods for controlling postharvest diseases. Biological control has been the most study area in the last few years. The bacterium *Pantoea agglomerans* PBC-1 was isolated from apple surface and has been tested, for many years, for their control activity against the major postharvest diseases of pome and citrus fruits. This bacterium is very effective in controlling *Penicillium expansum*, *Botrytis cinerea* and *Rhizopus stolonifer* on pome fruits. However in any biocontrol system the efficacy of a single biocontrol agent is inconsistent. One approach to improve the efficacy of the biocontrol system is the integration of different treatments. The exposure to low doses of Ultraviolet-C (UV-C) irradiation (254 nm) has significantly reduced incidence of several postharvest diseases. In this study the effectiveness of *P. agglomerans* PBC-1 in combination with different doses of UV-C for controlling *P. expansum* on pome was determined. The applications of the UV-C were made in a pilot device of UV-C light, with 10 germicidal lamps (TUV25W/G25 T8, Phillips). From the experimental results it can be concluded that the combination of *P. agglomerans* PBC-1 with UV-C light improves the control of *P. expansum* in pome fruits and allows the required concentration to achieve control to be reduced, with the consequent reduction in the cost of the treatment.

## Effect of 1-methylcyclopropene on juiciness of tomatoes

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Quality parameters of many products are not easily defined. Tomatoes may be readily described in terms of colour, firmness, freedom from disease and defects, and calyx or vine freshness. However, the aroma, taste and textural profiles are more complex. Juiciness may be perceived as being a quality parameter and for growers, handlers and importers may be a premium point of difference. Three varieties of tomato, 'Conchita', 'Catalina' and 'Aranca', were treated at even and equal colour stages with 625 ppb 1-methylcyclopropene (1-MCP) for 8 hours and compared for juiciness at daily intervals after treatment. Juiciness was significantly higher in the treated fruits as colour and cellular membrane physiology become asynchronous

## Investigations on the suitability for modified atmosphere packaging storage of some Romanian apricot cultivars

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Apricot are climacteric highly perishable fruit and their short postharvest life is a problem for marketing. Extending stone fruits shelf-life is very important for prolonged consumption period. MAP is an available technique for the prolongation of shelf-life and maintaining apricot quality. The objective of this study was to evaluate the suitability of two type of film packaging and low temperature storage for maintaining quality of 'Carmela' and 'Excelsior' apricots. Acoustic firmness, color ( $L^*$ ,  $a^*$ ,  $b^*$ ), dry matter, SSC/acidity ratio were determined to evaluate fruit quality at harvest and weekly during 15 days' storage. According to the results obtained, both apricot cultivars show a good storability when kept in unperforated films and have a pleasant commercial appearance at the end of storage period.





## **Section 4**

### **Non-destructive methods for quality assessment**

## Emerging technologies for assessing postharvest quality of horticultural products

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Horticultural products are perishable and notoriously variable in quality. Sorting and grading for internal quality (i.e., flavor, texture and/or aroma) is critical to ensuring consistent, high quality horticultural products. Currently, machine vision technology is widely adopted for sorting and grading fresh horticultural products for appearance (size, shape and color). More advanced technologies, such as near-infrared spectroscopy, are being used in some modern packinghouses for quality grading. This presentation gives an overview of emerging technologies that show great potential for nondestructive assessment of the quality and characteristics of horticultural products. Hyperspectral imaging, originally developed for remote sensing and space applications, has emerged as a useful technology for inspecting and grading horticultural products in the past decade. It combines the main features of imaging and spectroscopy and thus enables us to acquire a large amount of spectral and spatial information from individual product items. The technology is particularly useful for inspecting horticultural product items that are spatially variable in properties or characteristics. Several recent application examples of the technology are presented, which include measurement of the optical properties and quality (firmness and soluble solids) of fruits and real-time detection of external and internal defects of fruits and vegetables. The technology, however, has its limitations and pitfalls, which should be considered in its application. Texture, especially firmness, is a key quality attribute for many horticultural products. We recently developed a spectral scattering technique for characterization of light scattering in a fruit at selected wavelengths. Using proper mathematical methods and algorithms to describe light scattering in the fruit, we demonstrated that the spectral scattering technique could provide good prediction of fruit firmness and soluble solids content. The technique is fast and relatively simple and easy to implement for sorting and grading of horticultural products.

## An user's evaluation of the acoustic technique to assess apple quality in Southern Europe

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The acoustic firmness sensor (AFS) has been used in the last decades to evaluate quality of several fruits such as some varieties of apples, kiwifruit, potted radish and pear. Most of these evaluations have been done by those involved in the development of the technique. The evaluation presented here is from an independent user, and is the first on apples (*Malus x domestica*. Borkh.) from Southern Europe. Firmness, soluble solids content, titrable acidity and acoustic parameters of 'Royal Gala' and 'Golden Smoothie' apples were evaluated at harvest and after 8 months of cold storage in a controlled atmosphere with ultra low oxygen CA-ULO (0.5°C; 1% O<sub>2</sub>; 1% CO<sub>2</sub>) during 2002, 2003, and 2004. The apples studied were taken from 12 different orchards and harvested on a weekly basis on 6 different harvest dates per year. In parallel, consumer tests were carried out at two different locations in Spain (Girona and Lleida). In an independent experiment, the influence of different sources of variation on the AFS readings (harvest dates, turgidity before and after dehydration treatment and ripening after different storage periods) on 'Golden Smoothie' apples was evaluated also. These studies indicated that differences in the trend of acoustic firmness and acoustic frequency can be detected between both varieties, different maturity stages and storage periods. Extreme hydration situations of fruits: storage 0 days - dehydrated fruits and storage 60 days - hydrated fruits, resulted in an erratic AFS behaviour. While the capability of this technique to describe changes in apples during harvest and storage was not clear, the relationship between consumer acceptance and acoustic parameters showed interesting correlations. Acoustic firmness seems to be more appropriate to predict consumer satisfaction for 'Royal Gala' than 'Golden Smoothie' apples. All factors involved in the measure of acoustic firmness from the point of view of users will be discussed.

## Spectral properties of 'Jubilaenum' plums: a non-destructive approach to assess the fruit quality

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Efforts have been made in the recent past to utilize innovative techniques, like time-resolved reflectance spectroscopy (TRS) to study the quality aspects of nectarines. Optical properties depend on the absorption and scattering of laser light pulse passing through the fruit, which have been well related to different quality attributes like firmness, sugars and acids. The TRS measurement was performed on plums cv. 'Jubilaenum' at two different wavelengths: 670 nm and 758 nm. The fruit were harvested in Norway and brought to Italy under protected conditions. After sorting the fruits by size, TRS measurement was made followed by randomizing the fruits for different quality examinations. It was observed that the absorption coefficient ( $\mu_a$ ) increased for both wavelengths as the ripening progressed towards the melting stage of the fruit. The  $\mu_a$  values at 670 nm were higher than those of  $\mu_a$  at 758 nm, while the scattering coefficients ( $\mu_s$ ) for both wavelengths were more or less in the same range. The higher rate in the  $\mu_a$  was distinguishable from third day onwards as the fruit ripened. Similarly, it was interesting to note that the internal colour measured after destructing the fruits behaved in accordance with the TRS measurements i.e., a decrease in the CIE: L\* (towards darker region) and b\* (towards blue) value along with an increase in the a\* (towards red) value from third day of the fruit storage.

## Non-destructive measurement of water flow in small plants using cold neutron radiography - an application to investigate rose bent neck symptom -

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The bent-neck syndrome is a widespread problem damaging millions of cut roses. Structural weakness of the vascular bundles, reduced cell wall strength or water supply limitations etc. are assumed to cause the bent-neck phenomenon. However, the exact reasons for this disorder are still unknown. Non-destructive methods to in-situ study water transport would be effective tools to investigate the phenomenon. Conventional methods providing information on water transport in plants either offer a macroscopic image only or give a detailed picture of a very small region of the plant. In contrast, 3D imaging with neutrons and X-rays provides both high resolution and a relatively large field of view. Using cold neutron tomography water flow images were successfully obtained in tomato seedlings by applying a D<sub>2</sub>O tracer technique. In experiments performed at HMI's neutron tomography instrument CONRAD, two different cut rose (*Rosa Hybr.*) varieties were used as samples. The cultivars 'Akito' and 'Red Giant', respectively, have low and high bent-neck resistances. Controlled by an automated device for exchange of liquid tracers, cut rose samples were supplied with either H<sub>2</sub>O or D<sub>2</sub>O for some times and neutron radiograms of the plants were taken at regular time intervals. Due to the different attenuation coefficients of D<sub>2</sub>O and H<sub>2</sub>O for cold neutrons, these two liquids can be clearly distinguished in the radiography. From observing the D<sub>2</sub>O level in the stem at different times after the exchange, it was possible to deduce the velocity of water uptake and water transport in the roses. As indicated by neutron radiography, water flow velocity was different in stems of 'Akito' and 'Red Giant'. Hence, neutron radiography and the D<sub>2</sub>O tracer method is an effective tool to non-destructively observe water movement. Consequently, neutron radiography provides reliable information on the water transport processes in plants.

## Measuring apple texture quality with acoustic emissions

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Acoustic emission (AE) is a method of texture measurement based on phenomenon of elastic waves generated by sudden cracking within investigated material. In case of apples the AE characteristic for given object can be monitored within typical puncture test. When plunger penetrates apple tissue, waves generated by cracking biopolymer structure propagate to the fruit surface, where they can be detected by a sensor. The AE is recorded as the number of detected bursts (AE events) occurring within the frequency range of 1-16 kHz. AE measurements are sensitive to differences in apple texture that are due to differences in fruit ripeness. The texture attributes crispness and crunchiness are connected with the noise sensations that occur during eating and are also usually associated with freshness and wholesomeness of fresh fruit and vegetables, thus it was interesting in this experiment to compare the results of AE measurements with the sensory perception of the texture of stored apples. The AE events were measured for three apple cultivars 'Elstar', 'Jonagold', and 'Gloster' and correlated with sensory tests. The results show good relationships between particular sensory attributes and AE events, with a higher correlation than with the regular flesh firmness as measured by the puncture test. There are some differences between cultivars and a better fit to the data when a logarithmic relationship is used in some cases. The AE technique seems able to measure other texture attributes of the fruit, such as texture hardness, juiciness and mealiness. This suggests AE could be a useful tool to predict consumer texture quality perceptions. While AE is a destructive technique, it has promise as a technology to measure apple texture, especially as it can potentially be included in with existing routine quality control checks and where an expert sensory panel is not available.

## Investigation of ripening process of fruit and vegetable samples with acoustic method

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The non-destructive acoustic test offers an excellent possibility to measure the hardness of the individual produces during their maturation, ripening process. Method was developed and a new mechanical parameter was introduced for in-vivo characterization of mechanical properties of the tested fruits and vegetables. Both the repeatability, and the reproducibility of the method were tested under field conditions, and they were found to be very encouraging. Repeated tests of individual fruit (apple and pear) and vegetable (cucumber) samples during their ripening process were performed with high resolution and without any destruction. The ambient temperature and the relative humidity were recorded parallel with the firmness tests. Superposition of a short period firmness fluctuation (related to the daily fluctuation of the temperature and humidity) and a long-term softening (related to the physiological changes) were recognised based on the experiments. This latter change was modelled as a function of the cumulative effect of the ambient conditions to find a prediction model to the optimum harvest date.



## Non-destructive determination of post-harvest ripening of *Capsicum annum* cv. Kárpia

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Our aims were the evaluation of quality change during postharvest colouration of Kárpia pepper variety by the use of non-destructive chlorophyll fluorescence image analysis, the investigation of surface colour development by digital image analysis and non-destructive texture analysis by acoustic impulse-response technique. For the measurements 65 pieces of fresh greenhouse-grown Kárpia pepper fruits of uniform size and initial maturity were used. Pepper samples were stored at 10°C and 20°C unpacked and in LDPE packaging, respectively. Postharvest ripening phenomena were detected by the FluorCAM 690MF chlorophyll fluorescence imaging system, by digital image analysis, and by acoustic stiffness method. Chlorophyll activity and chlorophyll content decreases with progressive ripening only in the fruit bodies independently of the treatment while the stalks clearly retain a high potential photosynthetic competence. However, the velocity of the changes was significantly different. The analysis indicated that ripening induced postharvest chlorophyll degradation was the most effective in samples stored at room temperature, independent of whether they were packed or not. The images taken by a commercially available digital camera clearly showed the rapid change in surface colour due to postharvest maturation. The rapid and significant change in the red to green surface colour-ratio also reflects the visible changes. The temperature effect on decline in fruit stiffness became significant in non-packed samples after the 4<sup>th</sup> day. In the case of the LDPE-packed samples, storage temperature significantly affected stiffness changes only after the 8<sup>th</sup> day, resulting in better overall quality and longer shelf-life of cool-stored packed fruits. Non-packed sample stiffness of the 3<sup>rd</sup> and 4<sup>th</sup> day (stored at 20°C and 10°C, respectively) was observed to be almost equal as the stiffness of LDPE-packed samples on the 9<sup>th</sup> day. LDPE-packed sample stiffness decreased by less and more slowly than the stiffness of non-packed fruits, independently of storage temperature. Variation in relative water loss very closely reflected all changes in acoustic stiffness coefficient.

## **New nondestructive method based on spatial-temporal speckle correlation technique for evaluation of apples quality**

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This work presents a new spatial-temporal speckle correlation technique applied for quality evaluation of apples. Evaluations were performed using a nondestructive and noninvasive method based on the interpretation of an optical phenomenon that occurs when the fruit is illuminated with coherent light, referred as biospeckle. The temporal and spatial changes of speckle patterns created by laser light scattered in fruit have been measured through their correlation functions. The cross-correlation coefficient of biospeckle patterns decrease or increase in fruits with different speeds subject to conditions of their freshness, moisture and preservation. Significant exponential changes of the cross-correlation coefficient value difference  $C_t=15$  were observed during apple shelf life. This shows that the method can be utilized for quality evaluation of apples.

## **A robust strategy for the use of chlorophyll fluorescence as a non-invasive method to assess physiological damage of fresh produce**

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Chlorophyll fluorescence has been tested by many researchers as a non-invasive method for assessing physiological damage in chlorophyll containing fruits and vegetables. The characteristic Fv/Fm is most commonly considered. One draw-back of this method is that the fluorescence signal is affected primarily by the state of photosystem II in the thylakoids, which is one of the components most sensitive to stresses, including heat, chilling and oxidative stress. A more reliable strategy may be to look at the ability of the tissues to resynthesise photosystem II after damage, by looking at the rate of Fv/Fm recovery. Data is presented showing the use of this strategy to assess chilling injury in peppers, cucumbers and tomatoes, for low temperature damage in apples and for heat damage of asparagus.

## **Grain active ventilation using ozonized air**

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Decrease of the consumption of energy resources is possible if grain is actively ventilated at low air temperatures, which also has a more favorable effect on a single grain. By using the new low-temperature technologies in a grain drying, the same effect can be reached as if using grain dryers with high air heating temperatures. One of such technologies could be active ventilation of the grain layer at low air temperatures in ozone medium. The presence of ozone in grain active-ventilation process increases the amount of carried out moisture. Ozone when decaying to ordinary oxygen creates additional energy, which can be efficiently used in grain drying. As a result, grain drying is accelerated and energy consumption is decreased. Laboratory experiments have proven the effectiveness of the presence of ozone in grain active ventilation process.

## Site-specific fruit maturity monitoring using Vis/NIR-spectroscopy

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Determining the fruit maturity stage in the orchard is essential for producing high quality fruit and keeping quality in shelf life. Especially, the harvest manager needs site-specific information on the maturity stage and quality of the fruit to decide on the optimum harvest date. Furthermore, objective data on the physiological fruit maturity can be used to adapt the postharvest handling conditions. In the present study, non-destructive fruit analysis based on spectroscopic measurements has been applied in commercial orchards using a portable spectrophotometer with optical geometry for remittance readings. Two-year experiments were carried out in citrus and apple orchards for monitoring quality and maturity-related changes in weekly interval. In citrus monitoring the fruit SSC [°Brix] was carried out on two cultivars of *Citrus reticulata* from October to February in two harvest periods 2004/2005 and 2005/2006 (n=3849) in a growing location in California. Applying a calibration built in the former season resulted in high errors as expected from earlier studies. However, after re-calibration a root mean square error of rmse=8.57% (0.86°Brix) and coefficient of determination of  $r^2=0.57$  was found. During fruit development on tree, the fruit SSC level was influenced by cultivar, production system, and micro-climate. Site-specific monitoring of the variation in fruit development rate was possible with the non-destructive fruit analysis. In *Malus x domestica* weekly on-tree monitoring of the apple fruit pigment changes was carried out in the period from August (unripe fruit) to end of September (over-ripe fruit) in seasons 2006 and 2007 on two cultivars grown in Germany. Fruit spectra (n=2800) were recorded taking into account geodetic data. From the fruit remittance spectra recorded the fruit chlorophyll (green pigmentation) and anthocyanins (blush pigments) were analyzed separately from the fruit spectrum at the specific absorption wavelengths. The separated analysis of the fruit pigments enabled the detection of the fruit chlorophyll [mg/m<sup>2</sup>] without additional re-calibration with rmse=7.56% (21.77 mg/m<sup>2</sup>) and  $r^2=0.93$ , even if it is masked by the blush pigments. For web-based visualization of the spatially resolved results an integrated system including the spectrophotometer system for non-destructive sensing of fruit parameters and site-specific data visualization was developed.

## Quality assessment of kiwifruits based on laser-induced backscattering

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The objectives of the present work were to find a non-destructive method to grade kiwifruits (*Actinidia deliciosa*) and investigate the effect of the optical parameters of fruit tissue with stochastic simulation. Analysis of laser induced diffuse reflectance (backscattering) may offer an inexpensive and non-destructive way to estimate the internal quality parameters of fruits. Kiwifruits of three commercial grades (hard, premium, and soft), assigned by a sensory panel, were subjected to the backscattering imaging readings. Conventional force-deformation analysis and Bayesian thresholding were performed to confirm the classification done by the sensory panel. Backscattering intensity profiles were produced using a laser module emitting at 785 nm with the geometry of 0/15°. Digital images of 768x572 pixel size were captured and processed. The size of the backscattering area and additional statistical parameters extracted from the radial intensity profiles were used in linear discriminant analysis. This analysis resulted in 16.32% classification error (n=98) with leave-one-out cross validation. Monte Carlo simulation was performed and tissue anisotropy (g) was found to affect the apparent photon propagation the most. The estimated g values of kiwifruits show significant difference between grades of optimum market quality and soft fruits.

## Analyzing the browning of apple juice by fluorescence and near-infrared spectroscopy

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Apple juice was produced from *Malus x domestica* 'Pinova', stored at 20°C for 4 days or heated at 80°C for 10 min and stored at the same conditions, in order to obtain both enzymatic browning and non-enzymatic browning reactions. Fluorescence and near-infrared (NIR) spectroscopy as well as color readings were applied to monitor the quality changes of apple juice during storage. A standard set-up for color readings with a colorimeter and NIR spectroscopy using an optical geometry for transmittance readings were applied. The fluorescence spectra were recorded with adapted parameters. Fluorescence excitation was set at 250, 266, 355, and 408 nm and emission at 280-899 nm resulting in an excitation-emission-matrix (EEM) of 1240×4 for each sample. The sign test pointed out an enhanced sensitivity of EEM in comparison to NIR spectra and the L\*, a\*, and b\* values. The often used color b\*-value for monitoring browning was correlated with the EEM and a reasonable calibration was built by means of N-way partial least squares model. The correlation coefficients were >0.9 in all treatments. NIR spectra had good result for predicting soluble solids content, but had poor capability to measure the extent of browning. Fluorescence EEM were used to classify differently treated apple juice exhibiting various browning degrees. For classifying fresh and stored juice, as well as for differentiating fresh juice and heated-stored juice, the classification correctness was always >90%.

## An approach to invasive and non-invasive quality assessment of edible coated plum

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The effects of edible coating, semperfresh and versasheen, on shelf life of plum (*Prunus domestica* 'Sapphire') were studied. Uncoated plums and four treatments were applied after pretests. Plums were coated with 1% semperfresh and 1% semperfresh with 0.2% sorbitol as plasticizer, with 5% versasheen and 5% versasheen with 0.2% sorbitol. The plums from each of the above groups were stored at 20°C and 85% relative humidity. Changes in ethylene, weight loss, firmness, soluble solids contents, total acidity, diffuse reflectance spectra, and malondialdehyde were recorded in 3-day interval. No significant differences in weight loss, soluble solids contents, and total acidity were found between coated and uncoated plums. However, the firmness of fruits treated with edible coating was higher than uncoated plums after 6 days storage. Also the ethylene production was decreased by treatment with edible coating materials. The addition of sorbitol to the semperfresh treatment decreased the ethylene production. Versasheen application additionally resulted in reduced malondialdehyde production indicating a delay in fruit senescence. Versasheen treatment with and without plasticizer showed no difference. Fruit ripening during the experimental period was measurable in the visible (350-750 nm) and near infrared (750-1100 nm) wavelength ranges due to decrease in the fruit chlorophyll but also water loss, respectively. Differences in reflectance spectra of coated and uncoated plum appeared on day 3, while after 6 day storage the chlorophyll content was below the detection limit in all samples.

## Increasing the rate of operation of automatic quality classifiers for agricultural products – software and hardware decisions

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Machines for automatic quality sorting of agricultural products (MAQS) have been implemented in practice since the middle of the 20<sup>th</sup> century. The improvement of the agricultural technologies and the food industry goes along with the remarkable development of the sorting technique: the range of products being non-destructively qualified using machines continually enlarges. The accuracy and the rate of qualification of the products increase while the design and maintenance features are being modernized. In the structure of MAQS the informative technologies enable differentiating an automatic classifier (AC), which accomplishes the entire processing of information and control of the processes in the system, that altogether could be defined as "a complex informative system" (CIS). Automatic classifiers, as a "brain trust" of MAQS, are determinative for their functional resources and performance, that is to say the development of the machines for automatic sorting consists in the improving of the AC. Some directions for increasing the rate of operation of AC have been analyzed and adequate software and hardware decisions will be presented in this paper. The investigations are based on the developed and put into practice, with the participation of the authors, several generations of sorting machines for fruits and vegetables of series AQS.



## New methods to determine the level of low oxygen limit

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The use of controlled atmosphere facilities for long-term storage of produce has long been accepted as the optimum method for preserving fruits and vegetables. Controlled atmosphere (CA) facilities use a range of sensor technologies to monitor temperature, oxygen and carbon dioxide levels within the controlled environment. Nowadays, the state of the art CA technology is provided facilities to store fruits and vegetables at ultra low oxygen. Damage resulting from incorrect environmental storage conditions reduces the quality and market potential of the produce. Decrease of the oxygen concentration to the lowest levels tolerated by the fruit should optimize the greatest benefits of ultra low oxygen storage without risk of losses caused by anaerobic conditions; which can encourage anaerobic volatile (acetaldehyde and ethanol) growth, with disastrous effect. During the controlled atmosphere storage, the early correct prediction of the disorders of the low oxygen levels is important for the field of post-harvest. A non-destructive, fast and yet objective technique could improve to understand and prevent the undesirable effects of low oxygen. The main objective of this work was to determine the low oxygen limit of 'Granny Smith' apples. Two methods were applied on this study. Either of them was the application of solid phase microextraction for detection and qualification the volatiles components in the gas-phase beyond the fruits. The purpose of this procedure was to recognize the effect of different storage conditions on the volatiles aroma production capacity. Furthermore to investigate how these components follow the physiological processes and to determine the anaerobic respiration metabolites under the level of low oxygen limit. The other method was based on the measurement of chlorophyll fluorescence. Below the fruit specific oxygen-threshold the Fv/Fm value decrease, hence the natural fluorescent characteristics of chlorophyll were followed in plant materials. Our results showed that the low oxygen limit of the 'Granny Smith' apples is near by 1.4% oxygen.

## TRS-measurements as a nondestructive method assessing stage of maturity and ripening in plum (*Prunus domestica* L.)

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Time resolved spectrophotometry (TRS) has been tested as a nondestructive method to measure changes in fruit during maturation and ripening. Most promising results have been reported in stonefruits as nectarines and peaches. A major advantage of TRS over other related spectrophotometric methods is that the measurements are not influenced by the surface colour of the fruit. In some stone fruit cultivars the cover colour of the fruit (often deep red or dark purple/blue blush) develops at an early stage of maturity, making it difficult to predict the stage of maturation and ripening by the change in flesh colour from green to yellow. The plum fruits of the cultivar 'Jubileum' (*Prunus domestica* L.) turn dark blue 1-2 weeks prior to optimum harvest date. In 2006 and 2007 Norwegian grown 'Jubileum' were transported to Milan for TRS-measurements during 5 days storage at approx 20°C. In 2006 the plums were fully ripe when the measurements started. In 2007 the experiments were performed two weeks earlier. The plums were hence less mature that year. The TRS-measurements were performed at 670 nm in both seasons. In 2007 additional measurements were performed at 758 nm. The quality measurements included colour, firmness, soluble solids content and titratable acidity. In plums, firmness is regarded as the property most closely related to maturity and ripening. Data analyses (correlations, stepwise multiple regressions) showed that firmness to some extent can be predicted by the TRS-measurements. Possible applications of the TRS measurements in practical plum growing and marketing will be discussed.

## On-line measurement of humidity in the agri-food chain

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Disadvantageous climatic conditions can forward bacterial affection and finally formation of mould. A basis of quality assurance is a monitoring of environmental climate parameters, such as temperature, humidity, composition and gas flow of air. Capacitive humidity and a resistive temperature sensor were developed and prepared by CMOS technology. Evaluation of the sensor was performed in a laboratory accredited according ISO EN 17025. The two important parameters to determine are relative humidity and air temperature. Because of temperature changes, air convection and product respiration, relative humidity at agricultural products can change drastically in short times and condensation can occur. The measuring range of relative humidity of evaluated data loggers is between 20 and 85%. Unfortunately there is no exact indication out of this humidity range. The sensor reading differs from reference by 2 to 4% of relative humidity. At low humidity range the sensor values are too high and oppositional at high humidity range data loggers indicate too little. Hysteresis, a difference of humidity reading of the sensor depending on increasing or decreasing ambient humidity of about 1% was observed. The time of response was determined. During increasing humidity 90% of final value was reached in 1 minute. By contrast at decreasing humidity the time of response was even longer. Impact of water condensation also was studied. It could not detect in time, but concluded from temperature fall. In addition the influence of gas flow was tested. Thus the aim of the paper is to evaluate the performance of climate data logger for monitoring of postharvest chain. Recapitulatory the climate of fruits and vegetables can be on-line monitored by new sensors systems. Due to tested properties data loggers are suitable for analysing climate components of storage and transportation of horticultural produce. The environmental conditions can be described and controlled. These small sized humidity data loggers can be used as a basis for monitoring in agri-food chain and give prognosis of shelf time.

## Moisture content reduction in carrots during storage

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The objective of the work was to determine changes in carrot moisture content, mass and texture during different storage conditions. Furthermore, the purpose was to determine changes both lengthwise and crosswise along the carrots. The experiments were performed with two different carrot cultivars. The storage conditions were as follows: temperature of  $6\pm 0.5^\circ\text{C}$ ,  $10\pm 0.5^\circ\text{C}$  and  $20\pm 0.5^\circ\text{C}$  with  $60\pm 5\%$  relative air humidity. 5 mm thick disks were cut out of the carrots and the slices were measured. Definite measurements were performed both on phloem and xylem parts and along the length of the carrots. The applied measurement methods were as follows: NIR absorbance in the 1000-2500 nm range with spectral resolution of 2.0 nm and hyperspectral imaging system. The NIR absorbance was measured on fresh cut surface of phloem and xylem parts of carrot. Furthermore, the measured characteristics were as follows: specific cutting force by texture analyzer, firmness by acoustic and impact test methods and moisture content. There was a definite decrease in the firmness as a function of the moisture content for both carrot cultivars. This was found for the specific cutting force and the impact firmness coefficient. Furthermore an acceptable relationship was determined between the specific cutting force and impact firmness coefficient for the phloem part of carrot. The NIR absorption decreased versus carrot moisture content during the storage. The phloem and xylem parts of tested carrot cultivars were distinguished by NIR absorption. A detailed analysis of the different storage conditions was performed.

## Inline detection of microbial infections on the basis of airborne metabolites using ion mobility spectrometry

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Harvest foodstuffs may be exposed to microbial infection and become brackish or even may contain toxic substances during their processing from acre to food product market. Therefore there is a necessity to control every step of processing. For this purpose it is possible to use different biological, chemical and physical methods. Unfortunately these analyses are more time-consuming and will take place in external laboratories. The main goal of this project is to launch an innovative procedure with a quick monitoring system of fungi (particularly mould), yeasts and bacteria during the storage and further processing along the lines of HACCP-concept. Characteristic microbial volatile organic compounds (MVOC) occur as degradation products of the metabolism e. g. fungi. In this case a handheld system on the base of ion mobility spectrometry (IMS) can be used to detect airborne substances in a very low concentration array (1  $\mu\text{g}/\text{m}^3$  to 100  $\mu\text{g}/\text{m}^3$ ). IMS is an analytical-chemical method for characterising gaseous substances on the basis of velocity of gas-phase ions in an electric field at ambient pressure. Vapour samples are introduced in an ionisation zone or reaction zone and molecules are ionized by radio activity or other energy sources. A separation of ions is realized in a drift region where the ion swarms move against a so called drift gas (often air) towards a FARADAY plate detector. Every substance ion has got its own drift time. A plot of drift time against intensity leads to an ion mobility spectra. The storage of carrots and tomatoes was monitored by IMS. The fruits were stored in a 5 L glass chamber at 18°C and a relative humidity of 70%. The glass chamber was purged in intervals of 6 hours with filtered ambient air. MVOC were detectable by IMS already after the sixth days of storage, but only after ten days of storage first spores of mould were visible on both types of fruit bodies. This shows that microbial infections (in this study caused by moulds) are detected before there is a visible degradation. Thus the method under development using IMS can contribute to increase quality and safety in processing of fruits and vegetables.

## Detection of rotten citrus using a hyperspectral image vision system under visible and near infrared illumination

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The post-harvest treatment of citrus includes the inspection of rotten fruits, which is currently performed manually under ultraviolet (UV) illumination. The rotten areas shine due to the fluorescence induced by UV while the sound skin remains dark, facilitating the inspection to the personnel working in the packing lines. But this kind of light is potentially dangerous for humans and operators must wear protective clothes and glasses. Colour of early damage caused by fungi is very close to the colour of the sound skin and is difficult to distinguish under visible light, which reduces the performance of machine vision systems for fruit sorting. In this work, we present and compare a set of techniques aimed at detecting damages in citrus caused by *Penicillium digitatum* without employing UV light. A hyperspectral imaging system sensible to the visible and near infrared is used to select an optimal set of wavelengths to maximise the detection of rotten fruit. A hyperspectral image is composed of a large set of monochromatic images, which increases the complexity and required time to analyse them automatically. For this reason, it is important not to process those spectral bands that provide redundant information. In order to select an appropriated set of bands, several feature selection methods have been compared, such as correlation analysis, mutual information, step-wise multivariate regression and genetic algorithms. These bands were then used to segment the images using two techniques that were also compared: linear discriminant analysis and classification and regression trees. Finally, an algorithm based on this segmentation procedure was proposed to identify rotten fruit. Sound and artificially rotten mandarins cv. 'Clemenules' were used in the experiments. Results showed that the proposed methodology was able to correctly classify 91% of fruit not employed for training purposes, thus demonstrating the feasibility of an automatic system to detect rotten citrus without using UV light.

## A preliminary approach to the prediction of 'Rocha' pear skin pigments by VIS/NIR reflectance spectroscopy

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'Rocha' pear (*Pyrus communis* L.) is an exclusively Portuguese certified pear variety commercialized worldwide. Mature unripe 'Rocha' pears were obtained from COOPVAL (Cadaval, Portugal) after 8 months at  $-0.5^{\circ}\text{C}$ , RH of 94-96% and CA (2%  $\text{O}_2$ +0.5%  $\text{CO}_2$ ). Then, they were transferred to shelf life, being maintained in a dark room at  $20\pm 2^{\circ}\text{C}$  and a RH of 70%. These fruits were followed along three weeks using Vis/NIR reflectance spectroscopy in the wavelength band between 400 and 950nm. Fruits were also evaluated in respect to the colour and firmness, using the standard techniques. 'Rocha' pear firmness decreased significantly along shelf life, paralleled by the yellowing of fruits skin ( $a^*$  and Hue increasing). Pigments were extracted from pears skin and assayed spectrophotometrically. Both Chl*a* and Chl*b* contents decreased along ripening in the shelf life, while carotenoids content remained unchanged. Vis/NIR reflectance spectra were correlated with the respective fruit skin pigments content by PLS. Prediction models were obtained for Chl (*a*, *b*, *a+b*), but not for carotenoids. Models were reasonably significant in regression terms [ $r(\text{Chl}a)=0.898$ ;  $r(\text{Chl}b)=0.897$ ;  $r(\text{Chl}a+b)=0.918$ ], but the respective SDR ( $2.2^{\text{Chl}a}$ ,  $2.3^{\text{Chl}b}$ ,  $2.2^{\text{Chl}a+b}$ ) suggest that only a coarse quantitative prediction is possible for all models. Although Chl*a* model required a higher number of latent variables [ $\text{Lv}(\text{Chl}a)=6$ ;  $\text{Lv}(\text{Chl}b \text{ or } \text{Chl}a+b)=3$ ], similarity between RMSEC and RMSEP was lower for the other parameters [Chl*a*: 4.6 and 4.6  $\text{g m}^{-2}$  Chl*b*: 3.9 and 2.3  $\text{g m}^{-2}$ , Chl*a+b*: 7.3 and 6.7  $\text{g m}^{-2}$ ]. We were expecting better performance for these models, since most of the differences found in the Vis/NIR spectra along ripening were on the Chl absorption region. However, only a coarse prediction capability was found. Thus, the data obtained suggest that changes on the background around 670 nm decrease the prediction capability of the PLS model and should be further investigated.

## **Section 5**

### **Modelling as a tool for integration and management of the whole chain**



## Importance of ISA-Fruit project for European fruit growers, fruit market and consumers

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The ISAFRUIT project with the title: "Increasing Fruit consumption through a transdisciplinary approach leading to high quality produce from environmentally safe sustainable methods", is a 54-month integrated project aimed at increasing fruit consumption in order to improve health of European citizens. Model fruit species in this project are apple and peach/nectarine with some activities on a few other species. The main goal is to contribute to a healthier diet by improving the quality, appeal, and consumption of fruit. This project with more than 60 participants from 16 European countries focuses on different topics in 8 different pillars. The first topic concentrates on consumer behaviour in order to stimulate fruit consumption, to identify suitable structures that maximize supply chain innovativeness and performance and to increase dissemination of fruit innovations. The second topic is to identify and document factors in fruit and fruit products, which lead to better health and to optimize safety of fruit products. Functional effects of processed fruit, low allergenic potential of varieties and campaigns on weight management are important items. Improved appeal and nutritional value of processed fruit, including juice products and dried fruits is also an important topic in this project. The project also aims to improve the knowledge on the genetic bases of fruit quality, to increase acceptability of GMO and to implement new high quality varieties meeting the preferences of the consumers. Two pillars concentrate on quality, safety and sustainability, one before harvest, one after harvest. In order to improve pre-harvest chain management attention is given to reduction of pesticides by development of a crop identification system and crop health status. Attention is also given to reduction of nutrient input, environment-friendly crop regulation methods and profitable production. Moreover, economical situations in selected growing areas around Europe are being compared and documented. In order to improve post-harvest chain management studies concentrate on the prevention of postharvest rot and on the development of a decision support system. It is aimed to find alternatives for pesticides against postharvest rot, as current retail wants no pesticide residues on the fruit. In apple and peach several alternative protection methods, like hot water treatment, biological agents, natural substances and GRAS methods (generally recognized as safe) are tested. It is expected that the individual treatments will not protect the fruits for each pathogen, but that a combination of the different treatments as a hurdle technology will protect the fruits during the postharvest chain. A decision support system for fruit quality management in apple and peach from harvest to point of sale will be developed in the project.

## Effects of CA treatments and temperature on broccoli colour development

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Broccoli combines high levels of vitamins, fibres and glucosinolates with a low calorie count and is sometimes referred to as the 'crown jewel of nutrition'. Colour is one of the most important quality attributes of broccoli, and yellowing due to senescence of broccoli florets is the main external quality problem in the broccoli production chain. Controlled atmosphere (CA) is a very effective method to maintain broccoli quality. The aim of this paper is to characterise the colour behaviour (RGB colour image analysis) of broccoli as affected by CA and temperature. Data on colour behaviour and gas exchange (mobile GC) were gathered for broccoli heads that were stored in containers at three temperatures (5, 10 and 18°C) and subjected to four levels of O<sub>2</sub> (1.5, 3, 10 and 21 kPa) and three levels of CO<sub>2</sub> (0, 6 and 15 kPa). Gas conditions and temperature have a clear effect on the colour change of broccoli especially at low levels of O<sub>2</sub> in combination with high levels of CO<sub>2</sub>, indicating that the rate of colour change depends on the CA conditions through the energy provided by the gas exchange. An integrated colour model is proposed that combines a colour model with a standard gas exchange model. The colour model is based on three differential equations describing the formation of (blue/green) chlorophyllide from the colourless precursor, the bidirectional conversion of chlorophyllide into (blue/green) chlorophyll, and the decay of chlorophyllide. The colour model is based on a key assumption: the level of the colourless precursor (protochlorophyllide) formed during preharvest is restrictive for the amount of chlorophyllide produced during (dark) postharvest storage. During the first step of building the integrated model, gas exchange data were analysed simultaneously using multi response regression analysis. No fermentation was encountered for this batch of broccoli. During the second step it was found that only one of the reactions of the colour model, the decay of chlorophyllide, is affected by the gas conditions. In the final step, a multi-response approach was applied where gas exchange parameters were estimated using the gas exchange model, the colour parameters were estimated using the colour model with both models linked via the reaction rate constant affected by the gas conditions. Such a calibrated, integrated, model describes the combined effects of O<sub>2</sub>, CO<sub>2</sub> and temperature on the colour change of broccoli and could be used as a tool for predicting colour change in the postharvest chain.

## Water loss in horticultural products: Modelling, data analysis and theoretical considerations

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Water loss in horticultural products is still a major problem for growers, wholesalers and retailers. Research on water loss however, is nowadays very limited. The problem has been solved, hasn't it? Water diffuses through the skin into the environment which seems to be a simple and straightforward formulation for modelling. However, recently strange results have been found for water loss in different fruits (nectarines, plums and melons). Non linear mixed effects regression analysis was applied to weight data in monitored individuals, without converting them into weight loss data. All the variation between the individuals in a batch could be attributed to the initial weight or size of the individuals. The rate constant of water loss (transpiration) was exactly the same for all individuals, even over different near-isogenic lines of melons with most probably large differences in skin thickness and properties. The amount of potential water loss is limited and certainly not equal to the total mass of the fruit. A fraction of the fruit mass is dry matter and will not be involved in water loss. That forces us to rethink and remodel water loss. In this paper the water loss of nectarines, plums and melons will be analysed using the same generic model that is generated from a chemical equilibrium reaction. All analyses result in explained parts well over 99%.

## Modelling the effect of 1-MCP on the ripening of avocado fruit

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Avocados are climacteric fruits that produce large amounts of ethylene and are sensitive to it. 1-MCP is a relative novel postharvest technology capable of blocking the natural perception of ethylene by the fruit, thus drastically reducing its production and effects during and after cold storage. The objective of this work is to determine and model the effects of 1-MCP in maintaining the firmness of Mexican 'Hass' avocados during simulated shipments and subsequent shelflife. Fruit from different batches coming from different regions from Mexico and harvested throughout the year softened at different rates during storage and responded differently to the applied 1-MCP levels. However the efficacy of 1-MCP strongly varies between batches and also between individual fruit within a batch. The current work focused on analyzing the various sources of variation using the developed model. Softening of avocado was modeled as being the result of a single enzyme system breaking down firmness. Most likely, ethylene, inducing the climacteric response of the fruit during fruit ripening, can be held responsible for the autocatalytic character of the overall firmness change. The effect of ethylene was included through an auto catalytically activation of the responsible enzyme system from an inactive precursor. To include the effect of 1-MCP it was assumed that 1-MCP, assuming it is inhibiting only the autocatalytic part of the ripening process, results in temporarily shutting down the activation of the enzyme system from its precursor. The two parameters, most obviously prone to fruit-to-fruit variation are the initial maturity at harvest and the response of individual fruits to the 1-MCP treatment. Both of them were treated as stochastic model parameters to explain differences between batches and individual fruit. The model was capable of describing the wide variation in softening responses observed for the individual fruit and enables better insight in how biological variation is affecting the overall batch behavior.

## Multivariate analysis and statistical monitoring of the growth of apples in the production

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In management of food production and processing, techniques such as multivariate data analysis and process monitoring are required, to maintain nutritional product quality and diminish the loss due to the decaying along the supply chain of perishable agro-food products. The critical limitation of univariate methods in process monitoring has been overcome by the multivariate techniques, since the latter uses the correlation among the various variables in developing the monitoring statistics and hence, enables the visualization and interpretation of the big picture about the process status. Multivariate statistical process monitoring techniques are based on statistical methods such as principal components analysis (PCA). PCA can be used as a visualization tool to describe the correlation among variables, as a model building platform to detect outliers, or as the foundation of monitoring techniques to describe the expected variation in a process under normal operation (NO) and deviations from NO can indicate significant variation from target values or unusual patterns of variation. Growth and preservation of fresh fruits and vegetables are batch processes, and may exhibit some batch-to-batch variation due to differences in genotype and phenotype. PCA is extended to multiway PCA to handle batch process data. With multiway PCA the data can be modeled including the time as a separate dimension in the model data, so that, the time evolution of, in the present study spectral properties of apples, can be investigated. In the present work, PCA based multivariate techniques were applied to the site-specific monitoring of commercially grown apples using non-destructively recorded apple remittance spectra during fruit development on tree. One batch of the trees suffered slight water deficiency during growth. These apples ripened earlier, however, were picked on the same days with the others and therefore, had a shorter shelf-life. Additionally, the fruit quality changes in time were studied and the samples were monitored in order to detect any impact due to their growth conditions. The effectiveness of multivariate statistical techniques is demonstrated based on non-destructive optical sensing of fresh apples and on conventional laboratory analysis data.

## 3-D virtual fruit microstructure modelling

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The traditional approach to study fruit from a macroscopic perspective is being redirected to the microscopic level as our understanding of the lower scale increases. The microstructural components (cells, cell walls and air voids) of fruits determine the fruit mechanical and transport properties. However, this relationship is unclear to date. Microscale models offer a means to compute the mechanical material behavior and transport properties in the true microscopic geometry of the fruit. This calls for the 3-D characterization and representation of fruit tissue components. Cells, cell walls and air voids of cortex tissue of pear (cv. Conference) fruit were defined based on imaging at submicron resolution by means of transmission electron microscopy (TEM) and synchrotron radiation X-ray computed microtomography. The cell wall thickness was determined from TEM images using digitization procedures. An ellipsoid tessellation algorithm was developed to cut individual cells from the microtomography images. The air voids were a result of the natural stacking of the ellipsoids in the 3-D microstructural domain. Validation of the structures was performed by means of conventional segmentation of the original microtomographs into air voids and cells, and calculating the geometric characteristics of the resulting networks. The resulting geometric solid model comprising the three principal components was modeled in ANSYS (ANSYS, Inc., Canonsburg, PA) working environment. The model geometry will be used in finite element or finite volume in silico simulations of gas and water transport and mechanical deformation of the microstructures. The advantages of the novel method are that individual cells are segmented and the tool provides a framework for in silico generation of fruit structures.

### 3-D microscale modelling of gas diffusion in fruit tissue

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Fruit such as apple and pear are often stored under controlled or modified atmosphere conditions. However, too low an oxygen partial pressure in combination with too high a carbon dioxide partial pressure may cause off-flavours and storage disorders during storage. Gas transport properties of fruit are important for understanding the internal atmosphere during controlled atmosphere storage. Gas-filled intercellular spaces are considered the predominant pathways for gas transport through plant organs and, as such, are greatly related to the tissue characteristics for gas exchange. To understand the gas transport in fruit tissue, a 3-D microscale model for the transport of gas in relation to the structure of the intercellular spaces and the cellular architecture of fruit tissue was introduced. The 3-D microstructure of pear tissue was obtained by synchrotron radiation tomography images, obtained at the ESRF (Grenoble, France). A microscale model for oxygen diffusion and respiration was solved on the 3-D geometry using a finite element fluid dynamics code (Comsol 3.3, AB, Stockholm). Cubic fruit tissue samples with edge dimensions of approximately 450  $\mu\text{m}$  required a computational mesh consisting of 4,000,000 Lagrange-linear cube elements (2.8 micron per element). Physical transport properties of oxygen in gas and water were assigned to the air and cell phases, respectively, while the resistance of cell wall and membrane was taken into account at the interface between gas and liquid phase by an effective estimated permeability value. The program was run on a node of 16 GB of RAM (Opteron 250) of the High Performance Computer (HPC, AMD Opteron cluster) of the K.U.Leuven (Leuven, Belgium). Simulation results showed that the  $\text{O}_2$  transport was mainly by means of the intercellular space and less through the intracellular liquid. The epidermis and subepidermis layers of pear showed a large barrier to diffusion with apparent diffusivity values of  $7.9 \times 10^{-11}$  to  $1.85 \times 10^{-10} \text{ m}^2 \text{ s}^{-1}$ . The pear parenchyma tissue that displayed a high connectivity of the void network had high oxygen diffusivity ( $4.4 \times 10^{-10}$  to  $7.9 \times 10^{-9} \text{ m}^2 \text{ s}^{-1}$ ). The characteristic brachysclereids (stone cells) that appear frequently in pear fruit cortex have a large effect on the void network distribution resulting in an increased barrier to diffusion: a sample with stone cells had a diffusivity of only  $1.48 \times 10^{-10} \text{ m}^2 \text{ s}^{-1}$ . Simulated diffusivities of epidermis and subepidermis were comparative to the measurement value while measured cortex diffusivity was in between the simulated values of brachysclereids groups and parenchyma tissue. Structural changes and heterogeneity of tissues are related to imbalances in gas exchange that may eventually lead to cell death at a certain storage condition.

## Modelling post harvest vase life of two gerbera cultivar using fuzzy logic and genetic algorithms

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Postharvest quality of cut flowers is strongly affected by environmental condition during production period. To identify the effects of pre-harvest condition on postharvest keeping quality of cut gerbera, vase life and bending incidence of cut scapes of two gerbera cultivars 'Red explosion' and 'Fiction' were determined during storage at 25°C. Data of time taken to neck bending, discoloration of ray flowers and petal fall was modeled using a Genetic Fuzzy Rule Base System and evolutionary optimizations was done using genetic algorithms. We observed that low and high air temperature negatively affected keeping quality. In addition, supplementary lighting during stem elongation may intensify this trend in some treatments.



## Fruits and vegetables passive refrigeration transport: modelling respiration process

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The passive refrigeration is a system developed with the aim to improve the shelf-life of fruits and vegetables during transport; it guarantees good storage temperature and relative humidity without energy supply. During the transport in a closed cold mobile container, the respiration process of fresh vegetables causes both CO<sub>2</sub> accumulation and also O<sub>2</sub> reduction and affects the product quality. Thus, modelling respiration rate is important to the design of a successful modified atmosphere (MAP) system. In order to predict the respiration rate of fresh products as a function of O<sub>2</sub> and CO<sub>2</sub> concentration, a general mathematical model was employed. The time variation of respiration rate at a constant temperature of grape, tomato and peach has been modelled by a Michaelis-Menten type equation, while its dependence on temperature has been defined using an Arrhenius-type equation. To validate the model a simulated transport was arranged. Tomato, grape and peach were packaged in carton boxes; each one was sealed in polyethylene films and stored in a cold room for a week in order to study the respiration rate. In our study the results confirmed the applicability of the model to predict the modification of the atmosphere composition inside a closed system and to represent the respiration process of tomato, grape and peach; in particular the predicted values obtained by the model agreed well with those measured during the experiment. This tool is important to improve the storage of fruits and vegetables during the transport selecting the optimal MAP in order to avoid the development of physiological and microbiological alteration. Finally, the adoption of a predictive mathematical model is an economic way to improve and control the transport system compared to more expensive experimental methods.

## Possibilities to include biological variations in statistical analysis on destructively measured data

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Usually data are gathered in postharvest research using destructive measuring techniques (cross sectional data). Only in special cases non-destructive techniques can be used (longitudinal data) that allow proper analysis including the always present biological variation using the mixed-effects non-linear regression techniques. The success and the power of this last methodology can be taken from recent reports. Until now, however, no such methodology exists for data gathered using destructive measuring techniques, used in approximately 80 to 90% of the cases. From the information and understanding of the dynamics of biological variation in time for different batches of product on longitudinal data, some rules and plausible assumptions could be deduced that should also apply to cross sectional data. In this paper several analysing techniques are presented to include information on the dynamics of biological variation in the analysis on cross sectional data. The first method is based on the indication that the biological shift factor should be distributed according a normal or Gaussian distribution. Optimising the model parameters and the mean and standard deviation of the biological shift factor with respect to the p-value of the normality test of Shapiro would then deliver the best result. The second method is based on the likelihood derived from the theoretical density function for the model applied. Optimising the likelihood with respect to the parameters in the model will then deliver not only estimated values for the model parameters but also a characterisation of the biological variation present. A variation on the second method is also based on optimising the likelihood. However, with this method a difficulty arises due to the random biological shift factor. The likelihood corresponding to the observed variables writes as an integral with respect to the distribution of that shift factor, and does therefore in general not admit an analytical expression. Possible approximations to this integral to compute approximate maximum likelihood estimators will be explored and to a measured data set where the answer is not known. All methods will be used to analyse the same set of simulated data to compare the applicability of the three methods.

## Applying mathematical models in the development of an active packaging system incorporating a volatile antimicrobial agent

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The focus of this research is the development of an active packaging system in which a volatile component can be delivered and sustained in the headspace at an appropriate concentration to control postharvest pathogens throughout the required storage period. Hexanal vapour was taken as a model volatile due to its degree of volatility and proven antimicrobial activity. Its antifungal activity was tested against *Botrytis cinerea* inoculated on tomato and the minimum inhibitory concentration (MIC) for continuous exposure was determined to be 40-70 ppm. Sachets for the controlled release of hexanal vapour were developed using different masses of silica gel adsorbent contained within low density polyethylene (LDPE) film. These sachets were inserted within LDPE bags (300 mm size) containing intact tomatoes and the gas atmosphere and tomato quality parameters were measured during storage periods of up to 14 d at 20°C. Hexanal vapour concentrations in the package headspace were sustained above the MIC level during the first 7 days of the storage period. Mathematical models were developed to predict the concentrations of hexanal and other key gases (O<sub>2</sub>, CO<sub>2</sub> and H<sub>2</sub>O) in the package atmosphere. Model predictions were assessed against experimental data and showed good agreement. The models and their potential to be further developed to design active packaging systems for other horticultural products will be discussed.

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