

Symposium 9 (S09): Issues and Advances in Postharvest Horticulture

Monday · August 12

Location: Metro Toronto Convention Centre, Room 105

1100–1140

S09–0–1

CURRENT STATUS AND FUTURE CHALLENGES FOR THE POSTHARVEST SECTOR IN DEVELOPING COUNTRIES

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This paper provides an overview of the current and likely future importance of the postharvest sector to the global economy, while emphasizing its particular relevance for developing countries. First, the paper highlights the contribution of postharvest activities to output, exports and employment in various parts of the world, and its vital role in promoting food security and rural welfare. Second, the paper examines the key qualitative trends which are propelling growth in the postharvest sector and changing its structure in dramatic ways with important implications for farmers, firms and consumers. In particular, this section considered the contraction of agriculture, the drive toward urbanization, increased awareness of gender roles and the environment, technological advance, and perhaps most importantly, the massive changes being wrought by globalization and increased attention to food safety. While the overall impact on postharvest development should be positive, the aggregate trends might mask adverse distributional consequences. Third, the paper turns to the challenges firms and governments will face in the coming years, in seeking to ensure that the continued growth of postharvesting is dynamic and broad-based. As they seek to cope with these challenges, governments face a number of pressing policy issues. The paper closes by outlining those that appear most relevant on a national level: the need for a regulatory framework that promotes growth while safe-guarding welfare; for adequate market information to be given to all actors involved; for further investment in postharvest research; and for participation in international agreements that promote trade and food safety.

1140–1220

S09–0–2

“FROM QUANTITY TO QUALITY” A GLOBAL INITIATIVE TOWARD STRENGTHENING THE POST-HARVEST SECTOR

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Post-production operations account for more than 55% of the economic value of the agricultural sector in developing countries and up to 80% in developed countries. Although they are the basis of socio-economic development in rural areas and are of critical importance in meeting the food security and nutritional requirements of populations, relatively little public sector and developmental support is targeted to addressing these fundamental concerns and the growing and changing trends within the sector. Three decades have elapsed since the last major conference geared toward soliciting developmental support for the post-production sector. The focus then was on the reduction of post-harvest losses. Considerable growth in the sector, as well as changes in market demands and trade regulations point to the increasingly important dimension of produce and product quality, if developing countries are to gain advantages from the safety, security and potential trade benefits of a stable food supply. By and large, this growth and change is very poorly supported by developmental policies and strategies, and technical capacity within the sector remains very weak. In recognition of these deficiencies in policies, strategies, and technical and financial inputs to address the fundamental and growing concerns of the post-harvest sector, the Agro-Industries and Post-Harvest Management Service of FAO (FAO/AGSI) with the endorsement of Ph Action, and the collaboration of GFAR embarked upon launching an international initiative geared toward facilitating development within the post-harvest sector of developing countries. This initiative is implemented in two-phases: Phase 1) 2001/2002. Developing a global perspective of the post-harvest sector, through the planning and implementation of five co-ordinated technical regional workshops (Africa, Asia, Near East, Central Asia and South America); Phase 2) 2003 Conducting an International Technical Consultation on Post-Harvest, with the objective of launching a Global Initiative on Post-Harvest (GIpHT).

1220–1240

S09–0–3

POST-HARVEST ACTION

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Post-harvest interventions, rather than production research, should be the focus in many developing countries. This is the claim of the Global Post-harvest Forum, PhAction. Developing countries have often been assisted to increase their production of agricultural commodity crops for export, only to find the price falling as a result of over-supply. And worse than that, the diversion of effort into growing commodities for export can damage domestic food security. Research by the International Food Policy Research Institute shows that putting more emphasis on market-oriented post-harvest research can make a major contribution to improving food security, enhancing rural employment and alleviating poverty. There is a growing awareness that niche marketing of perishable fruit and vegetables holds significant opportunities for rural communities in developing countries. And one of the most accessible markets for this produce will be the emerging affluent urban community in their own country. PhAction is working on a draft global programme in post-harvest, called “Linking Farmers to Markets”. This is a top-down conceptual approach which ideally complements the FAO’s bottom-up Global Initiative in Post-harvest Technologies; and the two initiatives may indeed become one, since many of the same people are involved in their design and execution. PhAction is a consortium of research institutions around the world committed to promoting the application of the best international post-harvest research to issues in developing countries. There are currently twelve members of PhAction, including several Consultative Group on International Agricultural Research Centres, and membership is increasing constantly.

1340–1440

S09–P–4

TRACEABILITY OF FRESH PRODUCE SUPPLY CHAINS: CONCEPTS, RECENT TRENDS AND ENABLING TECHNOLOGIES

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The ongoing globalisation of the world economy has increased the volume and value of international trade in fresh and processed foods. Increasing incidence of food safety scares and hazards associated with the consumption of fresh and processed produce, consumer concerns about genetic modification of foods, and growing interest in sustainable farming practices have heightened public concern for identity preservation and traceability of food products from field to plate. Recent trends toward vertical integration of supply chains and the increasing demand for traceability have opened up new challenges and opportunities for producers and marketers, both for those seeking market access for new products and services, and those already supplying to established markets. Traceability in the horticulture industry presents peculiar technical and operational problems since products are often marketed through multiple channels to the end-user. A fundamental feature of a traceable supply chain management system is the availability, access and integration of information about the product, activities, inputs and handling environment. This paper discusses the concept and meaning of traceability as applied to horticultural crops, and a distinction is made between different orientations of traceability based on recent debate between the US and Europe. A technological framework for integrating traceability into existing supply chain and quality management practices in horticultural enterprises is proposed. The emerging engineering and technological innovations for product identification, measurement of product and process attributes, and communication are highlighted and discussed.

1340–1440

S09–P–5

A NOVEL SIMULATION MODEL FOR STUDYING AIRFLOW PATTERNS AND IMPACTS DURING POSTHARVEST OPERATIONS

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Air distribution inside postharvest-built environments such as packaging and cool-stores is an important factor affecting cool-chain management since air motion inside the structure affects the heat transfer between product and the cooling medium (moist air). Literature evidence shows that airflow characteristics affect the magnitude of weight loss and quality degradation in stored fresh fruit. Accurate prediction of airflow patterns and heat transfer is therefore vital toward the optimal design and management of postharvest facilities. In comparison to extensive laboratory testing, computational fluid dynamics (CFD) provides a novel and sophisticated but economic tool for modelling and visualising airflow and other thermodynamic processes inside built environments. This paper outlines the development of CFD models for simulating the airflow patterns and temperature profiles inside single, stacked, and bulk ventilated fruit containers. The airflow and heat transfer models (programmed in MATLAB) were integrated into a user-friendly simulation software by dynamically linking the computer programmes to data files written in C language. Comparisons of model predictions against experimental results for apples undergoing pre-cooling inside a standard carton gave good agreement based on product cooling rates. Simulation results also revealed the existence of microenvironments inside ventilated packages for fresh fruit, but the impacts of these variations on product storage stability are not known. Potential applications of the new software in postharvest horticulture education, extension and research will be discussed.

1340-1440

S09-P-6

A MODEL TRAINING HANDBOOK FOR SMALL-SCALE POSTHARVEST HORTICULTURE AND MANAGEMENT

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There is considerable literature evidence on the magnitude and prevalence of postharvest losses in fresh produce, particularly in developing countries. In recognition of the need to reduce losses and improve food security in these countries, several national, regional and international programmes have been launched during the past 40 years and most notably, the FAO's 'Prevention of Food Loss Programme'. Reduction of postharvest losses requires the adoption of both improved 'hard' and 'soft' technological innovations. To ensure success and sustained impact, education and training in postharvest technology management is essential at all levels in the supply chain, including farmers, staff, extension agents, and their trainers. Many education and training resources exist, particularly in tertiary institutions, but most have been written from a purely technical perspective and targeting students who often have basic understanding of the principles of postharvest. However, the majority of resource-poor farmers and their trainers in developing countries do not have specialist technical knowledge in postharvest science and technology, and most often, the trainees do not speak the language (mostly English) used in postharvest textbooks available in their locality. A model handbook has been written, in cooperation with the UN FAO, as a guide in preparing and implementing training programmes on postharvest management, targeting resource-poor farmers and their trainers in LDCs. This paper will outline the contents and key features of the book, and demonstrate how it can be effectively adapted to develop a competency-based training kit to suit specific local needs.

1340-1440

S09-P-7

RESPONSES OF SIX APPLE CULTIVARS TO STORAGE ATMOSPHERE CONDITIONS DYNAMICALLY CONTROLLED BY CHLOROPHYLL FLUORESCENCE-BASED TECHNOLOGY

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It has been reported in lab-based trials with various fruits and vegetables that chlorophyll fluorescence (F*) suddenly increases if O₂ is too low or CO₂ is too high (Prange et al., 2001. ISHS CA Conference). Thus, we have hypothesised that continuous F* measurements could be used to optimize controlled atmosphere (CA) conditions and fruit quality. To test this hypothesis, simultaneous lab and commercial trials were conducted using F*-based CA storage regimes (Dynamic CA, or DCA) on six apple (*Malus x domestica* Borkh.) cultivars. In the lab and/or

commercial trials, 'McIntosh', 'Gala', 'Jonagold', 'Delicious', 'Golden Delicious', and 'HoneyCrisp' fruit were stored in DCA and standard CA conditions. The lab trial was done at the AAFC Atlantic Food and Horticulture Research Centre in Kentville, NS while the commercial trials were located in Canada, the Netherlands, Italy and New Zealand. In the DCA treatment, the O₂ concentration was held as low as possible without inducing an increase in F* whereas the standard CA treatment was the static O₂ and CO₂ concentration traditionally recommended for each cultivar. The standard CA and DCA treatments in both the lab and commercial trials will be compared for each cultivar, based on regular sampling of fruit quality attributes, e.g. firmness, total soluble solids, titratable acidity, volatile production, marketable fruit, disorders and decay.

1340-1440

S09-P-8

RAPID, ACCURATE, IN-FIELD PREDICTION OF CABBAGE MARKETABLE YIELD

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Declines in cabbage (*Brassica oleracea* var. capitata) crop quality may result from delaying harvest to allow for greater total yield. A rapid and reliable method to estimate marketable yield before harvest not requiring direct weight measurements would assist cabbage growers and handlers in harvest scheduling. Results from three years of study during which a tool to predict cabbage marketable yield was developed and tested are reported here. Plots containing a total of thirteen cabbage varieties (fresh/slaw, kraut type) were planted in May and June of 1999 and 2000 at the OARDC Vegetable Crops Research Branch (VCRB) in Fremont, OH. Exhaustive measurement of marketable yield and traits of hundreds of individual heads grown under varying conditions revealed stable relationships, especially head size-density, useful in the estimation of marketable yield. In 2001, marketable yield predicted by three individual formulae based on these relationships was compared to direct measures of yield in twelve commercial cabbage fields in NW Ohio encompassing five varieties and various planting dates, fertility regimens, and other factors. Similar comparisons are underway for crops grown in Wooster, OH and at the VCRB in 2001. Comparing actual and predicted marketable yield values from commercial fields revealed that yield estimates based on the average of polar and equatorial head diameters tend to be more accurate than yield estimates based on either diameter alone. The R² for predicted and actual marketable yield equaled 0.95 when using average head diameter. Nearly all marketable yield estimates were within 5% of actual yield values over a wide range of actual yield—on average, marketable yield estimates were within 3% of actual yield values. The tool reported here allows for rapid, accurate, in-field estimates of cabbage marketable yield and is easily adjusted for local conditions.

1340-1440

S09-P-9

FRUIT QUALITY MONITORING USING A MULTI-GAS SENSOR

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Fruit quality determination in closed storage rooms is of economic importance in order to decide on the potential storage duration. Various technologies have currently been investigated to provide data on the fruit ripening process in the storage container. However, there is no application available on the market so far, but headspace analysis measuring the gas exchange rate of volatile compounds may provide reasonable data to estimate fruit quality changes during storage. A multigas sensor (Jenasensorik, Germany) was tested and adapted for long-term monitoring of fruit quality in closed storage rooms. Particular problems appear from the temperature effect on the calibration model for ripeness prediction. This physiological phenomenon was addressed by parallel measurements of the gas exchange rate using the sensor, as well as gas chromatography. The data, thus obtained were used to calculate the Q10 factor of aroma compounds using the equation $Q10 = [k1/k2] \cdot \exp [10 / (T2-T1)]$. The ripeness models for *Malus x domestica* cvs. 'Elstar' and 'Jonagold' apple fruit were improved by insertion of the relevant Q10 factor.

1340-1440

S09-P-10

**LASER-INDUCED FLUORESCENCE SPECTROSCOPY (LIFS)-
APPLICATION IN HORTICULTURE**M. Zude*¹, M. Meurens²

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During the last few years there has been an increased concern about the nutritive value of phytochemicals in fresh fruit, nuts and vegetables for protection against cardiovascular diseases and different types of cancer. Chlorophyll fluorescence analysis has become an accepted tool for measuring the activity and capacity of photosystem II under various stress conditions. However, laser fluorescence kinetics may provide a non-destructive tool to measure active fruit compounds relevant for human nutrition. A joint experiment showed the potential and present limits of this method for high-quality fresh apples, stored oranges, grapes and fruit salad, as well as bruised apples.

1340-1440

S09-P-11

**ASSESSING APPLE QUALITY AND STORAGE CAPABILITY BY MEANS
OF FLUORESCENCE IMAGING**C. Huybrechts*¹, T. Deckers², R. Valcke¹

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Fluorescence imaging is a non-invasive method which can be used to study stress and senescence in the photosynthetic apparatus. It is based on red light-induced chlorophyll fluorescence after excitation with UV or blue light. Most portable fluorimeters, which are point-source chlorophyll fluorescence techniques, have been used to indicate physiological disorders and as a quality assessment of apple fruit ripening and senescence. A major limitation is its inability to detect local fruit surface differences. A fluorescence imaging system has been developed to overcome this problem. In this study fruit trees were exposed to different treatments, which may have affected the fruit ripening process. Apples were analysed by the fluorescence imaging technique in order to determine treatment differences in fruit quality and storage potential. Fruit trees of *Malus x domestica* Borkh 'Prince Jonagold' from Velm, Belgium were subjected to following stresses during the growing season: an ethylene stress with trees where the ethylene formation was stimulated by an Ethephon treatment and with trees where the ethylene formation was inhibited by a preharvest treatment of Aminovinyglycine. A second type of stress induced on the trees was a growth stress where the vegetative growth was stimulated by a combination of a short pruning system and post floral applications of gibberellines or was inhibited by post floral applications of the gibberelline blocking compound Prohexadione Calcium. The results indicated chlorophyll fluorescence imaging of fruit samples was influenced by the different treatments. Fluorescence images detected physiological changes caused by the different chemicals, thus allowing classification of the apples according to storage potential and quality at harvest. Apples treated with Aminovinyglycine had the highest storage potential because this chemical decreases ethylene production and slows down the ripening and senescence of the fruit. This experiment showed that chlorophyll fluorescence imaging may be a useful tool to assess fruit quality and storage potential.

1340-1440

S09-P-12

**EFFECT OF PRE AND POST HARVEST CALCIUM TREATMENTS ON
FRUIT QUALITY IN GUAVA CV. ALLAHABAD SAFEDA DURING
AMBIENT STORAGE**

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Guava (*Psidium guajava* L.) is a very nutritious fruit known for its ascorbic acid content but which is beset with the problem of poor shelf life. In India, the fruits are to be marketed at ambient conditions as the cold chain system has not been fully developed. Therefore it is imperative to develop an alternative, inexpensive and simple technique in order to retain the quality of the fruits during

marketing. The present study is an attempt to assess the effect of calcium infiltration, both at pre and postharvest levels, during the fruiting years 1999 and 2000 on winter crops of guava cv. Safeda. The experiment consisted of pre-harvest treatments of CaCl₂ 1.0, 1.5 and 2%, Ca(NO₃)₂ 1.0, 1.5 and 2.0% applied 20 days before harvest and postharvest treatments of CaCl₂ 2.0, 3.0 and 4.0 and Ca(NO₃)₂ 2.0, 3.0 and 4.0%. Tepol was used as surfactants. The control fruits were taken from the trees receiving no calcium treatments. The fruits of all the treatments were packed in CFB boxes, kept at room temperature and physico-chemical evaluations were done at 2 day intervals. CaCl₂ treated fruit were significantly better at harvest. CaCl₂ (3%) as post harvest treatment extended the shelf life of guava by ten days. The treated fruits exhibited low weight losses during storage and remained fresh and firm with little spoilage. The quality in terms of ascorbic acid was also better during room storage for 10 days. CaCl₂ (2%) as pre-harvest treatment was the second best treatment in retaining the high quality of fruits at harvest and during ambient storage for 10 days.

1340-1440

S09-P-13

**SHELF LIFE OF GREENHOUSE LETTUCE AFFECTED BY GROWING
AND POSTHARVEST CONDITIONS**

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Greenhouse lettuce is perishable after harvest. Recommendations are to store at 0 °C for a potential shelf life of 21-28 days. However, shelf life is much reduced in commercial practice. Two trials examined the effects of growing conditions and post-harvest procedures on lettuce shelf life. In four pre-harvest experiments in the first trial, supplementary lighting with high-pressure sodium (HPS) lamps accelerated shelf life decline from 0.86 days per °C of constant temperature in control to 1.34 days under HPS lighting. Fertilizer and use of fan had weaker effects, and cultivars had no effect on shelf life evaluated under constant temperatures of 1, 5, 10 and 20 °C. Four experiments in the second trial examined the effect of post-harvest procedures. Both living lettuce (with roots) and butterhead lettuce (with roots removed) were obtained from local commercial greenhouses. The samples were obtained at various points of post-harvest procedure: in the greenhouse, in the shipping area of a packing house, and at a retailer warehouse. Samples were immediately stored at 1 °C for shelf life evaluation. Living lettuce had longer shelf life than butterhead lettuce. Those that received vacuum cooling immediately after harvest had longer shelf life than those that were room-cooled. Living lettuce sampled in the shipping area of a packing house had longer shelf life than sampled at the retailer warehouse. It is apparent that both pre- and post-harvest factors significantly affect the self life of greenhouse lettuce.

1340-1440

S09-P-14

**INFLUENCES OF NITROGEN AND POTASSIUM FERTILIZER ON THE
QUALITY OF PEPPER FRUITS (*CAPSIUM ANNUM* L.) VAR.
JUPITER UNDER STORAGE**

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Pepper fruits at the mature green stage were harvested from plants treated with 0-0, 200-200, 300-200, 200-400, 300-400 kg/ha of nitrogen and potassium fertilizer, respectively. Fruits were washed, sorted and stored in polyethylene bag of 0.05 mm with 16 holes of 0.6 mm diameter. Three replicates for each treatment were used (one fruit per bag). Fruits were stored at 5 and 10 °C for 7, 14, 21 and 28 days for chemical and physical analysis (TSS, pH, titratable acidity, tss/ta, color and firmness). An aleatory block with a factorial design 2x2x4x4 was used. The TSS increased with storage time and showed significant differences in fruit stored in plastic bags. The pH increased in fruits from plants treated with 300 kg/ha of nitrogen and 400 kg/ha of potassium and stored at 5 °C. Fruit stored at 10 °C recorded the highest pH values. The titratable acidity reached high values in fruits with plastic covers stored at 5 °C and fruit from plants treated with 200 kg/ha of nitrogen and 400 kg/ha of potassium fertilizer. Color variables showed some change with the storage time with "L" increasing at 28 days of storage. The highest value of firmness resulted in those fruits stored in plastic bags treated with 300-400 kg/ha of nitrogen and potassium fertilizer and stored at 5 °C.

1340-1440

S09-P-15

A PREHARVEST APPLICATION OF LYSOPHOSHATIDYLETHANOLAMINE (LPE), A NATURAL LIPID, CAN INCREASE CRANBERRY FRUIT COLOR AND IMPROVE SHELF LIFE

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Lysophosphatidylethanolamine (LPE) is a natural lipid and is commercially extracted from egg yolks and soybeans. A number of studies from our laboratory have demonstrated that LPE is able to accelerate fruit ripening while at the same time promoting shelf life. We studied the influence of LPE on the pattern of anthocyanin accumulation and storage quality of cranberry fruits (*Vaccinium macrocarpon* Ait. cultivar Stevens). For this purpose 2 m x 1 m plots were established in cranberry beds at seven separate locations near Wisconsin Rapids. Experiments were conducted in 1997, 1998 and 1999 seasons. Plots were sprayed with LPE (extracted from egg yolk and soybean) 3-4 weeks before harvest. Spray solution included 200 ppm LPE, 3% ethanol and 0.005% detergents (Sylguard). Fruit samples were taken from a part in the plot periodically to determine the changes in the fruit color. The rest of the plots were commercially wet harvested and placed in cold storage. Marketable fruits were counted at various times during cold storage to determine effect of LPE on shelf life of cranberries. Evaluation of results from seven locations taken together showed a significant increase in fruit color by LPE. At 2 and 4 weeks after application fruit anthocyanin contents increased by 15 and 29%, respectively. At one and two months after cold storage preharvest LPE treatment resulted in an increase in 12 and 8% marketable fruits, respectively. The result of the present study shows that preharvest application of LPE can add value to cranberry crops, including higher and more uniform colored fruit and enhanced shelf life.

1340-1440

S09-P-16

PHOSPHORUS FERTILIZATION AND POST HARVEST QUALITY IN APPLES

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Phosphorus deficiency affects physiological and biochemical processes ranging from cell division, enzyme reactions requiring cofactors such as NAD, NADP and ATP, antioxidant enzyme function and biochemical pathways such as the pentose phosphate pathway, phenylpropanoid pathway, isoprenoid pathway etc., that ultimately determine the nutritional quality and shelf life of fruits and vegetables. In this study, we have evaluated the effect of soil and foliar phosphorus supplementation on the quality of McIntosh apples. Superphosphate (0:20:0) was supplied through the soil at a low dose (420 g/tree) or a high dose (420 g x 3/tree). Foliar formulations of phosphorus such as hydrophos and seniphos (Phosyn, UK) were applied at 20-day intervals after thinning. Apples were harvested at optimum ripeness. There were no significant differences in the initial fruit weights, fruit firmness or the starch index between control fruits and fruits from trees subjected to any of the treatments. The content of soluble solids was significantly higher in fruits from trees supplied with low phosphorus, high phosphorus and hydrophos. The colour of the apples was also significantly improved in response to soil and foliar phosphorus supplementation. Phosphorus supplementation did not affect the production of volatile components including α -farnesene and several esters. Internal ethylene levels were much lower in apples treated with low phosphorus, high phosphorus and hydrophos. The development of superficial scald was also affected by phosphorus supplementation in McIntosh apples. By comparison to a 20-30% scald development in control apples, those from trees supplied with low phosphorus, high phosphorus and seniphos showed very little (5-10%) scald development. As well, the intensity of scald development was much lower in these treatments.

1340-1440

S09-P-17

INCIDENCE OF BLOSSOM END ROT AND FRUIT FIRMNESS OF TOMATO AS AFFECTED BY IRRIGATION QUANTITY AND CA SOURCE

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'Equinox' tomatoes (*Lycopersicon esculentum* Mill.) were grown with black polyethylene mulch and drip irrigation on an Arredondo fine sand in Gainesville to study the influence of water quantity and Ca source on fruit firmness and the incidence of blossom end rot fruit (BER). Water quantities were controlled with tensiometers used to automatically schedule irrigation when soil matric potential reached 10 or 25 kPa (10 or 25 cb). Calcium treatments included no added Ca, Ca(NO₃)₂, Ca thiosulfate, CaCl₂, CaSO₄, and K rate reduced by 50% from 168 to 84 kg-ha⁻¹ (with no added Ca). Marketable fruit from plants irrigated at 25 kPa were significantly firmer than the fruit from plants irrigated at 10 kPa with all Ca treatments except with reduced K. Fruit firmness was lower and similar with both water treatments with reduced K than with all other Ca treatments at 25 kPa. Plants watered at 25 kPa had a 100% higher total weight and number of BER fruit than plants irrigated at 10 kPa. Tomato plants that received Ca(NO₃)₂, and reduced K produced the lowest number and weight of BER fruit and were significantly lower than with no added Ca, Ca thiosulfate, and CaSO₄. Marketable fruit yields were significantly greater with irrigation at 10 kPa than at 25 kPa and were higher with Ca(NO₃)₂ and CaCl₂, than with Ca thiosulfate.

1340-1440

S09-P-18

PRE-HARVEST SPRAYS AND POST-HARVEST FRUIT DIPS INFLUENCE FRUIT DROP, HARVEST QUALITY, AND COLD STORAGE OF APPLES AND PEACHES

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Aminoethoxyvinylglycine (AVG) sprays inhibited 'Arlot' fruit drop, increased pull force, and delayed the loss of fruit firmness, starch, fruit shriveling, and red color. 1-Methylcyclopropene (MCP), applied as a gas or spray, did not affect fruit drop or pull force. The combination of AVG + MCP (spray or gas) provided better control of fruit drop, loss of fruit firmness, starch degradation, and loss of pull force than AVG alone. Thirty five days past the optimum harvest date, fruit from trees sprayed with AVG + MCP was maintained at 74 newtons firmness compared to 61 newtons for the control. Eventually, treated fruit increased 2.5 cm in fruit diameter in the 35 days after the optimum harvest date. NAA, dicamba, floxypyr, cyclanilide, and AVG inhibited fruit drop of 'Law Rome', 'Redspur Delicious', and 'Golden Delicious', but cyclanilide or MCP did not. Dicamba + AVG + MCP provided the best control of fruit drop. Treatment combinations containing AVG inhibited the loss of firmness, starch, and percentage of fruit and the amount of red vascular bleeding into the cortex. When stored at 21 °C for 2 to 6 weeks, 'NuRed Rome 262' dipped in Mertect did not affect fruit firmness, starch, % rots, but increased soluble solids. MCP (gas or dip), MCP (gas or dip) + Mertect, or AVG + Mertect inhibited loss of fruit firmness and starch and reduced fruit rots, but cyclanilide + Mertect did not. Approximately 60 days after harvest, fruit dipped in AVG + MCP + Mertect on Sept 26 were still 92 newtons firmness on Nov 11; whereas, untreated fruit were only 53 newtons. When stored at 21 °C for 10 days 'Cresthaven' peach fruit dipped in Scholar fungicide, MCP did not affect fruit firmness or soluble solids. Fruit dipped in AVG, AVG + Scholar, or AVG + MCP + Scholar substantially inhibited loss of fruit firmness (Control = 9 newtons vs. AVG + MCP + Scholar = 45 newtons).

1340-1440

S09-P-19

DEFICIT IRRIGATION INFLUENCES YIELD AND LYCOPENE CONTENT OF 'DIPLOID' AND 'TRIPLOID' WATERMELON

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Many vegetable production regions in southwestern US are strictly regulated on water use. In addition, demand for high quality and nutritious vegetables has increased. This study was done to explore the effects of deficit irrigation on yield, fruit quality and lycopene content of red-fleshed 'diploid' (2n) and 'triploid' (3n) watermelon. Irrigation treatments were 1.0 ET, 0.75 ET and 0.5 ET rates. Cultivars used were 'SF 710', 'RWM 8036', 'Allsweet', 'Sugarlee', and 'SWD 7302' (2n) and 'SS 5244', 'SWT 8706', 'Sugar Time', and 'Tri-X-

Sunrise' (3n). Total water applied through a subsurface drip system was 395, 298 and 173 mm, for the 1.0 ET, 0.75 ET and 0.5 ET, respectively. Harvests were made on 25 June, 16 July and 1 August 2001. Fruit firmness was measured with a digital force meter, and soluble solids content (SSC) with a digital refractometer. Fruit lycopene content was extracted by acetone and hexane and measured spectrophotometrically at 503 nm. Total yields were highest at 1.0 ET (53.9 t·ha⁻¹) compared to 0.5ET (26.8 t·ha⁻¹). Triploids had a 34% higher total yield and fewer culls (2%) compared to diploid cultivars (25%). Highest yields were obtained for Sunrise, SWT 8706, and SWD 7302. Triploid watermelons had a higher water use efficiency (range 106-133 kg·mm⁻¹) than 2n watermelons (54-107 kg·mm⁻¹). Highest SSC was measured for Sugar Time (13.4%) and was significantly higher than other cultivars (range 9.7-11.0%). Triploid cultivars had a more firm flesh compared to 2n cultivars (12.0 vs. 9.9 N). Lycopene content increased slightly with maturity (55.8 to 60.2 µg·g⁻¹ fw), and was significantly higher at 0.75 ET than 1.0 ET in melons at ripe and over-ripe maturity stages. Lycopene content averaged over all treatments was 60-66 µg·g⁻¹ fw for triploids and 45 to 80 µg·g⁻¹ fw for diploid fruits.

1340-1440

S09-P-20

PREHARVEST AND POSTHARVEST STRATEGIES FOR REDUCING NITRATE CONTENT IN ROCKET (*ERUCA SATIVA* L.)

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Rocket is an important leafy vegetable in Mediterranean countries and is mainly used to flavour salads. Rocket grown in soil has a nitrate content about 7000-8000 ppm and during the winter period this value can easily surpass 9000 ppm. Rocket was used in our experiments as model system for studying new technologies for reducing the nitrate content in the preharvest and postharvest stages. Experiments carried out as preharvest strategies were focused on the comparison between soil cultivation and floating systems with and without oxygen (respectively 6 and 1.5 mg·L⁻¹). Oxygen reduction of the nutrient solution was applied one week before harvest and its effect was evaluated on the nitrate accumulation in rocket leaves. During postharvest life, rocket was stored at 5 °C under 200 mmol·m⁻²·s⁻¹ of light or darkness. Also the effect of 15 g·L⁻¹ of sucrose and 50 mg·L⁻¹ of ascorbic acid was tested both in light and darkness for nitrate content reduction and keeping quality of rocket leaves. The effect of the soil and floating system with and without oxygen was assessed by measuring the nitrate content at the harvest time. During postharvest life the effect of treatments was evaluated by nitrate content, nitrate reductase activity, relative water content, chlorophyll and carotenoid content. Results showed that rocket grown in soil has higher nitrate content and lower yield than those produced with a floating system. Moreover, rocket grown in the floating system without oxygen has a lower nitrate content. Finally, during postharvest life the rocket stored at 5 °C under light had lower nitrate content. Further experiments are being conducted to characterize the effect of sucrose and glutamine on nitrate reductase activity. Future investigations will be focused on changing nitrate reductase gene expression in the most significant treatments.

1440-1500

S09-O-21

POSTHARVEST TECHNOLOGY AS A CATALYST FOR POVERTY ALLEVIATION, FOOD SECURITY AND AGRO-INDUSTRIALISATION: THE ROLE OF IN-COUNTRY TRAINING PROJECTS

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It has been argued that least developed countries (LDCs), with 80% of the world's population and projected to be 90% by 2050, must strive to produce more food from the same cultivated area in order to improve food security. However, in a majority of these countries, postharvest activities represent more than 55% of the economic value of agriculture and horticulture, and the figure is even much higher (up to 80%) in developed countries. Good postharvest management and development of rural agro-industries of various types, therefore, is now widely recognised as good foundations for socio-economic improvement in rural areas because of their crucial role in improving food security, nutrition, and poverty alleviation through employment and income gen-

eration. With increasing external pressures such as demographic shifts to urban areas, globalisation of the food supply chain, and growing emphasis on product quality, safety and traceability, small-scale resource-poor farmers need access to appropriate postharvest innovations to reduce losses, maintain quality and enhance market access. These trends are leading to renewed attention among development agencies, donor agencies, policy experts and research institutions on the role of postharvest technology in sustainable agri-based economic development in LDCs. In the first part of this paper, I will summarise the relative superiority of investments in the postharvest sector in alleviating rural poverty based on literature evidence. The second part discusses recent personal experiences gained in formulating and implementing in-country training programmes in three LDCs, which were designed to expose resource-poor farmers and other stakeholders to principles and techniques of improved postharvest management. An agenda is proposed to instigate debate and global discussion on the integration of postharvest technology in sustainable food security and poverty alleviation programmes.

1500-1520

S09-O-22

LOW COST COOL CHAMBER FOR STORAGE OF TROPICAL FRUITS

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India produces about eight per cent of the total world's fruit production. The production figure of the fruits in India is estimated to be over 40 million tonnes of which about 80 per cent belong to tropical and subtropical group. Tropical and subtropical fruits present a special problem in conservation and transportation because they are much more perishable than temperate fruits. In the last two decades, production of tropical and subtropical fruits has markedly increased in all the Asian countries, Australia, New Zealand, South Africa and Japan where they make a significant contribution toward earning foreign currency or to diversify the economy. A large quantity of fresh fruits in India is wasted after harvest due to lack of enough storage facilities. The high cost involved in developing cold storage or controlled atmosphere storage facilities is a pressing problem in several developing countries. In view of the current energy crisis, the low cost environment-friendly cool chamber working on the principle of evaporative cooling developed at the Indian Agricultural Research Institute was found very effective to increase the storage life of tropical fruits like mango, litchi, guava, banana, and sapota. The paper will discuss the working principle and advantages of using cool chamber at the farmhouse.

1520-1540

S09-O-23

POST-HARVEST PRACTICES AND TECHNOLOGY NEEDS: A MULTINATIONAL FOOD CORPORATION PERSPECTIVE

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Our company is one of the largest commercializers of fresh fruits and vegetables in the world. Many of these fruits and vegetables are grown in developing countries where we face many challenges in transferring, implementing, and applying the most adequate post-harvest practices and technologies to ensure that produce we grow, pack, transport, and distribute meets the very stringent quality standards and preferences demanded by developing countries, our clientele. Post-harvest operations do not have to be sophisticated, they can be quite simple, but they do need to be adequate, effective, efficient, and cost-effective. Some of our large scale operations justify investment in high-tech machinery and post-harvest treatments, however, for many small scale operations, especially those where we only source from, simple, low cost technologies can be more appropriate. Innovation does not equate sophistication and high cost. Most common causes of post-harvest losses in developing countries include rough handling, poor sorting and selection before packing, inadequate packing, and cooling. It is clear that effective management during the post-harvest period is the key. More and more, pressures for more environmentally friendly post-harvest operations can result in important constraints to more cost-effective or efficient practices and require alternatives to traditional post-harvest methodologies.

1540–1600

S09–0–24

REDUCING POSTHARVEST LOSSES—A TRAINING MODULE DEVELOPMENT FOR WEST AFRICA

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Demand for fresh vegetables is high year-round. Large amounts of vegetables are produced by traditional farming systems during the rainy season when produce is abundant. Lack of processing and storage facilities limit the year-round availability of vegetables such as tomatoes in west Africa. Most produce is lost through bruises, decay and wilting. This results in scarcity and high prices of vegetables. Produce is transported over various distances on poor roads, making vegetables and other produce expensive, as well as reducing quality. In traditional systems, produce is harvested manually from the farm to roadsides for transportation. Casual workers perform the harvesting. Small and medium sized producers use family labour. Women traders known as >market queens= are responsible for distribution and sale of produce. These women are mostly urban who purchase produce from farms. The produce is transported to cities for bulk sale to women traders who sell at retail. All people involved in handling produce lack understanding of factors affecting postharvest produce quality. A case in point is the tomato. This perishable crop requires careful handling and marketing due to its short shelf life. The training needs for postharvest handling were assessed for tomato producers in northern Ghana by a participatory research approach. Postharvest produce loss and marketing were identified as main problem areas. Modules were designed for use by master trainers and trainers focusing on farmers' needs. Module development involved meetings with farmers and workshops for the master trainers and trainers. The outcome included training modules covering: harvesting, preparation for the fresh market, grading, packaging, and transport. The method of delivery and handling are explained in the module. Each module has fact sheets usable alone or with other modules. Design of modules and adaptation for use in West Africa will be discussed.

1600–1620

S09–0–25

DEVELOPMENT OF A LARGE CAPACITY EVAPORATIVE COOL STORAGE CHAMBER FOR CITRUS AND OTHER PERISHABLES WITH SPECIAL REFERENCE TO MANDARIN FRUIT (CITRUS RETICULATA BLANCO)

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The chamber with 8.5 m³ storage volume (225 cm length x 180 cm width x 210 cm height, inside dimension) has been constructed using bricks, sand, bamboo, wood wool panels and jute cloth (gunny bags). The drip system for continuous trickling of water and overhead water tank of plastic material with 200 litre capacity is installed. Small exhaust fan with regulator (maximum 100 ft³/minute airflow, 22.5 cm fan size, 900 rpm) is provided opposite to entrance door of the chamber for air movement. On two sides, double layer brick wall with cavity (5 cm) are made with masonry work in mud (as done in rural areas for construction of houses). The walls are supported from inside and outside by iron net and bamboos which are fixed in four columns erected at corner using bricks, cement and sand. The floor is made by arranging bricks in single layer. On front side, asbestos door is provided with wooden frame. The wood wool and jute (gunny bag) panels (90 cm length x 45 cm width) of 4 cm thickness are fitted in wooden frame on front and backside. The top ceiling is made of wooden frame and asbestos sheets. The hut shaped roof cover made of bamboos, locally available grass panel, gunny bags and plastic sheet is placed over asbestos ceiling with support of four columns and tied with wires to the bamboo structure. The average maximum temperatures of the cool chamber are considerably low (10–15 °C) as compared with outside. The relative humidity is also above 90% throughout the year. Mandarins, sweet oranges and acid limes can be stored up to 21, 42 and 30 days, respectively in acceptable condition in this chamber. This chamber can accommodate 65 plastic crates (55 cm x 35 cm x 30 cm) with 1.5 tonne citrus fruit. Energy requirements for storage of fruit in this chamber vis-à-vis mechanical storage are discussed. This chamber can be a boon for storage of perishables (including citrus) for short period at remote farm areas in tropical and sub-tropical regions.

1620–1640

S09–0–26

SWEET POTATO PRODUCTS

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Sweet potato (*Ipomea patatus* L.) is an important food crop in many countries where it was consumed traditionally as a supplemental staple to rice. However, due to recent economic development, sweet potato consumption patterns have changed. It is now consumed mainly for its nutrients rather than for energy. Thus there is a need to develop value-added products from sweet potatoes. In order to improve consume acceptability, toffee, ice cream, nankhatai (cookie) and doughnuts made with sweet potato flour were assessed by a panel of judges. Sweet potato flour toffee was found to be highly acceptable. It was found that 50% of corn flour used in the preparation of ice cream could be replaced with sweet potato flour without in any way affecting the consumer acceptability. Nankhatai and doughnuts prepared using refined wheat flour with 50% of sweet potato flour were also found to be highly acceptable. The results of this study revealed that sweet potato flour could successfully replace or be incorporated with cereal flours in the preparation of selected snacks.

1640–1700

S09–0–27

POSTHARVEST HOT AIR TREATMENTS EFFECT ON INSECT MORTALITY AND QUALITY OF MAMEY SAPOTE FRUIT (POUTERIA SAPOTA)

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Mamey sapote fruit are very sensitive to attack by fruit flies, especially by *Anastrepha serpentina*. Fruit were exposed to several humid, forced hot air treatments at a temperature range of 40 to 50 °C for 120 to 180 minutes, then were immediately cooled in water at ambient temperature, and stored at 10 °C for up to 15 days. Larvae and eggs mortality were achieved at 43 °C for 120 minutes. Lower temperature (40 °C for 120 minutes) was effective in causing mortality of larvae, but not of eggs. Heat treatment at 43 °C for 120 minutes did not cause fruit injury, and caused the least losses in firmness, fruit mass, and colour. However, heat treatment at 50 °C caused fruit injury and significant losses in texture, fruit mass and colour. We conclude that postharvest hot air treatments can be developed as quarantine insect control treatments for mamey sapote fruit.

1700–1720

S09–0–28

PROJECT TO PHASE-OUT METHYL BROMIDE IN THE DRIED FIG SECTOR IN TURKEY

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Turkey is the one of the major dried fruit (figs, raisins, apricots, hazelnut, pistachio etc.) and nut producing and exporting countries. MBr (methyl bromide) is the common fumigant to control storage pests, which infest these commodities during drying and storage. Compared to other dried fruits, dried fig production is the most heavily threatened by storage pests. MBr is regarded as a major anthropogenic compound that depletes the ozone layer. Furthermore, MBr is a toxic gas and can pose risk to human health if over-exposure or accidents occur. The Montreal protocol and the phase-out of methyl bromide has increased the urgency to search for new technologies. This project will lead to the phase-out of MBr as a stored product treatment in Turkish dried fig sector by evaluating the economic and technical feasibility of two alternative technologies: 1) CO₂ at elevated temperatures and/or CO₂ in combination with pressure, and 2) magnesium phosphide in combination with heat in chambers and under gas tight chambers. In addition, the project will include activities for ensuring a proper technology transfer, through a training programme and dissemination of information directed at the actual MBr users in the dried fig industry. Until today, field surveys were arranged to evaluate the important pests in fig growing region. Dried fig fruits were treated with magnesium phosphide and CO₂ at various concentrations and at different temperatures. Quality parameters such as total soluble solids (%), titratable acidity (%), pH, dry matter (%), water activity (WA), color (L, a

and b values by Minolta chromometer) and sugaring (%) were assessed in treated and non-treated samples.

Tuesday · August 13

1100-1140

S09-O-29

THE ETHYLENE RECEPTORS AND HOW THEY WORK

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Recent breakthroughs in understanding ethylene signal transduction have come from pursuing a genetic approach in *Arabidopsis thaliana*. A number of mutants affecting ethylene responses in *Arabidopsis* have been identified, and these define a common initial pathway for all ethylene-induced changes in the plant. The cloning of genes represented by these mutants has revealed much about the biochemical mechanism of ethylene signal transduction. The ethylene receptors are related to the so-called two-component histidine-kinase-based signaling systems common in bacteria, while down-stream events appear to be mediated by a RAF-related kinase, CTR1. Recent genetic and biochemical studies indicate that a family of ETR1-like receptors interact with CTR1 to repress ethylene response pathways and that ethylene binding inhibits this activity. According to this model, dominant mutations in any one receptor isoform produce ethylene insensitivity by locking the mutant receptor in this negative signaling mode. These mutations are all located in the ethylene sensor domains of the receptors and some, but not all, mutations work by disrupting ethylene binding activity. The existing models for receptor function have implications for the mechanisms of action of ethylene response inhibitors such as 1-methylcyclopropane (MCP). Experiments with the yeast expressed ETR1 and ERS1 receptors indicate that MCP competes with ethylene for binding to the receptor. Based on the negative regulator model for receptor function, we propose that while ethylene binding to receptors converts receptors to a non-signaling state, the MCP binding to receptors locks them in an active signaling state, resulting in an inhibition of response pathways. The efficacy of MCP in blocking ethylene response pathways may be due to its high affinity for the receptor. Alternatively, if MCP-bound receptors behave as the dominant mutant receptors, then binding of MCP to only a subset of receptors may be sufficient to block responses.

1140-1200

S09-O-30

THE ROAD TO DISCOVERY OF 1-METHYLCYCLOPROPENE AS AN ETHYLENE ACTION INHIBITOR

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Work with the ethylene action inhibitor, diazocyclopentadiene (DACP), helped lead to the discovery that cyclopropenes could inhibit ethylene action. DACP, when exposed to light, generates another product that inhibits ethylene action. A series of experiments aimed at identifying the light product of DACP and some library work provided key information that cyclopropenes, such as 1-methylcyclopropene, were likely to be good ethylene inhibitors. Bioassays, methods development, and progress in science will be discussed as it relates to the challenges of working with unknowns, volatile products and plant growth regulators.

1200-1220

S09-O-31

IMPACT OF 1-MCP ON CLIMACTERIC FRUIT VOLATILE PRODUCTION AND AROMA

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Elucidation of the role of ethylene in regulating production of compounds contributing to aroma has been enhanced by the use of 1-MCP. Research with

climacteric fruit has demonstrated production of esters that impart ripe, fruity characters to aroma is significantly reduced in fruit treated with 1-MCP. This response is reversible over time with resumption of ester production dependent on a number of factors including 1-MCP dose and duration, fruit maturity at the time of treatment and post-treatment storage conditions. Exposure of 1-MCP treated fruit to ethylene or propylene generally is not sufficient to restore ester production. The reduction in ester production results in part from reduced availability of precursors for ester synthesis including alcohols and carboxylic acids. While ester production by fruit previously treated with 1-MCP is enhanced after exposure to exogenous alcohols and carboxylic acids, the final step of ester synthesis does appear to be regulated in part by ethylene. Studies with banana and melon indicate a partial inhibition of acetyl transferase activity in 1-MCP treated fruit via accumulation of alcohol (banana) and reduced utilization of exogenous alcohol for ester production (melon). Aldehyde production is not significantly reduced following treatment with 1-MCP. Several aldehydes impart "green" aroma notes, indicating this aspect of aroma may be impacted less than the "ripe" character attributable to esters. Production of compounds such as α -farnesene, β -damascenone and 4-allylanisole that originate from other pathways is also reduced in 1-MCP treated fruit indicating ethylene action is required for synthesis of a variety of volatile compounds by climacteric fruit.

1220-1240

S09-O-32

FIRMNESS CHANGES IN RIPENING AND ETHYLENE-TREATED FRUITS IN RESPONSE TO 1-METHYLCYCLOPROPENE

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The influence of 1-methylcyclopropene on storage duration and quality has been documented for horticultural crops of diverse morphological origin. Although most horticultural commodities do respond to 1-MCP, the most dramatic effects are evident for organs displaying climacteric behavior and those exhibiting specific responses to exogenous ethylene. Among fruits, nearly all aspects of ripening are influenced by 1-MCP. In the context of postharvest handling protocols, delays in softening are of particular interest. The influence of 1-MCP on firmness changes is most certainly multi-faceted. Firmness of mature-green tomato fruit in response to 1-MCP remains unchanged for a period of days, declining eventually at rates comparable to those of control fruit and paralleling the recovery in other ripening properties. In avocado fruit, softening continues following 1-MCP treatment but at dramatically reduced rates. More generally, trends of firmness change also reflect fruit maturity at the time of treatment, and 1-MCP concentration and exposure temperature. In avocado fruit, 1-MCP delays changes in the activities of several cell wall enzymes and affects the metabolism of pectic and, to a lesser degree, hemicellulosic polymers. The recovery patterns of cell wall enzyme activities in 1-MCP-treated avocado fruit differ significantly, indicating that these proteins are differentially influenced by ethylene. Disparities in enzyme recovery may explain reports that 1-MCP treatments (i.e., deficiencies in ethylene perception) can sometimes result in abnormal texture. In watermelon fruit, 1-MCP prevents ethylene-induced placenta water soaking and phospholipid breakdown, the latter being consistent with increases in phospholipase and lipoxygenase activities in response to ethylene. A few reports suggest that 1-MCP appears promising for improving the firmness properties of fresh-cut fruits; however, the more advanced maturity of these commodities will likely require adjustments in 1-MCP treatment strategies.

1340-1440

S09-P-33

RIPENING CONTROL OF 'PACKHAM'S TRIUMPH' PEARS BY MEANS OF 1-MCP AND ETHYLENE APPLICATIONS

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In order to attain maximum organoleptic quality, i.e. within a narrow range of texture, color and juiciness, 'Packham's Triumph' pears should be cold-stored for a given period, with extended storage being limited because of senescence. Trials were conducted during two seasons with 1-methylcyclopropene application to inhibit ethylene action once the cold requirement was completed or immediately after harvest. In the second season, fruit was stored both in air and con-

trolled atmosphere (CA), with ethylene being applied shortly after harvest to replace cold requirement and to counteract 1-MCP effects. Applications of 1-MCP once cold requirement was completed did not influence subsequent fruit ripening. Ethylene at saturating levels could replace cold requirement and overcome ripening inhibition caused by 1-MCP depending on its concentration and duration of cold storage. Ripening inhibition by 1-MCP is dependent upon its concentration, with given dosages allowing fruit to eventually ripe as storage is prolonged. CA conditions allow prolonged storage, with effects being added up to ethylene inhibition. Application of these techniques in different combinations can allow to exert ripening control of Packham's Triumph pears according with marketing requirements to attain adequate quality.

1340-1440

S09-P-34

DURATION OF 1-METHYLCYCLOPROPENE-INDUCED RESPONSES ON VOLATILE PRODUCTION BY 'GALA' APPLE FRUIT

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The ethylene action inhibitor 1-methylcyclopropene (1-MCP) reduces the rate of ripening of climacteric fruit including apple. The longevity of 1-MCP responses induced by a single application at harvest is dependent in part on 1-MCP treatment concentration and post-application storage conditions. Ripening specific volatile production by apple fruit required continuous ethylene action, and fruit treated with 1-MCP exhibit reduce production of many volatile compounds. Experiments with 'Gala' apples were conducted over 3 production seasons to characterize the duration of 1-MCP responses of fruit stored in air or a controlled atmosphere (CA). After various storage durations, 1-MCP was reapplied at the same or higher concentrations, or the initial application rate was made. The increase in production of esters typical of normal ripening is delayed following 1-MCP treatment by 3-5 months. Apples treated with 1-MCP then stored in CA did not exhibit an increase in ester production at any point during storage. Increased production of aldehydes, particularly C8-10 compounds, occurred late in the storage period and was only partially inhibited by previous treatment with 1-MCP.

1340-1440

S09-P-35

EFFECTS OF REPEATED APPLICATIONS OF LOW CONCENTRATIONS OF 1-MCP ON STORAGE AND RIPENING OF 'BARTLETT' PEARS

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Application of 1-methylcyclopropene to 'Bartlett' pear fruit may extend storage life by reducing storage scald and loss of firmness. However, it is critical that pear fruit ripen fully prior to consumption, and develop the characteristic flavor and buttery texture. We explored the use of repeated applications of 1-MCP on the storage quality and ripening characteristics of 'Bartlett' pear fruit. In earlier studies, fruit treated with 1 ppm 1-MCP did not ripen, while fruit treated with 0.25 and 0.5 ppm showed intermediate levels of ripening inhibition. Freshly harvested 'Bartlett' pear fruit were cooled overnight to 0 °C, then exposed to 0, 0.2 or 0.4 ppm 1-MCP for 12 hours at 0°C. Fruit were stored at -1 °C for 4 or 6 weeks. After storage, half the fruit were removed for assessment, and the remaining fruit were treated again with the same concentration of 1-MCP as at harvest. Retreated fruit were stored for a further 4 or 6 weeks, doubling their time at -1 °C before assessment. Pears were evaluated upon removal from storage and after 6 days at 20 °C. After 4 weeks of storage, the fruit treated with 1-MCP yellowed and softened slower than control fruit. However, fruit that were retreated after 4 weeks of storage showed increased differences between the treatments. Fruit that were treated twice with 0.4 ppm 1-MCP showed little color change during ripening, while those treated twice with 0.2 ppm were intermediate between the 0.4 and control fruit. Fruit treated twice with 1-MCP (at 4 and 8 weeks) yellowed and softened slower than fruit treated once (at 4 weeks) with the same concentration. These results suggest that the ability of the fruit to produce new ethylene binding sites diminished during storage. Whereas previous work showed that 1-MCP had a greater effect on fruit softening than on color development, in this case there appeared to be a somewhat greater effect on color.

1340-1440

S09-P-36

ETHYLENE REGULATES MRNA EXPRESSION OF THREE BETA-GALACTOSIDASE GENES IN TOMATO FRUIT AT THE ONSET OF RIPENING

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Recent studies indicate that β -galactosidases play an important role in fruit development and ripening. The temporal mRNA expression patterns of a family of tomato (*Lycopersicon esculentum*) β -galactosidase (TBG) genes also suggest that some of these genes may be regulated by ethylene. Because of the dramatic changes in mRNA expression patterns that some of these genes exhibit at the onset of ripening, we analyzed the effects of ethylene on TBG4, TBG5 and TBG6 transcript abundance. Also, we analyzed the expression patterns of these TBGs in wild type and three tomato ripening mutants: rin, nor and Nr. We focused on the Mature Green III stage of fruit development (35 days after pollination; dap), because at this stage wild type fruit are not yet producing climacteric ethylene, but will respond to exogenous ethylene. RNA gel blot analysis indicated that, upon 48 hours of ethylene exposure, the mRNA expression of TBG4 increased 11- to 20-fold in the wild type, rin and Nr, but remained the same in the nor mutant. We conclude that the nor gene product may be required for this ethylene-induced increase in TBG4 mRNA expression. Conversely, ethylene decreased mRNA abundance of both TBG5 and TBG6 in wild type and mutant fruit, although each at different levels. Down-regulation of TBG6 by ethylene also occurs in earlier stages of fruit development (25 dap). We present a model on the effects of the rin, nor and Nr gene products on TBG mRNA abundance as influenced by ethylene, and in relation to the climacteric production of ethylene in tomato fruit. We also present the results of how these ethylene-induced changes in TBG mRNA levels correlate with changes in fruit firmness, enzyme activity and cell wall composition.

1340-1440

S09-P-37

ENHANCING STORAGE LIFE OF 'MACOUN' AND 'CORTLAND' APPLES WITH 1-METHYLCYCLOPROPENE

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1-Methylcyclopropene (1-MCP) was tested on 'Macoun' and 'Cortland' apples at two harvest times to determine effectiveness on prolonging storage life. 'Macoun', harvested at a starch index of 3.0 and 4.4, was treated with 1-MCP. 'Cortland' was harvested at a starch index of 3.8 and 5.7. Fruit were exposed to 1 μ L·L⁻¹ MCP for a duration of six hours in sealed coolers at a fruit temperature of 11 to 14 °C. Fruit were stored in air at 3 °C for approximately five months and then held at room temperature for two days prior to evaluation. Firmness was measured on ten fruit and internal breakdown on 60-70 fruit per plot. Internal ethylene concentration was measured on five 'Cortland' fruit per plot. The study was replicated five times. There was a significant interaction between harvest date and 1-MCP effect on firmness after storage in both cultivars. Untreated 'Macoun' harvested 27 Sept. softened more than 1-MCP-treated fruit, but fruit harvested 11 Oct. were not affected by 1-MCP. With the earlier harvest, 1-MCP appeared to reduce the occurrence of breakdown, but this was not significant. MCP had no effect on internal breakdown with the second harvest. 1-MCP had no effect on firmness of 'Cortland' harvested 1 Oct., but slightly reduced loss of firmness compared to untreated fruit harvested 12 Oct. Internal ethylene concentration of 'Cortland' was not affected in fruit from the first harvest, but was reduced by MCP in fruit from the second harvest.

1340-1440

S09-P-38

EXPRESSION OF GENES FOR ETHYLENE RECEPTORS, CTR-GENE HOMOLOGUES AND THE TRANSCRIPTION FACTOR EIN3 IN MINIATURE ROSE FLOWERS WITH DIFFERENCES IN POSTHARVEST LIFE

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Miniature roses (*Rosa hybrida*) vary distinctly in postharvest life and ethylene sensitivity. Comparing cultivars with different postharvest characteristics, clear differences in flower longevity of the cultivars 'Bronze' and 'Vanilla' were found, even though both cultivars exhibit a climacteric rise in ethylene production in senescing tissues. In an effort to elucidate the reasons for the observed differences, genes involved in ethylene perception and signal transduction were examined. Rose gene fragments encoding products with similarity to the Arabidopsis ETR1 ethylene receptor, two CTR-gene homologues (RhCTR1 AF 271206, RhCTR2 AY029067) and a transcription factor homologue RHEIN3 (AY052825) were isolated and characterized. Ethylene receptor genes were regulated during flower senescence and in response to ethylene, and transcript levels differed clearly between the two genotypes. The results indicate that differences in flower life among rose cultivars may be due to differences in receptor levels. Furthermore, expression of two homologues of CTR—a Raf-like protein kinase acting downstream of the ethylene receptors in the signal transduction pathway—was investigated. The protein RhCTR1 has 66% amino acid identity to Arabidopsis CTR1. A fragment of a second homologue, termed RhCTR2 is 90% and 69% identical to the corresponding region of tomato CTR2 and RhCTR1 respectively. RhCTR1 expression increased during flower senescence in the two rose cultivars with differences in ethylene sensitivity and flower longevity, while RhCTR2 was constitutively expressed during flower development. Additionally, the expression of both RhCTR1 and RhCTR2 increased in response to exogenous ethylene. The differential expression of the CTR-homologues indicated an impact of these genes on postharvest performance of miniature roses, while the transcription factor EIN3 (83% identity to ATEIN3) seemed to be constitutively expressed during flower senescence, in response to ethylene and ABA.

1340-1440

S09-P-39

UNDERSTANDING THE ROLE OF ETHYLENE DURING STONE FRUIT COLD STORAGE

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The influence of ethylene contamination on quality attributes, brown rot (*Monilinia fructicola*) decay development and internal breakdown during long-term cold storage at 0 and 5 °C was investigated on climacteric and non-climacteric stone fruits. Quality attributes such as fruit flesh firmness, soluble solids concentration, titratable acidity, stem browning, and flesh and ground color were not affected by constant ethylene exposure (10 ppb, 100 ppb and 1,000 ppb) during long-term cold storage at 0 and 5 °C. Constant ethylene exposure did not affect decay development, expressed as lesion size and incidence, on peaches, plums, nectarines and cherries wound-inoculated with *Monilinia fructicola* during long-term cold storage. In peaches, ethylene treatments did not affect development of visual mealiness symptoms. In one case, flesh mealiness symptoms were delayed by ethylene present during storage. This work indicates that there is no commercial benefit to remove ethylene during cold storage for peaches, nectarines, plums and cherries.

1340-1440

S09-P-40

REDUCED SENSITIVITY OF CUT INFLORESCENCES OF ADVANCED BREEDING LINES OF LUPINUS HAVARDII TO ETHYLENE

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Racemes of 'Big Bend' bluebonnet (*Lupinus havardii* Wats.) hold great promise as a new specialty cut flower crop. However, we observed that selected germplasm continued to exhibit variable sensitivity to ethylene. Therefore, a

major goal of breeding *L. havardii* is to minimize ethylene sensitivity by utilizing recurrent phenotypic selection, including traits of reduced shattering and extended display life of flowers on the raceme. Over the years, as a result of our selection efforts and breeding, we have been successful in obtaining several advanced lines with different flower colors. This investigation was designed to evaluate the relative response of cut racemes of seven breeding lines of *L. havardii* viz. 'Texas Sapphire', 'Blue-2000' (B-2000), 'Pink', 'Dark Pink' (DP-95 and DP-99), 'White Select' (WS-2000) and 'Texas Ice' to ethylene. Florel (2-chloroethylphosphonic acid, CEPA: 10 mm, 100 mm) was used as the source of ethylene supply to the cut inflorescences. Ethylene sensitivity was scored based on the results relating to flower abscission and flower senescence which are two key components affecting longevity and display life. In general, it was observed that the white-flowered lines were relatively more tolerant to ethylene than the blue and pink flower lines. Among the genotypes tested, Texas Sapphire was the most sensitive, while White Select (WS-2000) was found to be least sensitive to ethylene. These results clearly establish that by further careful selection and breeding strategies it may be possible to obtain improved lines of *L. havardii* which are less sensitive to ethylene

1340-1440

S09-P-41

ETHYLENE BIOSYNTHESIS AND PERCEPTION IN PEACH FRUIT RIPENING

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Peach fruit ripening is regulated by ethylene. Biosynthesis of ethylene has been studied at a molecular level in this species mainly in relation to 1-aminocyclopropane carboxylate (ACC) oxidase (ACO), the enzyme involved in oxidation of ACC to ethylene. It has been demonstrated that this enzyme is encoded by a multigene family, in which two members (Pp-ACO1 and Pp-ACO₂) have been fully characterized. Expression of Pp-ACO1 increases at the climacteric stage and is up-regulated by ethylene. This behavior seems to be related to the presence within the gene promoter of two sets ethylene responsive elements (EREs). Expression of Pp-ACO₂ is ethylene-independent and unrelated to fruit ripening. As far as ethylene perception is concerned two genes have been characterized. Pp-ETR1, hortologous to ETR1 types, is structured in six exons and five introns. Main characteristics of Pp-ETR1 are the unusual length of the second and the fifth intron. Pp-ETR1 is constitutively expressed and ethylene-insensitive. The second receptor, named Pp-ERS1, is hortologous to ERS type, expressed at the ripening stage and ethylene stimulated. This behaviour might be related to the presence of ERE in the promoter region. 1-methylcyclopropane (1-MCP), an inhibitor of ethylene action that competes with the hormone for receptor sites, does not seem to affect Pp-ETR1 transcription, while it down-regulates Pp-ERS1. This would provide additional evidence for the role of ethylene in Pp-ERS1 transcription.

1340-1440

S09-P-42

REGULATION OF FRUIT FIRMNESS, MATURITY AND QUALITY OF LATE MATURING CULTIVARS OF PEACH WITH PREHARVEST APPLICATION OF RETAIN™

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To test the efficacy of time of application of ReTain™ on fruit maturity, firmness, colour development and fruit quality of peach (*Prunus persica* Batsch). Experiments were conducted at Pickering Brook and Bickley in Western Australia during the 1999 and 2000. An aqueous solution containing wetting agent ABG-7011 (0.1%) and ReTain™ [0.125 g a.i./ha (830 g product/ha equivalent to ReTain™ 1.034 g a.i.)] was sprayed onto trees 15, 10 or 5 days before the anticipated harvest date. All these treatments were applied to 'O'Henry' and 'Summerset' during 1999 and 'Zee Lady' and 'Elegant Lady' during 2000. The results of these trials showed that a preharvest spray application of ReTain™ to peach extended harvesting period and delayed fruit maturity in 'O'Henry' and 'Summerset'. The preharvest spray application of ReTain™ improved fruit firm-

ness, total soluble solids, and acid content in both cultivars. Fruit colour development (red colour on yellow background) in 'O'Henry' and 'Summerset' was not affected with the preharvest application of ReTain™. Preharvest application of ReTain™ also significantly improved fruit firmness in 'Zee Lady' and 'Elegant Lady'. The 'Elegant Lady', the exogenous preharvest application of ReTain™ showed no effects on fruit colour development during the first picking, but it significantly reduced fruit colour during the second picking. Conversely, in 'Zee Lady', ReTain™ reduced fruit colour development during the first picking and had no effect during the second pick. In conclusion, application of ReTain™ 5–10 days before harvest proved more effective than at 15 days before harvest in improving fruit firmness and quality of late maturing cultivars of peach.

1340–1440

S09–P–43

CHILLING STORAGE TEMPERATURE AFFECTS ETHYLENE BIOSYNTHESIS IN MANGO FRUIT DURING FRUIT RIPENING

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Low temperature storage is usually employed for prolonging the shelf life of fruits. However, mango (*Mangifera indica* L.) fruits are susceptible to chilling injury when stored below 13 °C. Mature mango fruits cv. Kensington Pride were stored at chilling (5 °C) and nonchilling (15 °C) temperatures for 2 weeks to investigate the effects of chilling temperature on ethylene biosynthesis during fruit ripening. The fruits were removed from the storage and allowed to ripen at 22±1 °C for 11 days. Fruits were assessed for chilling injury development, ethylene production and activities of ACC (aminocyclopropane-1-carboxylic acid) synthase, ACC oxidase and ACC content in the peel and pulp during the ripening period at 1 or 2 days intervals. Chilling injury symptoms observed were darkening of peel, prominence of lenticels, development of poor colour, flavour and uneven ripening. These symptoms progressed during ripening period at 22 °C. Ethylene production was suppressed during the ripening period in the fruits, which were stored at chilling temperature as compared to those stored at 15 °C. Peel and pulp of the fruits stored at chilling temperature exhibited lower activities of ACC synthase, ACC oxidase and ACC content during ripening period of 11 days as compared to the peel and pulp of fruits stored at 15 °C. The activities of ACC synthase, ACC oxidase and ACC content in the peel and pulp revealed similar trends during the ripening period. In conclusion, ethylene production was suppressed as a result of reduced activities of ACC synthase, ACC oxidase and ACC content during ripening period both in the peel and the pulp of the fruits stored at chilling temperatures. Suppression of ethylene production during ripening period seems to be associated with the development of chilling injury symptoms on fruits.

1340–1440

S09–P–44

STORAGE TEMPERATURE OF 'GRANNY SMITH' APPLE INFLUENCES EFFECTIVENESS OF 1-METHYLCYCLOPROPENE (1-MCP)

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Scald disorder is the main cause of 'Granny Smith' apple deterioration in cold storage but it is commercially controlled by a single application of Diphenylamine (DPA) at harvest. Because of restriction to DPA, SmartFresh (methylcyclopropene (1-MCP)) was evaluated as a commercial alternative treatment for scald control. Three concentrations of 1-MCP (0, 0.5, 1.0, 2.0 g/m³) were applied at 5 °C for a period of 48 hours and compared with a single application of 2,000 ppm of DPA at harvest and fruit without treatment (control). Fruit color, firmness, respiration rate, ethylene, conjugated trienes and farnesene production were evaluated at 3.5, 5 and 7 months at 0 and 3 °C. The incidence and severity of scald were assessed after 10 days at 20 °C at every storage period. The incidence of scald increased in the control and DPA treatments when the fruit were stored at 0 °C compared with 3 °C at any stage of evaluation. Total reduction of scald was obtained with any 1-MCP concentration, at every storage period and temperature evaluated. Reduction of conjugated trienes and farnesene production was the main

characteristic of 1-MCP treated fruit. However, superficial black pit symptoms were detected on fruit treated with 1-MCP at 0 °C storage temperature and they were enhanced as the length of storage increased. Otherwise, the incidence was significantly low at 3 °C. The role of 1-MCP to enhance chilling injury on 'Granny Smith' is discussed. Adequate temperature management of 'Granny Smith' apple is required with the application of 1-MCP.

1340–1440

S09–P–45

APPLE VOLATILE RECOVERY FOLLOWING 1-METHYLCYCLOPROPENE TREATMENT

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Aroma production is an ethylene dependent process. The ethylene action inhibitor, 1-methylcyclopropene (1-MCP) prevents ethylene action and suppresses the formation of aroma-related volatiles. The relationship between 1-MCP application and volatile recovery for fruit stored in refrigerated air was studied for 'Jonagold' apple fruit. Fruit were harvested just prior to the onset of autocatalytic ethylene production. Half the fruit were treated with 1-MCP at a concentration of approximately 1 ppm. Treated and nontreated fruit were divided into six lots. One lot from treated and nontreated fruit was left to ripen at room temperature (22 °C). The remaining five lots of treated and nontreated fruit were placed in refrigerated air storage at 0 °C. The ontogeny of volatile production was determined by gas chromatography/mass spectrometry immediately following harvest and following each storage removal date. Aroma production was measured every three to four days while holding at room temperature. The time required for aroma production to begin and for peak biosynthesis to occur was determined. After harvest, nontreated fruit required approximately 10 days to begin synthesizing aroma volatiles, treated fruit required 33 days. Aroma production peaked after 25 days at room temperature for nontreated fruit, while those treated with 1-MCP required more than 46 days. After one month in cold storage, nontreated fruit were already producing moderate amounts of aroma volatiles at the time of removal, while treated fruit had no aroma production. We did not detect unusual volatile compounds produced as a result of 1-MCP treatment.

1340–1440

S09–P–46

EFFECTS OF 1-METHYLCYCLOPROPENE AND CONTROLLED ATMOSPHERE STORAGE ON RIPENING AND PATHOGEN-INDUCED DECAY DEVELOPMENT IN 'GOLDEN DELICIOUS' APPLES

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1-Methylcyclopropene (1-MCP) was tested for its ability to inhibit ripening and maintain quality and disease resistance of 'Golden Delicious' apples (*Malus x domestica* Borkh.) during air storage at 0 °C for 5 months and/or 20 °C for 7 d. The 1-MCP treatment was 1 *L*L-1 for 17 hours at 20 °C applied at harvest or following cold storage. For comparison, untreated fruit were stored in air or a controlled atmosphere of 1.5 kPa O₂ and 2.5 kPa CO₂ for the same temperature and time periods. At harvest 1-MCP application and CA storage similarly decreased decay development caused by wound-inoculated *Penicillium expansum* Link, *Botrytis cinerea* Pers.:Fr., and *Colletotrichum acutatum* Simmonds (teleomorph *Glomerella cingulata* (Stonem.) Spauld. & Schrenk). Treatment with 1-MCP following cold storage had no effect on decay development at 20 °C. At harvest 1-MCP application was more effective than CA storage at delaying ripening as indicated by better retention of green peel color, titratable acidity, Magness-Taylor and compression firmness, and the reduced respiration, ethylene production rates and volatile levels that were observed upon transferring the fruit to 20 °C. Following 5 months cold storage, the harvest 1-MCP application maintained the shape of the compression force/deformation curve similar to that of fruit at harvest; as did CA storage, but at a lower force profile. Treatment with 1-MCP following cold storage had little to no effect on fruit ripening characteristics at 20 °C. The results indicated that prestorage treatment with 1-MCP may provide an effective alternative to CA for reducing decay development and maintaining postharvest quality of 'Golden Delicious' apples.

1340-1440

S09-P-47

EFFECT OF 1-METHYLCYCLOPROPENE AND OZONE ON THE QUALITY OF BROCCOLI

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Fresh broccoli florets (*Brassica oleracea* L. Italica group) were treated with or without 1 $\mu\text{L}\cdot\text{L}^{-1}$ methylcyclopropene (1-MCP) for 14h, and then stored at 10 °C with 0, 200, or 700 $\text{nL}\cdot\text{L}^{-1}$ ozone. Samples were evaluated after 1, 2, 5, 8, or 12 days of storage. Treatments with 1-MCP delayed the yellowing of florets, and at day 5 the hue angle of 1-MCP treated florets was 116 compared with 102 for the controls. Respiration rate of florets was reduced by 1-MCP for the first 5 days and ethylene production was stimulated during the first 2 days following treatment. The 1-MCP treatment maintained higher chlorophyll fluorescence expressed as Fv/Fm during 12 days of storage. Also, 1-MCP inhibited dimethyl trisulfide production, which contributes to off-odor development in broccoli florets. Compared with the controls, florets stored in 200 $\text{nL}\cdot\text{L}^{-1}$ ozone had less mold growth, but no differences were observed in color, respiration, ethylene production, or chlorophyll fluorescence. Florets stored in 700 $\text{nL}\cdot\text{L}^{-1}$ ozone were greener at day 12 than florets held in air or 200 $\text{nL}\cdot\text{L}^{-1}$ ozone, but interestingly, chlorophyll fluorescence decreased significantly. At day 12, Fv/Fm was only 30% of its initial value. Storage in 700 $\text{nL}\cdot\text{L}^{-1}$ ozone stimulated respiration and ethylene production of florets after 1 day of storage, and caused stem browning of florets. A synergistic effect of 700 $\text{nL}\cdot\text{L}^{-1}$ ozone and 1-MCP on respiration and ethylene production was found. The 1-MCP, 200 $\text{nL}\cdot\text{L}^{-1}$ ozone, and 200 $\text{nL}\cdot\text{L}^{-1}$ ozone plus 1-MCP treatments were considered to be suitable to maintain the quality and extend the shelf-life of broccoli florets stored at 10 °C.

1340-1440

S09-P-48

OZONE AND 1-METHYLCYCLOPROPENE TREATMENTS AFFECT QUALITY AND THE STORAGE LIFE OF FRESH CARROTS

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Fresh carrots (*Daucus carota* L.) were treated with or without 1.0 $\mu\text{L}\cdot\text{L}^{-1}$ 1-methylcyclopropene (1-MCP) for 16 hours before storage or after 3 months of storage at 0 °C, and then exposed to 0, 300, or 1000 $\text{nL}\cdot\text{L}^{-1}$ ozone at 10 °C for 0, 1, 2, or 4 days. The carrots were stored at 0 °C for up to 6 months. Decay and mold incidence, electrolyte leakage, surface discoloration, and 6-Methoxymellein (6-MM) content in the peel tissue of carrots were evaluated. While no decay of the roots was observed, the incidence of saprophytic mold on the crowns was reduced during the first 2 months of storage, following the 300 $\text{nL}\cdot\text{L}^{-1}$ ozone treatments of 1, 2, or 4 days. A similar effect was found on the carrots treated after 3 months. The 1000 $\text{nL}\cdot\text{L}^{-1}$ ozone treatments for 2 or 4 days caused severe tissue injury resulting in the highest mold incidence of 65% after 6 months of storage. The 1000 $\text{nL}\cdot\text{L}^{-1}$ ozone also induced a greater rate of electrolyte leakage in the peel and caused surface discoloration. The discoloration index, using a scale of 0 (absent) to 3 (severe), was 1.55 compared to 0.3 for those treated with 300 $\text{nL}\cdot\text{L}^{-1}$ ozone. Bitterness, which results from the accumulation of 6-MM, was affected by the concentration of ozone and the treatment time. Treatments of 300 and 1000 $\text{nL}\cdot\text{L}^{-1}$ ozone for 4 days induced 6-MM production in carrot peels reaching concentrations as high as 180 and 365 $\mu\text{g}\cdot\text{g}^{-1}$, respectively. Treatment with 1-MCP effectively prevented bitterness induced by the ozone treatments. 6-MM remained below 150 $\mu\text{g}\cdot\text{g}^{-1}$ in carrots treated with 1-MCP and 1000 $\text{nL}\cdot\text{L}^{-1}$ ozone for 4 days.

1340-1440

S09-P-49

EFFECTS OF MCP AND 1.52 KPA OXYGEN ON APPLE SCALD CONTROL AND ALPHA-FARNESENE BIOSYNTHESISP. Trivedi¹, A. Matto², T. Solomos*¹¹Dept. Natural Resource Sciences and Landscape Architecture Univ. Of Maryland College Park Md 20742 USA; ²Vegetable Lab, USDA, Beltsville, Md 2075

In the past 4 years we have studied the effects of MCP on scald control in "Granny Smith," "Rome," and "Red Delicious" apples, which are susceptible to scald, and in "Gala" and "Braeburn" cultivars, which are scald-resistant. Application of MCP and 1.52 kPa oxygen immediately after harvest inhibited development of the disorder during 180-220 days storage at 1 °C followed by 10-15 days at room temperature in all cultivars. This was accompanied by a strong inhibition of the increase in α -farnesene and conjugated trienols. The effectiveness of MCP in controlling scald in "Granny Smith" apples was attenuated whenever its application was delayed. Furthermore, in "Red Delicious", if the onset of the ethylene climacteric had been initiated at harvest the effectiveness of MCP was greatly diminished. We have cloned the genes of 3- methyl-3-hydroxyl glutaryl-CoA reductase (HMGR1) and the pharneseny-pyrophosphate synthase (FPPS) of the mevalonate pathway of α -farnesene synthesis. The expression of either of these genes does not appear to be inhibited by MCP despite the strong inhibition of the rise in α -farnesene content. 1.52 KPa of oxygen strongly enhances the expression of HMGR1. In fact the expression of HMGR1 parallels that of ADH at different O₂ concentrations. Low oxygen does indeed inhibit the accumulation of FPPS transcripts.

1340-1440

S09-P-50

EFFECTS OF MCP AND HYPOXIA ON ETHYLENE EVOLUTION AND EXPRESSION OF GENES INVOLVED IN ETHYLENE BIOSYNTHESIS AND PERCEPTIONT. Solomos*¹, P. Trivedi, A. Matoo²¹Dept. Natural Resource Sciences, Univ. of Maryland, College Park MD 20742 USA; ²Vegetable Lab, USDA, Beltsville Maryland MD 20705 USA

Low oxygen (1.53 KPa) and MCP suppressed onset of the ethylene climacteric in "Gala" and "Granny Smith" apples for 250 days. This was associated with a strong inhibition in accumulation of ACS-synthase (ACS) transcripts, while their effect on the amount of ACC-oxidase (ACO) mRNA was marginal. Neither treatment had any effect on the expression of ETR1, whereas there was a strong inhibition of the increase in the ERS1 type of C₂H₄ receptor that occurred in control fruits. The effectiveness of MCP in retarding the ethylene onset depends on fruit maturity. In 1999 MCP retarded onset of the ethylene climacteric in "Red Delicious" apples for longer than 220 d. However, in 2000 initiation of the ethylene climacteric had already started at harvest, and the retardation by MCP of the rise in ethylene evolution was greatly attenuated. Furthermore, with the rise in ethylene evolution in MCP-treated fruits there was an increase in the transcripts of both ACS and ERS1. Similar results were observed with "Rome Beauty" fruits. Both MCP and 1.52 kPa had no effect on the rate of System 1 ethylene evolution.

1340-1440

S09-P-51

SHIPPING AND ETHYLENE EFFECTS ON FLOWER BUD ABSCISSION IN POTTED HIBISCUS

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Shipping potted flowering hibiscus (*Hibiscus rosa-sinensis*) is a commercial problem due to abscission of flowers and buds. A series of experiments was conducted to evaluate factors affecting bud drop during shipping. Flower buds were divided into six developmental stages with stage 1 being the smallest (<1 cm) and stage 6 an open flower. When 'Pink Versicolor' was shipped for 2, 4 or 6 days at temperatures of 13, 18, or 25 °C, a three-way interaction ($P < 0.0001$) between shipping, temperature and bud stage was found. The stage 5 and 6 buds went through normal development and senescence under all conditions. However, abscission of undeveloped stage 1 and 2 buds increased with temperature and shipping duration. When plants were exposed to ethylene, stage 5 and 6 buds abscised quickly without undergoing normal development. There was not a difference between exposure to 1 or 3 ppm of ethylene. Even at 3 ppm, the stage 1 and 2 buds did not abscise and continued normal development. These studies showed that hibiscus are sensitive to ethylene, which can result in loss of larger buds and flowers. However, the pattern of flower bud drop during shipping was not found to be parallel to flower bud drop on plants exposed to ethylene.

1340-1440

S09-P-52

TREATMENT WITH 1-METHYLCYCLOPROPENE COMPLEMENTS TEMPERATURE MANAGEMENT IN MAINTAINING POSTHARVEST QUALITY OF BROCCOLI

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Postharvest life of broccoli is short, limited by yellowing, water loss, decay, and off-odor development. In this study we evaluated the effectiveness of 1-MCP as a supplement to low-temperature storage in protecting the appearance of harvested broccoli. 'Marathon' broccoli heads were treated immediately after harvest with 2 ppm of 1-MCP for 6 h, cut into 2-cm florets, placed in folded, unsealed plastic bags and stored at 1, 10, and 20 °C. Untreated controls were handled and stored similarly. Postharvest changes in color and fresh weight were measured throughout the storage period. Untreated broccoli lasted 3, 14, and 82 days at 20, 10, and 1 °C, respectively. Broccoli treated with 1-MCP retained an acceptable postharvest appearance for 4, 22, and 94 days, at 20, 10, and 1 °C, respectively. Postharvest life of broccoli stored at 20 and 10 °C was shortened by yellowing, whereas at 1 °C decay was the limiting factor. The average hue angle of broccoli florets at the beginning of the storage period was 125.1. Untreated broccoli reached a hue angle of 110 in 2.6, 15.1, and 75.2 days, at 20, 10, and 1 °C, respectively. 1-MCP-treated broccoli needed 3.4, 22.9, and 97.3 days to reach the same hue at 20, 10, and 1 °C, respectively. Initial chroma was 11.2 and increased during senescence. Untreated broccoli reached a chroma value of 20 in 2.6, 15.2, and 74.6 days, at 20, 10, and 1 °C, respectively. In 1-MCP treated samples the same chroma was achieved in 3.6, 20.2, and 86.6 days, at 20, 10, and 1 °C, respectively. Lightness (L*) also increased during senescence. Fresh weight decreased during storage at an average rate of 1.16, 0.36, and 0.03% per day, for broccoli stored at 20, 10, and 1 °C, respectively. 1-MCP treatment is a useful supplement to low temperature storage in preserving postharvest appearance of broccoli.

1340-1440

S09-P-53

IMPROVING SHELF LIFE OF PRE-RIPE AND RIPE 'GALIA' MELON FRUIT BY 1-MCP

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Galia melons (*Cucumis melo* L. var. *reticulatus* 'True Galia') harvested at pre-ripe and ripe stages were treated with 5 µL·L⁻¹ 1-methylcyclopropene (1-MCP) for 18 h at 20 °C and stored at the same temperature. Respiration and ethylene production, mesocarp firmness, soluble solids concentration, electrolyte leakage, pH, titratable acidity, and visual changes were noted for the period of storage. 1-MCP not only delayed the respiratory climacteric peak 10 days but reduced the respiration rate as well. In contrast, the respiration pattern of ripe fruit was not significantly affected by 1-MCP. Peak climacteric ethylene production of pre-ripe fruit treated with 1-MCP was delayed 6 days and reduced by 65%. 1-MCP resulted in higher ethylene production rate in ripe fruit (68%) from day 3 to the end of storage. Fruit treated with 1-MCP at the pre-ripe stage demonstrated higher firmness values throughout storage compared with control. Firmness was 11.1 N in pre-ripe fruit on day 11 (last day of control fruit), while only 2.4 N in pre-ripe control. The firmness was also higher (67%) in ripe 1-MCP-treated fruit after day 3: Ripe 1-MCP-treated fruit, were 14.6 N and 12.2; and ripe control fruit, were 5.04 N and 4.85 on day 5 and 9, respectively. Loss of titratable acidity and green rind color was delayed by 1-MCP in both pre-ripe and ripe fruit. Electrolyte leakage of mesocarp tissue was lower in 1-MCP-treated, compared with control fruit, in both pre-ripe (throughout storage) and ripe fruit (after day 6). Windows of edibility of both pre-or ripe 1-MCP-treated fruit was extended by 40 to 50%.

1340-1440

S09-P-54

POSTHARVEST QUALITY OF FRUIT FROM A LONG-LIFE CULTIVAR OF TOMATO TREATED WITH 1-METHYLCYCLOPROPENE

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Long-life tomatoes (*Lycopersicon esculentum*, Mill cv. Thomas) at pink stage of maturity, were treated with 1-Methylcyclopropene at 0 (control), 0.085 or 0.845 µL·L⁻¹ for 20.5 h at 20 °C, and then stored at 20 °C for 12 d in polypropylene macroperforated bags. The harvest at this stage of maturity is common for exporting to UK markets. The goal of the work was to study the extent of the delay in ripening events due to 1-MCP treatment during no refrigerated storage. Control fruit were too soft after 10 d of storage, while only 1-MCP treated fruit developed decay after 10 or 12 d at 20 °C. 1-MCP treatment reduced the rate of ripening as measured by a delayed decrease in skin lightness or hue angle, while chroma index (a*2+b*2) 0.5 of the skin increased irrespective of the treatment used. Only fruit treated at 0.845 µL·L⁻¹ showed signs of delayed changes in the juice pH and coloration (recorded as hue angle), as well as in pericarp firmness or deformation characteristic of the fruit measured with a deformer. Both treatments reduced the rate of normal ripening as measured by increased pH, and decreased titratable acidity or soluble solids. These results reveal some barrier to 1-MCP gas diffusion within tomato tissue and the stronger effects on delaying ripening at higher 1-MCP concentrations below 1 µL·L⁻¹.

1340-1440

S09-P-55

EFFECT OF ETHYLENE AND 1-METHYLCYCLOPROPENE ON CHLOROPHYLL CATABOLISM IN FLORETS OF BROCCOLI

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Branchlets of broccoli (*Brassica oleracea* L.) were used to examine ethylene-stimulated chlorophyll catabolism. Branchlets treated with: 1) air (CK); 2) 1 mL·L⁻¹ of 1-methylcyclopropene (1-MCP) for 14 hours at 20 °C; 3) 1000 mL·L⁻¹ ethylene (C₂H₄) for 5 hours at 20 °C; or 4) 1-MCP+ C₂H₄ were stored in the dark at 20 °C for up to 3 days. Hue angle of controls decreased during the storage period, and 1-MCP treatment delayed this change. Yellowing of broccoli was accelerated by C₂H₄ treatment, however, prior treatment with 1-MCP prevented degreening stimulated by C₂H₄. Treatments did not result in differences in lipoxygenase activity, however, 1-MCP with or without ethylene resulted in reduced activity of chlorophyllase (Chlase) and peroxidase (POD). Exposure to C₂H₄ stimulated Chlase activity and remained a higher level of POD activity. In 1-MCP+ C₂H₄ treatment, the activity of POD was reduced and the increase of Chlase activity was delayed. The results suggested that chlorophyll in broccoli was degraded by the POD – hydrogen peroxide system normally, and C₂H₄ induced the activity of Chlase and remained higher POD activity to accelerate yellowing. 1-MCP treatment delayed the yellowing of broccoli due to the inhibition of POD and Chlase activities.

1340-1440

S09-P-56

APPLICATION OF GIBBERELIC ACID TO SWEET CHERRIES (PRUNUS AVIUM L.) CV. 'SWEETHEART': EFFECTS ON FRUIT QUALITY AT HARVEST AND DURING COLD STORAGE

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Large fruits are preferred by most consumers and gibberellic acid (GA) is used to increase fruit size and firmness. The effects of a preharvest GA application on quality of 'Sweetheart' cherries, at harvest and during cold storage were evaluated. Sweet cherry trees were sprayed with 10 and 30 ppm GA (T10 and T30, respectively) when fruit color was straw-yellow (aprox. 74 Hue) and compared with a control (unsprayed trees). When fruits reached their commercial color (aprox. 21 Hue), samples of 20 fruits/tree were harvested and quality was evaluated in terms of: weight, size, color, firmness, flesh/stone ratio, pedicel aspect, soluble solids content (SSC) and cracking index. Additional samples of 20 units were placed in plastic trays, packed in HDPE bags and stored at 0 °C during 21 days. Fresh weight loss, firmness, color, SSC, pedicel aspect and decay were registered on a weekly basis. Treated fruits reached harvest maturity 5 days later and an increase in size, weight and firmness was observed when compared to the control. T10 had the highest flesh/stone ratio, followed

by T30 and untreated fruit, while no significant differences were found for SSC and cracking index. During cold storage, T30 was significantly firmer than T10 and this, in turn, firmer than the control. Fresh weight loss was negligible and firmness increased toward the end of the experiment in all the treatments. No differences were found in color or SSC and, regardless of the quantity of GA applied, the percentage of cherries with commercial pedicels was higher for treated fruits. The 5-day delay in the harvest period, extending the fruit growing period, may be responsible for the increase in size, weight and firmness obtained with the GA. These differences were also maintained during the 21 days of cold storage when treated fruits showed a superior quality than the control.

1340-1440

S09-P-57

XYLOGLUCAN DEPOLYMERIZATION AND ENDO-XYLOGLUCANASE ACTIVITY IN ETHYLENE-TREATED WATERMELON FRUIT

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Ethylene-induced placental-tissue water soaking in harvested watermelon fruit is accompanied by cell separation and collapse, depolymerization of water- and chelator-soluble pectic fractions, a loss in total uronic acids, and increased polygalacturonase activity. In this study, we investigated whether hemicellulosic polysaccharides were altered in response to ethylene treatment. Watermelon fruit harvested at the full-ripe stage were treated with 50 $\mu\text{L}\cdot\text{L}^{-1}$ ethylene or air for 5 days at 20 °C. Visual inspection confirmed the development of water soaking in ethylene-treated fruit. Alkali-soluble (4 N) hemicelluloses were prepared, and mol mass distributions examined using Sepharose 6B-200 chromatography. Polymers from 0 day and 5 day air-treated fruit were similar in mol mass distribution, with the majority of polymers eluting within the void volume of Sepharose 6B (MWCO for polysaccharides = 1×10^6). In contrast, polymers from ethylene-treated fruit showed significant mol mass downshifts involving xyloglucan (XG) polymers. Total hemicelluloses were enriched in XG, with xylose and glucose comprising nearly 70% of total 4 N alkali-soluble neutral sugars. Treatment of watermelon fruit with ethylene was not accompanied by changes in hemicellulose composition, indicating that depolymerization did not result in increased solubility and loss of XG. Cell-free protein extracts from watermelon placental tissue degraded tamarind xyloglucan, resulting in significant mol mass downshifts. Similarly, watermelon hemicelluloses were degraded by the protein extract, resulting in mol mass distributions similar to those noted for ethylene-treated fruit. Xyloglucanase activity assessed using tamarind xyloglucan was similar between ethylene- and air-treated fruit, indicating that enzyme levels per se are not the primary factor increasing xyloglucan depolymerization in ethylene-treated watermelon fruit. Purification of the xyloglucanase (s) is in progress.

1340-1440

S09-P-58

EFFECTS OF ABA ON FLORAL SENESCENCE

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Placing cut flowers of a range of species in 100 μM abscisic acid (ABA) hastened the onset of symptoms of senescence, such as color change, water soaking and necrosis of the perianth, corolla wilting, and petal abscission. The response to ABA was prevented, in ethylene-sensitive flowers (carnation and petunia) by pretreatment with 1-methylcyclopropene (1-MCP), indicating that the ABA response was mediated by ethylene. In contrast the accelerated senescence caused by ABA in a number of monocotyledonous flowers (gladiolus, iris, alstroemeria and daffodil) was apparently not mediated by ethylene, since 1-MCP did not affect the response to ABA. In gladiolus, some cultivars were more obviously affected by ABA than others. In alstroemeria, the accelerated water soaking and wilting of the petals resulting from ABA treatment was not prevented by 1-MCP pretreatment, but the accompanying petal abscission was, suggesting that in this species senescence symptoms were differently regulated. Since the handling of cut flowers usually includes extended periods of dry storage, which can result in increased levels of endogenous ABA, the senescence-accelerating effects of ABA may have important implications in postharvest floriculture.

1340-1440

S09-P-59

STANDARDIZATION OF COST EFFECTIVE ETHYLENE ABSORBENT FOR EXTENSION OF SHELF LIFE OF 'RASTHALI' BANANA (SILK)

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A cost effective ethylene absorbent with talc and kaolin (inert materials) as carriers for KMnO_4 was developed. Ethylene absorbents prepared in sachets were tested based on the ethylene level inside the 200 gauge poly bag packed with 'Rasthali' banana fruit as source of ethylene production. The ethylene level was less inside the poly bag packed with absorbent (0.300 $\text{ppm}\cdot\text{kg}^{-1}$) than the control (0.725 $\text{ppm}\cdot\text{kg}^{-1}$) after ten days of storage. The ethylene inside the poly bag after ten days was lower (0.292 $\text{ppm}\cdot\text{kg}^{-1}$) in talc than in kaolin (0.307 $\text{ppm}\cdot\text{kg}^{-1}$), which indicated that talc is more effective than kaolin. The extension of green life was greater (22.44 days) when talc was used as carrier compared with kaolin (20.67 days). The highest green life (25.17 days) was obtained when 20 g of absorbent was used. The absorbent prepared by using talc as carrier was low in cost (Rs 0.9 per 20 g sachet) compared with kaolin sachets. Packing of 'Rasthali' banana with absorbent resulted in more green life (21.56 days) than control (15.33 days). The loss in weight was less (3.13%) under control than fruits stored with absorbent (5.46%). The quality of the stored fruit with absorbent was as good as control fruit. The TSS content of stored fruit was 25.06 °Brix while the fruits under control recorded 26.00 °Brix. Sensory evaluation, showed that over-all acceptability was similar for the stored and fresh fruits on ripening. However, they rated the skin colour appearance lower in the stored fruits (3.00) than in fresh fruits (4.00). This technology could be of economic importance in developing countries like India where refrigeration is not readily available. Hence, it is worthwhile to explore this technology on a larger scale

1340-1440

S09-P-60

INFLUENCE OF ETHYLENE AND 1-METHYLCYCLOPROPENE ON SOFTENING, RIPENING, AND CELL WALL MATRIX POLYSACCHARIDES OF AVOCADO FRUIT

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Pre-ripe avocado (*Persea americana*) fruit were treated with 0.09 $\mu\text{L}\cdot\text{L}^{-1}$ per L 1-methylcyclopropene (1-MCP) for 12 hours at 20 °C. After 19 d storage in air at 13 °C, half of the 1-MCP-treated fruit were treated with 100 $\mu\text{L}\cdot\text{L}^{-1}$ per L ethylene for 12 hours and then transferred to 20 °C. 1-MCP significantly delayed softening, and delayed the onset of the ethylene climacteric by 12 days. Fruit treated with 1-MCP retained more green color than air-treated fruit at the ripe stage (firmness 10–20 N). The delay in avocado ripening in response to 1-MCP was not influenced by the treatment with exogenous ethylene. 1-MCP affected the activities of polygalacturonase, pectinmethylesterase, alpha- and beta-galactosidase, and cellulase and completely suppressed the appearance of polygalacturonase activity for up to 24 days, at which time fruit firmness had declined to 35.1 ± 5.5 N. The activities of PG and cellulase increased and beta-galactosidase decreased in 1-MCP-treated fruit in response to exogenous ethylene treatment. 1-MCP treatment significantly delayed the solubilization and degradation of water- and CDTA-soluble polyuronides, apparently due to reduced PG activity. The mol mass downshifts of polyuronides were accompanied by changes in neutral sugar composition. At the full-ripe stage, neutral sugar levels of CDTA-soluble polyuronides were similar among all treatments. In contrast, galactose levels of water-soluble polyuronides decreased significantly in control fruit (40.6%) and decreased slightly (17.1%) in 1-MCP treated fruit. 1-MCP or ethylene treatment did not affect the sugar composition of hemicelluloses.

1340-1440

S09-P-61

RIPENING PROMOTION AND ETHYLENE EVOLUTION IN RED PEPPER AS INFLUENCED BY NEWLY DEVELOPED LYSOPHOSPHATIDYLETHANOLAMINE FORMULATIONS

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This experiment evaluated the ripening promotion and ethylene evolution in red pepper (*Casicum annuum* L.) as influenced by newly developed lysophosphatidylethanolamine (LPE) formulations. Spray applications of LPE wettable powder (WP) and suspension concentrate (SC) at 50, 100, 200 mg·L⁻¹ were made in a field near Dong ryang-myun, Chungju-si on 31 August and fruits were hand-picked on 9 September. All the LPE treatments promoted fruit ripening of red pepper. Among the all tested LPE treatments, LPE SC 200 mg·L⁻¹ was found to be most effective. Additional experiment was carried out to evaluate the effectiveness of LPE WP and SC with or without ethephon as ripening promotor in red pepper. When treated with LPE SC + ethephon at 100+500 mg·L⁻¹, total weight of red-ripen fruit was increased by 150% as compared to the control. Ethephon treatment significantly increased the effectiveness of LPE on fruit ripening. We measured the changes of time-dependent ethylene evolution as influenced by LPE WP and SC with and without ethephon. All LPE treatments stimulated ethylene evolution. LPE SC treatments resulted in marked increases in ethylene evolution. Ethylene evolution was significantly higher when treated with chemicals at high concentrations. When treated with LPE WP and SC with ethephon, ethylene evolution was increased, 8.9 to 9.2-fold higher than that from the control. The SC type was more effective for ethylene evolution than WP type. These results suggest that LPE can stimulate the ripening of red pepper, which was closely related with ethylene evolution. Newly developed LPE SC formulations were more effective for promotion of red ripening in red pepper.

1340-1440

S09-P-62

DIFFERENTIAL GENE EXPRESSION IN WATERMELON FRUIT FOLLOWING ETHYLENE EXPOSURE

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Watermelon fruit are extremely sensitive to ethylene, exhibiting acute symptoms of softening and water-soaking following short periods of exposure to the gas. In an attempt to isolate and identify genes possibly involved in ethylene-induced water-soaking, a comparative study of gene expression was performed using differential display Reverse Transcriptase-Polymerase Chain Reaction (RT-PCR). Watermelon fruit were harvested at the full-ripe stage and exposed to 50 *L per L ethylene for 24 hours at 20 °C. Total RNA was isolated from ethylene-treated and air-treated watermelon fruit and treated with DNase I to eliminate possible genomic DNA contamination. Total RNA (0.2 µg) was reverse transcribed using three different one-base-anchored oligo dT primers. High stringency PCR was performed using eight different 18-mer arbitrary primers in combination with the fluorescent-labeled one-base-anchored oligo dT primers. The PCR fluorescent-labeled products were separated on a 6% polyacrylamide sequencing gel and scanned with a fluorescent scanner. Confirmation of true positive bands were performed by Northern blotting. The comparison of mRNA transcripts between ethylene- and air-treated fruit revealed that 13 genes were differentially expressed in response to ethylene exposure. The differentially expressed genes were cloned into PCR-TRAP cloning vector. The cloned genes will be sequenced for comparison with known gene sequences already published in the database.

1340-1440

S09-P-63

RETARDATION OF YELLOWING AND ABSCISSION IN CUT LEAVES OF ASPARAGUS BY BENZYLADENINE SPRAYING UNDER LOW TEMPERATURE

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This study was conducted to extend vase life in cut leaves of asparagus (*A. densiflorus* and *A. sprengeri*) by inhibiting yellowing and abscission of the leaves. Spraying on leaves with 100 mg·L⁻¹ BA once a day for three days continuously treating from initiation of experiment made it possible not only to inhibit yellowing and abscission but also to preserve protein and chlorophyll

content considerably highly. Spray treatment of benzyladenine (BA) was the most effective in preventing yellowing and abscission among three treatments of spray, and holding plus spray. Consequently, vase life of asparagus was prolonged by BA spray treatment more two-fold compared with control under temperatures 15-30 °C. Moreover, vase life was extended at 15 °C, and shortened at 30 °C. Between the two species, the vase life of *A. densiflorus* was longer than *A. sprengeri*. This result shows that BA spray treatment was significantly effective in prolonging vase life for both of species by simultaneously retarding yellowing and abscission.

1340-1440

S09-P-64

USE OF HIGH PRESSURE TREATMENT TO PROLONG THE POSTHARVEST LIFE OF MUME FRUIT (PRUNUS MUME)

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High-pressure treatment (HPT) has the potential of extending the postharvest life of fresh fruits by the suppression of ethylene production. Pressures over 5 MPa, however, are above the threshold for irreversible tissue damage for several fruits. This study was conducted to evaluate whether HPT below 5 MPa could prolong the postharvest life of mume (*Prunus mume* Sieb. et Zucc.) fruit that produces large amounts of ethylene after harvest. The pressure was generated by compressing air into a high-pressure unit (OM labotech, Japan). Fruit were subjected to HPT at 5, 4, 3, 1 and 0.5 MPa for 10 min, and subsequently maintained at 0.5 MPa for 5 days. The physical and physiological changes of fruit subjected to pressures were investigated. The HPT of 5 MPa for 10 min changed surface color and decreased ethylene production. Fruit subjected to weaker pressures (<3 MPa) had kept a commercially acceptable color quality. These fruit exhibited higher rates of CO₂ and ethylene production just after transfer to atmospheric pressure. The peel of control fruit and those subjected to <3 MPa changed in color from green to yellow correspondingly. The treatment of 0.5 MPa for 5 days decreased CO₂ and ethylene production during storage. It dramatically decreased weight loss and showed benefits against chilling injuries such as skin pitting and browning. Visual comparison indicated a retardation of peel color development in treated fruit. These results indicated that long-term HPT at 0.5 MPa affects not only CO₂ and ethylene production but also water loss, and it may prolong the postharvest life of mume fruit.

1340-1440

S09-P-65

CHLOROPHYLL FLUORESCENCE AND CHILLING INJURY OF GREEN PEPPER AS AFFECTED BY STORAGE CONDITIONS

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The symptoms of early stages of chilling injury—a physiological disorder of green pepper fruit stored at low but non-freezing temperatures—can be monitored using the chlorophyll fluorescence technique. The effect of storage of green pepper (*Capsicum annuum* L.) at 1 °C, 4 °C and 8 °C for 18 days on chlorophyll fluorescence parameters and chilling injury occurrence on fruit was investigated. 'Roxy F1' green pepper fruit were grown in non-heated plastic tunnel in soil and harvested at mature-green stage. After harvest fruit were stored in perforated PE bags, non-perforated PE bags or without bags. At 3-6 days intervals, the chilling injury symptoms were evaluated and chlorophyll fluorescence parameters (Fo, Fm, Fv, Fv/Fm) were measured at the storage temperature and after 2 hours of warming to room temperature, as well as after additional 3 days of shelf life at room temperature. The results showed a gradual decrease of Fv/Fm fluorescence from 0.85 for fresh-harvested pepper to 0.55 after 3 days of storage at 1 °C and to 0.45 after 18 days of storage for both packaged and non-packaged fruit. There were no differences in rate of Fv/Fm decrease between pepper stored in non-perforated bags, perforated bags and without packaging. The earliest visible symptoms of chilling injury were observed on non-packaged pepper after 6 days of storage at 1 °C or after 3 days at 1 °C and additional 3 days at room temperature. Packaging of pepper significantly delayed chilling injury occurrence, up to 18th day of storage at 1 °C.

1340-1440

S09-P-66

STANDARDIZATION OF REFRIGERATED CONDITIONS FOR STORAGE OF 'MOSAMBI' SWEET ORANGE AND 'KAGZI' ACID LIME GROWN IN TROPICAL CENTRAL INDIA

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'Mosambi' sweet orange (*Citrus sinensis* Osbesk) fruit were stored at 4 ± 1 °C, 6 ± 1 °C and 8 ± 1 °C whereas 'Kagzi' acid lime (*Citrus aurantifolia* Swingle) fruit (mature yellow) were stored at 6 ± 1 °C, 8 ± 1 °C and 10 ± 1 °C with 90-95% relative humidity up to 90 days in vented polyethylene-lined corrugated cartons. Fruit were washed with chlorine solution (1000 ppm) and dip-treated with carbendazim (500 ppm) before storage. Chilling injury appeared in 'Mosambi' orange after 90 days at 4 ± 1 °C + 6 days at 30 ± 5 °C. Chilling injury symptoms did not develop inside storage up to 90 days under all three temperatures regimes. In acid lime, at 6 ± 1 °C, 10.20% fruit developed chilling injury symptoms like pitting and sunken areas inside the storage after 30 days and injury increased to 28.60% after 90 days. 'Mosambi' orange and acid limes developed deeper rind colour at 8 ± 1 °C and 10 ± 1 °C, respectively. At 10 ± 1 °C acid limes developed senescent symptoms (dry brown sunken irregular spots on rind) in 16.40% fruit after 90 days. Decay losses were <1% after 90 days. Changes in physico-chemical characteristics such as ascorbic acid, soluble solids, titratable acidity and juice content, fruit firmness, rind colour and fruit weight loss at various temperatures are discussed. Temperatures of 8 ± 1 °C and 6 ± 1 °C were found most optimum for long-term refrigerated storage of 'Kagzi' acid lime (yellow) and 'Mosambi' sweet orange fruit, respectively.

1340-1440

S09-P-67

EFFECT OF HARVEST DATE AND POST-HARVEST CALCIUM CHLORIDE TREATMENT ON STORAGE LIFE AND QUALITY OF 'SHAHMIVEH' PEARS

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An experiment was carried out in pear orchards (*Pyrus communis*) in Karaj region, to find a method to reduce post-harvest losses of 'Shamiveh' pears during the cold storage period, as well as by dipping the fruit in 2% and 4% solutions of calcium chloride. The first harvest time was done when fruit firmness was about 8 kg/cm² and the skin was still green. The second harvest was done one week later. The fruit were then dipped in solutions of 2% and 4% calcium chloride after harvest and before being stored in cold 5 °C and 85% relative humidity for 60 days. The results indicated that the time of harvest had a significant effect on fruit firmness, color, total sugar, TSS, pH and taste indexes and marketability, while calcium treatments affected some indexes such as firmness, TSS and color but not on others, e.g. taste, marketability. The weight loss during the whole period of storage was only affected by the time of harvest ($P = 0.01$), but the amount of calcium absorption in fruit tissue was affected by calcium treatments ($P = 0.01$). The treatment interactions indicated that there were significant effects on fruit firmness, pH, color skin and TSS and there were not any significant effects on other investigated characteristics.

1340-1440

S09-P-68

THE EFFECT OF STORAGE ON QUALITIES OF TWO CULTIVARS OF ZUCCHINI (*CUCURBITA PEPO*)

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An unusual vegetable, zucchini, is increasingly being consumed in Japan. Two different skin color types, 'DYNA' (green type) and 'AURAM' (yellow type) were stored at 6 and 20 °C packaged with polypropylene (OP, thickness 0.025 mm) and perforated OP (OPpf). We measured changes in appearance, the appearance and L*, a*, b*, ascorbic acid, free amino acid, reducing sugar and total sugar. The yellow zucchini showed chilling injury, pitting, after being stored

for 3 days at 6 °C. A few days later, the same injury appeared on the green one. Both Zucchini types packaged in OP showed pitting later than OPpf. At 20 °C, green and yellow zucchini become moldy and the flesh of the fruit softened and browned. The L* value was slightly decreased. At the beginning of storage, the amount of free amino acid in both zucchini types was the same; however the amount of amino acid increased in the green zucchini, but decreased in the yellow zucchini during storage. Both zucchini types had the same level of reducing sugar at the beginning. During storage, the green zucchini had no change, but the yellow had an increase. Ascorbic acid was a little higher level in the green zucchini than the yellow zucchini at the start and it changed very little during storage.

1340-1440

S09-P-69

IONIZING RADIATION EFFECT ON POSTHARVEST QUALITY OF 'RIORED' GRAPEFRUITS

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Irradiation is rapidly becoming the preferred method of treating citrus fruit for control of Caribbean fruit fly and improving shelf life of the fruit during storage. Citrus fruit contain several biologically active functional components that are known to prevent chronic diseases such as cancer and cardiovascular diseases. The preventative activity has been associated with polyphenol content in citrus fruit. 'Rio Red' grapefruits (*Citrus paradisi* Macf.) were harvested in the middle of March, 2001 and exposed to gamma irradiation from a cobalt-60 source at levels recommended to control fruit flies (0, 150, 300 Gy) and then stored at 100 °C and 90-95% relative humidity (RH) for 36 days, followed by an additional 20 days at 200 °C to simulate marketing conditions. Stored fruit treated with 300 Gy had less water loss compared to other treatments. Irradiation treatments had no consistent effect on total soluble solids (TSS) and titratable acidity. Stem end breakdown and peel pitting were slightly higher in fruits treated with 300 Gy at the end of the storage period. Irradiated fruits had higher total phenolic content than controls during storage. However, during marketing simulation there was a decline in total phenolics in all of the treatments, although treated fruit retained higher levels of phenolics than controls. Organoleptic characters were more affected by storage than by irradiation treatments. At the end of storage sensory panels preferred fruits exposed to 300 Gy irradiation. Irradiation may be useful in retaining the beneficial polyphenols that have been shown to have preventative effect on degenerative diseases in addition to insect control.

1340-1440

S09-P-70

EFFECT OF CULTIVAR AND LOCATION ON YIELD, TUBERS QUALITY AND STORAGEABILITY OF JERUSALEM ARTICHOKE (*HELIANTHUS TUBEROSUS* L.) II- STORAGE MEDIA AND TEMPERATURE

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This study was carried out in the cold storage rooms of the Horticulture Research Institute, Giza Governorate during the two successive seasons of 1998/1999 and 1999/2000. The aim of this study was to identify suitable storage conditions, storage media, and storage temperature for 'Fuseau' and other local Jerusalem artichoke cultivars. Tubers were stored either without media (control), in peat moss, or in sand. All treatments were cold stored at 0 or 5 °C. A complete randomized design with three replicates was used. Data were recorded on weight loss, decay, sprouting, shrinkage, discoloration and some chemical components of tubers. Results indicate that 'Fuseau' showed a lower percent of decay compared with the other local cultivars. Regarding the effect of storage media, tubers stored without medium (control) gave the best results for weight loss, decay, dry matter and reducing sugars. In respect to the two tested temperatures, no significant effect on weight loss, sprouting, shrinkage, discoloration, decay, dry matter, inulin, carbohydrates and reducing sugars of tubers were noted.

1340-1440

S09-P-71

STORAGE AND APPROPRIATE PACKAGING FOR HERBS

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Lemon thyme, oregano, marjoram, lemon balm, sweet basil and rosemary were stored in plastic basket, plastic basket with paper liner, plastic basket with polyethylene liner and perforated polyethylene bag. These herbs were kept at 0, 5 and 10 °C. The results showed that lemon thyme and oregano stored at 5 °C had the longest shelf life. Marjoram, lemon balm sweet basil, and rosemary had similar quality and shelf life at both 5 °C and 10 °C degree celcius. At 0 °C the color of these herbs was dark green. Weight loss of all herbs stored at 0 °C was higher than the ones stored at 5 °C and 10 °C. Herbs stored in plastic basket with polyethylene liner and perforated polyethylene bag showed better appearance than the others. Lemon thyme, lemon balm and sweet basil that were trimmed were packed in several kinds of packaging. These herbs were stored at 0, 5 and 10 °C. It was found that the appropriate temperature was 5 °C for these herbs. Herbs that were packed in polyethylene bags with nitrogen or without nitrogen had longer storage life than herbs not packed in polyethylene bags.

1340-1440

S09-P-72

CONTROLLED ATMOSPHERE STORAGE OF FRESH-CUT SWEETCORN KERNELS

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Fresh-cut sweetcorn kernels are a newly introduced product to the fresh-cut industry. It is a very perishable product since the kernels have a very high respiration rate that increases the rate of deterioration compared to intact sweetcorn. There are two main problems limiting development of this product; the severe loss of sugar and flavor (dimethyl sulfide, the main component of sweetcorn aroma), and the severe browning which can occur after cooking when the cut kernels are stored in air at higher than optimum temperatures (Riad and Brecht, 2001). Browning in plant material has many causes, such as oxidation of phenolic compounds (especially in cut or injured tissues in which there may be an increase in phenolic production). The after-cooking browning could also be a result of the Maillard reaction (a nonenzymatic reaction between sugars and free amino acids). Maillard reactions are common in the food industry and are usually associated with thermal processing. This work is being carried out to determine the best method to reduce the loss of sugars and flavor in fresh-cut sweetcorn and to identify the cause of after-cooking browning and the best method to reduce its occurrence. An atmosphere of 2% O₂ plus 10% CO₂ at 1 °C reduced sugar and flavor losses and eliminated after-cooking browning in fresh-cut sweetcorn kernels after up to 10 days storage compared to storage in air or at 5 °C. Preliminary results indicate that 5-hydroxymethylfurfural (HMF), the final product of the Maillard reaction, is not present in cooked sweetcorn kernels exhibiting browning. The brown color appears to be due to several phenolic-protein complexes as yet unidentified.

1340-1440

S09-P-73

MANAGEMENT OF ONION POSTHARVEST IN SANTIAGO DEL ESTERO (ARGENTINA)

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In Santiago del Estero, Argentina, the second most important economic crop is the "short-day" onion (*Allium cepa* L., cv. Valencianita), whose principal feature is its early harvest time which allows it to be first in the internal market and captures the best prices. The low quality of these bulbs as well as poor conservation, along with inappropriate handling during the harvest and postharvest, contributes to a decrease in the quality. Traditionally, curing and storing locally are not common practices. If we want to introduce this kind of onion into "Mercosur"

it is fundamental to implement the necessary technological changes in order to provide a product with a high commercial quality. Half of the onion samples were artificially cured for forty-eight hours at 30 °C. The water content in the cured bulbs was found to be high during the storage period. The primary cause of commercial quality loss was due to *Aspergillus* presence during different periods of storage, but the loss was less pronounced in the cured bulbs. Only in the first month and in a controlled environment could the cured bulbs turned out to be 90% commercial quality onions.

1340-1440

S09-P-74

QUALITY OF THE PORTUGUESE APPLE 'BRAVO DE ESMOLFE' AFTER NORMAL COLD STORAGE OR CONTROLLED ATMOSPHERE AND TWO SHELF LIFE PERIODS

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The effect of cold storage life under normal commercial storage (NCS) or controlled atmosphere (CA) on quality attributes and shelf life of the Portuguese 'Bravo de Esmolfe' apples was investigated. Fruit samples were harvested on September 97 at 160, 171 and 183 d.a.f.b.. One sample at each harvesting date was analysed immediately at the laboratory (UdL-IRTA) while the others were stored in commercial cold rooms and CA (of 150 t capacity) for 180 days. Additional analysis were carried on after 7 or 14 days shelf life at 20 °C and 90% R.H. Quality attributes, including weight loss, flesh firmness, titratable acidity (malic acid) and color (CIE L*a*b* or L°C *H*) were determined. As expected, the percent of weight loss increased with duration of storage and was highest on 180 + 14 days (3, 8%). Also, the firmness and titratable acidity was lower at 180 + 14 days than at harvest. Additionally, flesh degreening was lower at removal from cold storage than 14 days later (a* and H⁹ were significantly higher). Physical and chemical analysis of the quality attributes studied confirm that fruits were overmature at 180 + 14 days (flesh firmness = 3.8 kgf·cm⁻²), whereas seven days earlier (flesh firmness = 4.6 kgf·cm⁻²) the apples were still suitable for fresh consumption. Thus, 180+7 days shelf life could be the limit for fresh consumption.

1340-1440

S09-P-75

AVOCADO AND MANGO COLD STORAGE DAMAGE AS RELATED TO WATER LOSS CONTROL

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Subtropical fruits exported from South Africa to distant markets require storage at low temperature for long periods. Defects usually defined as chilling injury often result. Shipping at higher temperatures, however, at times accentuates the external symptoms, accelerates fruit ripening, and decreases shelf life. The role of water loss prevention, particularly fruit coatings, were investigated for mango and avocado. Mango cv Heidi was used, and fruit stored at 11 °C for 15 days. Avocado cvs Fuerte and Pinkerton were stored at 2 °C, 6 °C, and 8 °C, for 30 days. Micro-perforated poly bags were included for avocado. Fruit mass loss was determined during storage and after ripening at 20 °C, shelf life and appearance were evaluated. Light and environmental scanning electron microscopy (ESEM) of the fruit surface was conducted. The most severe "chilling injury" occurred where water loss was not controlled, but not correlated with storage temperature, suggesting the symptom is strongly influenced by dehydration with temperature a secondary factor. Fruit damage always started around stomata or lenticels. However, the most efficient techniques of water loss control were not successful, especially for avocado, where internal disorders occurred. The correct balance between water loss prevention and fruit gas exchange is required. ESEM showed the best wax formulations cracked during storage. It is suggested that wax coatings should initially protect fruit from water loss but crack during storage to allow sufficient gas exchange during post storage ripening. Depending on fruit type and storage conditions, different formulations are required, and micro-perforated bags removed before ripening may in some cases be preferable to waxing.

1340-1440

S09-P-76

THE EFFECT OF LOW TEMPERATURE TREATMENTS ON PHYSIOLOGY CHARACTERISTICS AND TISSUE STRUCTURE OF PLUMS

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The effect mechanism of low-temperature treatments on physiology characteristic and tissue structure of "HeiHuPo" and "Chuanhong" plums was studied. The influence of four temperature patterns, (intermittent warming, 0-10? dual temperature cycle, 0-6.6? dual-temperature cycle and decreasing temperature in sequence), on chilling injury was evaluated along with 0.5-0? constant low-temperature storage as a matching test. The optimum temperature pattern was identified and determined and the mechanism of chilling injury was discussed. Results would provide theoretical support and technology reference for commercial storage of plums. This study demonstrated that -0.5-0? constant low-temperature storage had a low temperature effect on plums. "HeiHuPo" and "Chuanhong" plums exhibited obvious chilling injury symptoms on the fortieth day of storage. With prolonged storage time, chilling injury became more serious. Chilling injury promoted the increase of cell membrane permeability and MDA content. Cell membrane permeability was regarded as index of chilling injury in plums. The 45th and 30th day were the critical times of irreversible chilling injury in "HeiHuPo" and "Chuanhong" plums. Low temperature induced an increase in PPO and POD activities decrease in phenol content, accelerated flesh browning, disturbed PG: PE enzyme balance, altered pectin metabolism, accelerated the decrease of reduced sugars and acid content and shortens shelf life of plums. It was shown through microscopy that changes occurred in tissue structure during the middle of the storage period: epidermis cells sank, cell wall was irregularly thickened, cells became long and the gap between cells enlarged. At the end of storage, the cuticle was broken, epidermal cells became over-overlapped, deformed and broke into pieces. Intermittent warming efficiently moderated the low-temperature effect.

1340-1440

S09-P-77

FRUIT DEHUSKING AND PULP STORAGE OF 'MONTHONG' DURIAN (*DURIO ZIBETHINUS* MURR.)

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Dehusking of 'Monthong' durian along the natural suture was more difficult and caused more damage than dehusking along the carpel groove when durian began to ripen. Dehusking became easier and less damaging at a more advanced ripening stage. Mold appearance on durian pulp obtained by both methods was not different during storage at 25 °C. When Monthong durian at 113 and 120 days after anthesis (DAA) were sprayed with ethephon 2,000 µL/L (whole fruit) or stem dipped with 10,000 µL/L and stored under normal or high velocity air movement at room temperature, it was found that ethephon treatment and storage under high velocity air movement enhanced dehusking, dehiscence and weight loss. Ethephon enhanced pulp softening at a faster rate than the high velocity air treatment and the control. However, pulp texture was firmer than untreated fruits when compared to that at the start of dehiscence. Storage of pulp of durians at 106, 113 and 120 DAA at 2.5 and 10 °C for 15 days showed that the quality of durian pulp of different maturities were about the same. Those at 2 °C could be stored longer with very little change in quality. At higher temperatures (5 and 10 °C) ripening process of durian pulp proceeded moderately. Ripening processes of durian pulp with firm texture at the beginning proceeded further during storage. Durian pulp fumigated directly with SO₂, or indirectly using Na₂S₂O₅, ethanol vapor, or irradiation with gamma rays before storage effectively limited microbial growth at 25 °C, particularly at higher doses. Ethanol vapor appeared to be the most appropriate treatment to reduce microorganism on durian pulp.

1340-1440

S09-P-78

EFFECT OF WRAPPERS ON THE SHELF LIFE OF PATHARNAKH PEARS. Singh*¹, R. Mohla², N.S. Antaal³¹Warden House Girls Hostel, Khalsa College Amritsar-143002 Punjab India; ²361,Akash Avenue Fatehgarh Churian Road, Amritsar-143001 Punjab India; ³940, Sector-III, Block-C Ranjit Avenue Amritsar-143001 Punjab India

Pear cultivar Patharnakh [*Pyrus pyrifolia* (Burm) Nakai] fruit harvested on July 15 and August 1 were wrapped individually in high-density polyethylene (10 and 20 µm), low density polyethylene (100 and 200 gauge), newspaper, tissue paper or paddy straw and stored at ambient temperature (30-38 °C) in wooden boxes for analysis at fortnight intervals up to 60 days. Non-wrapped fruits served as controls. With the advancement of harvesting date, a significant increase in physiological loss in weight, spoilage losses, total sugars and reducing sugars were recorded except starch percentage, which showed a decreasing trend, while organoleptic rating, total soluble solids and acid content of fruits showed non-significant results. High density polyethylene 20 µm film wrapped fruits experienced significantly lower physiological loss in weight followed by high density polyethylene 10 µm compared with that of the controls after ambient storage. Spoilage losses were 3.5 times lower in high density polyethylene 20 µm wrapped fruits when compared with control. Appearance and flavour were not acceptable after 45 days in controls and paddy straw (score less than 5 on 1-9 scale). Fruit were considered acceptable (score more than 7 on 1-9 scale) after ambient storage in low density polyethylene (100 and 200 gauge) films. Acidity and starch level retention were higher in high density polyethylene 20 µm wrapped fruits when compared with control. Newspaper wrapped fruits recorded higher level of total soluble solids and reducing sugar than all other treatments. With the advancement of the storage interval from 15 to 60 days, significant increases in physiological loss in weight, spoilage, total soluble solids, total and reducing sugar content were recorded, whereas organoleptic rating, acidity and starch percentage decreased.

1340-1440

S09-P-79

FRUIT RIPENING STUDIES IN PEARS. Singh*¹, N.S. Antaal², R. Mohla³¹Warden House Girls Hostel, Khalsa College Amritsar-143002 Punjab India; ²940, Sector-III, Block-C Ranjit Avenue Amritsar-143001 Punjab India; ³361, Akash Avenue Fatehgarh Churian Road, Amritsar-143001 Punjab India

Pyrus pyrifolia (Burm) Nakai fruit were treated with ethrel fast dip (1000-3000 ppm), ethrel slow dip (300-500 ppm), hot water immersion, rice straw wrapping or ice exposure at four stages. Hot water treatment, rice straw wrapping and ethrel 3000 ppm produced excellent intense yellow coloured glossy fruits with a high palatability rating. These treatments resulted in increased TSS contents, decreased acidity levels, maximized sugar contents and reduced phenolic contents in fruits. Total pigments and pectin methyl esterase contents showed increasing trends under these treatments. Loss in fruit firmness was demonstrated to be the lowest in ice-treated fruits.

1340-1440

S09-P-80

ELEVATED LEVELS OF CO₂ IN CONTROLLED ATMOSPHERE STORAGE AFFECTS SHELF LIFE, FRUIT QUALITY AND AROMA VOLATILES OF MANGOH.D.J. Lalel¹, Z. Singh*¹, S.C. Tan²¹Horticulture/Viticulture, Muresk Institute of Agriculture, Division of Resources and Environment, Curtin Univ. of Technology, GPO Box U1987, Perth, Western Australia 6845, Australia; ²Dept. of Agriculture, 3 Baron Hay-Court, South Perth 6151, Western Australia 6983, Australia

Controlled atmosphere (CA) storage of mango fruit (*Mangifera indica* L.) 'Kensington Pride' (KP) was studied using three combinations of carbon dioxide (3, 6 and 9%) and one level of oxygen (2%) at 13 °C to extend shelf life. Fruit were removed 21 and 35 days after storage and allowed to ripen for seven days at 21 °C. All CA treatments slowed the rate of fruit respiration during ripening. The beta-carotene content increased with an increase in carbon dioxide concentration in CA storage after 35 days. All CA treatments led to significantly reduced physiological weight loss and improved fruit firmness 21 and 35 days after storage. The acid content of the fruit increased with all CA treatments during the storage period up to 35 days. Reducing, non-reducing, and total sugar content of the fruit, and taste, was improved with CA treatments and the increase was most pronounced after 35 days of storage. Sixty-six volatile compounds were identified from the pulp of ripe mangoes by gas chromatography-mass spectrometry (GC-MS). Hydrocarbon monoterpenes and sesquiterpenes were found as major

compounds of CA-stored ripe KP mangoes, which comprised 65 percent of the total compounds. Alpha-terpinolene was the most abundant compound in all CA-stored ripe fruit. All major aroma volatile compounds, except alpha-gurjunene, in ripe KP mango decreased as the level of carbon dioxide was increased during 21 days of CA storage. Fruits stored in controlled atmosphere with 6 and 9% carbon dioxide resulted in 70 and 89% reduction in alpha-terpinolene, respectively, than 3% carbon dioxide. In general, the elevated levels of carbon dioxide reduced the production of volatile compounds and the reduction was more pronounced in fruits stored for 35 days. These results showed that CA storage (6% carbon dioxide and 2% oxygen) at 13 °C seem to be promising for extending the shelf life and maintaining fruit quality of mango.

1340-1440

S09-P-81

ON-FARM MODIFIED ATMOSPHERE PACKAGING OF SWEET CHERRIES

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Modified atmosphere packaging (MAP) trials are generally performed in laboratories under very controlled conditions. Conditions on-farm are generally less controlled due to changes in room load and heat exchange when loading and unloading rooms. As the permeability and performance of MAP films is highly affected by temperature, MAP films were tested for performance under on-farm conditions. Three sweet cherry cultivars were stored for 2, 4 and 6 weeks in an on-farm cold storage facility. Temperatures ranged between 1 and 3 °C. Three MAP films composed of polyolefin with oxygen permeabilities of 3000, 7000 and 16500 mL·m⁻² (24 h at 23 °C) were evaluated. The test films were compared to the grower's standard practice of packing the cherries in an unsealed, non-permeable but perforated bag. The cherries were pre-cooled prior to packaging. The only additional equipment required by the grower was a heat sealer. MAP improved the storage quality of all three cherry cultivars, although results were quite variable. Weight loss was highest for the control, ranging from 0.45 to 5.5%. Weight loss was significantly lower for the MAP packaged fruit (0.02 to 0.7%) with minimal differences between films. Overall, the MAP films with the lowest oxygen permeabilities produced the best results. These films modified the atmosphere to within the recommended oxygen and carbon dioxide levels for extended controlled atmosphere storage. For 'Hedelfingen' cherries, MAP reduced decay by 50% and significantly increased firmness. Decay was reduced by 85% in short-term storage (14 day) of 'V-690616'. Stem loss was also reduced in this cultivar but there was no effect on firmness. MAP moderately reduced stem loss and decay for the cultivar 'Vandalay'.

1340-1440

S09-P-82

THE RESPONSE OF STRAWBERRY FRUIT EXPOSED TO HIGH CARBON DIOXIDE CONDITIONS—IN VIVO ACTIVITIES OF PYRUVATE DECARBOXYLASE AND ALCOHOL DEHYDROGENASE

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Some strawberry cultivars respond to high (15-30 kPa) CO₂ partial pressures with acetaldehyde and ethanol production whereas others respond with succinate accumulation. We are testing the hypothesis that these varietal differences relate to differences in the in vivo activities of pyruvate decarboxylase and alcohol dehydrogenase. These enzymes could affect the amount of pyruvate that is diverted from the tricarboxylic acid (TCA) to the anaerobic fermentation pathway. Strawberry cultivars with known differences in the accumulation of intermediates of the anaerobic metabolic pathway were exposed for up to nine days at 2 °C to atmospheres with either 0, 15 or 30 kPa carbon dioxide in the presence of 20 kPa oxygen in a flow through system. At regular intervals, container inlets and outlets were closed for up to five hours to determine oxygen consumption and carbon dioxide emission and to sample the headspace for volatiles. The direct sampling of headspace volatiles followed by immediate column injection allowed for the determination of the emission rates of acetaldehyde, ethyl acetate and ethanol. Comparison of these rates with the volatile contents of replicates of fruits that were frozen after either six or nine days of treatment is making it possible to

estimate the in vivo activities of pyruvate decarboxylase and alcohol dehydrogenase. These results will be presented in relation to other differences in metabolic responses of the cultivars to high CO₂.

1340-1440

S09-P-83

AN INVESTIGATION OF THE ROLE OF TEMPERATURE IN MESOCARP DISCOLORATION OF 'PINKERTON' AVOCADOS

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The 'Pinkerton' avocado was introduced into South Africa as a high yielding green skin cultivar. However, the susceptibility of this cultivar to mesocarp discoloration after storage has threatened its export. The disorder was suspected to be cold injury. In this study, fruit from areas varying in mesocarp discoloration intensity were subjected to storage at 8 °C, 5.5 °C or 2 °C for 30 days. Comparisons were made with fruit allowed to ripen at 20 °C. Fruit quality and membrane stability evaluations were made after harvest, after storage and after softening. Fruit softness and carbon dioxide (CO₂) evolution were monitored daily. Results of CO₂ evolution showed that the number of days to the climacteric peak was similar throughout the harvesting season. However, fruit harvested later in the season had a higher evolution rate than the less mature fruit picked earlier in the season. The difference in respiration rate between temperature treatments was minimal. Higher storage temperatures caused higher discoloration ratings, and this was correlated with poorer membrane stability. Fruit stored at the lowest temperature had the least damage indicating that the disorder is not entirely cold injury. More mature fruit harvested later in the season appeared to be more susceptible to the disorder. Throughout the study, mesocarp discoloration was found to be site related, indicating that the disorder does not develop solely postharvest, but rather that preharvest conditions play an important role.

1340-1440

S09-P-84

EFFECT OF EXOGENOUS SALICYLIC ACID ON POSTHARVEST PHYSIOLOGY OF PEACH FRUITS (*PRUNUS PERSICA*)

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Salicylic acid (o-hydroxybenzoic acid), is one of many phenolic compounds produced in plants. Many important functions of salicylic acid in plant had been discovered since the 1960s, which include flower-inducing, disease-resistance, inhibition of ethylene biosynthesis, etc. The purpose of the present investigation research was to determine the effect of postharvest immersions of peach fruits in SA solution on physiological changes of intact fruit during storage. Harvested peach (*Prunus persica* L.) fruits cv. Okuba were immersed in 0 g/L, 0.10 g/L or partial-vacuum infiltrated in 0.10 g/L salicylic acid (SA) solutions for 10 minutes (1996), or were immersed in 0 g/L or 0.10 g/L salicylic acid solution for 20 minutes (1997), then stored at room temperatures (26-30 in 1996 for 10 days; 30-34 in 1997 for 11 days). Results showed that immersions of peach fruit in proper concentrations of SA inhibited the respiration rate of ripening fruits. The ethylene production peak of peach was delayed by SA immersion. The cell membrane electrolyte leakages of SA treated fruits, compared to control, were high during early days and low during subsequent days. By contrast the activities of polyphenoloxidase (PPO) and peroxidase (POD) of SA fruits were low at 2nd day and high during later days of storage. Partial-vacuum infiltration of SA had no advantages in comparison with the immersion at the same concentration.

1340-1440

S09-P-85

THE EFFECTS OF TEMPERATURE AND OXYGEN ON THE TOLERANCE OF 'FUJI' APPLES TO CARBON DIOXIDE

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The results from successive three year experiments indicated that although 'Fuji' apples were easily injured by CO₂ when they are stored at standard controlled atmosphere conditions (CA: 0.3% CO₂ + 3% O₂), as the temperature or O₂ concentration increased, tolerability of 'Fuji' to CO₂ increased. In 1996, 'Fuji' apples

were stored at 0, 5, and 10 °C, and 5% O₂ for two months. No browning fruit were found with the treatment of 0% CO₂ under the three temperatures. Browning fruit were found in the treatment of 3% CO₂ under the temperatures of 0 and 5 °C; no browning fruit were found in the temperature of 10 °C. As CO₂ increased to 6%, browning fruit were found in the three storage temperatures: 100% in 0 and 5 °C and 75% in 10 °C. When the CO₂ was increased to 9%, browning fruits increased to 100% in 0 and 5 °C and 85% in 10 °C, and fruits were more seriously injured. During this year, we also used MA to store 'Fuji' apples. Surprisingly, we did not find the fruit in the regime of O₂ above 10% and CO₂ of about 6% were injured. In the following year, the fruits were stored in 10 °C. After two months we did not find browning fruit in the treatment of 0% CO₂ + 3% O₂. The treatment of 3% CO₂ + 3% O₂ induced browning of 20%. However, no browning fruit was found in 3% CO₂ + 5% O₂. When oxygen concentration was increased to 10%, no browning fruit were found in the treatment of 3% and 6% CO₂. In the treatment of 9% CO₂, browning fruit of 20% were found. In 1996 and 1997 we repeated the experiments of 1996 and 1997 and found the similar results. Although the lower temperature and lower O₂ accentuated the CO₂O₂ injuries, they effectively maintained the firmness and chlorophyll content in the peel of the fruits.

1340-1440

S09-P-86

THE EFFECT OF HOT AIR TREATMENTS ON THE QUALITY AND ON SOME ANTIOXIDANT COMPONENTS OF TOMATO FRUIT

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'Rapsody' tomato fruit were exposed to 34 °C for 24 hours in air, to 38 °C for 24 hours in air, or to 38 °C for 24 hrs in 5% O₂ (balance was N₂), and then stored in air either at 4 or 10 °C. Fruit exposed to 38 °C at 5% O₂ were most injured, while fruit that were not heat treated, and those exposed to 34 °C for 24 hrs in air, were the least injured. Fruits that were maintained at 10 °C and previously either not heated or exposed to 34 °C in air developed the best colour, having the least chlorophyll and the highest lycopene contents when ripened. Fruit that were exposed to 38 °C in 5% O₂ had lower α-tocopherol and higher activity of peroxidases, ascorbate peroxidase, superoxide dismutase, glutathione reductases, and glutathione S-transferases than fruits of the other treatments.

1340-1440

S09-P-87

EFFECTS OF ELEVATED CO₂ CONCENTRATIONS IN MODIFIED ATMOSPHERE PACKAGING OF PRICKLY PEAR CACTUS STEMS (*OPUNTIA* spp.)

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In this work we have tested the effect of modified atmosphere packaging either in a passive form or with the addition of elevated CO₂ concentrations (20, 40 and 80%) on the physicochemical and microbiological parameters in nopalitos (flattened stems or cladodos of the prickly pear cactus) stems (*Opuntia* spp.) stored at 5 °C. Elevated CO₂O₂ concentrations (40 and 80% CO₂) increased the losses in texture, weight, chlorophyll content, dietary fiber content and color. Passive modified atmosphere (up to 8.9% O₂ and 7% CO₂) and 20% CO₂ (added to the package) significantly decreased losses in the above parameters and in the microbial counts (total aerobic mesophiles, moulds and yeast counts), but slightly increased the total anaerobic mesophiles counts. The microorganisms identified were *Pseudomonas*, *Leuconostoc*, *Micrococcus*, *Bacillus*, *Ruminococcus*, *Asidia*, *Cladosporium*, *Penicillium* and *Pichia*.

1340-1440

S09-P-88

THE EFFECT OF CONTROLLED ATMOSPHERES AT HIGH TEMPERATURES ON THE MORTALITY OF *ANASTREPHA LUDENS* AND *A. OBLIQUE* AND ON MANGO FRUIT QUALITY

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The in vitro and in vivo (artificially and naturally infested in mango fruit) mortality of different stages (eggs, first and third instar larvae) of *Anastrepha ludens* and *A. obliqua* were determined after exposure to controlled atmospheres (0 kPa O₂ + 50 kPa CO₂) at different temperatures (35-55 °C) and different exposure periods (80-240 minutes). Controlled atmospheres (CA) at >40 °C for >160 minutes increased insect mortality. The in vivo mortality was more rapid than the in vitro mortality. Eggs were more tolerant than larval stages. *A. obliqua* is slightly more tolerant than *A. ludens*. The mean estimated temperatures for 50%, 99% and 99.9968% of the in vitro mortality (LT50s, LT99s, LT99.9968s) of eggs of *A. obliqua* exposed to 0kPa O₂ + 50 kPa CO₂ at 51, 54 and 55 °C for 240 minutes were 49.4, 54.8 and 60.9 °C, respectively. 'Manila' mango fruit can tolerate these CA treatments at <44 °C for 160-240 minutes, but fruit becomes injured at higher temperatures.

1340-1440

S09-P-89

ROLES OF ELEVATED CARBON DIOXIDE ON POSTHARVEST CHILLING SUSCEPTIBILITY IN 'MOSCHATA' SQUASH

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Effects of CO₂ on chilling susceptibility and physiological changes were investigated during cold storage of squash. The severity of chilling injury (CI) in squash stored at 4 °C was reduced by 5 and 10% CO₂ treatments. Squash treated with 10% CO₂ showed CI below 10% when stored for 18 days at 4 °C and then 20 °C for 2 days. Little effect was found with 1% CO₂ on reduction of CI. Some physiological parameters such as electrolyte leakage and carbon dioxide proportionally increased with the increase of CI and storage duration. The maintenance of catalase, peroxidase and superoxide dismutase activities in CO₂ treated squash was apparently important to maintain the beneficial effect on reduction of chilling susceptibility through the defence mechanisms against hydrogen peroxide. The different effectiveness of the CO₂ concentrations in increasing chilling tolerance of moschata squash may be related to different activities of antioxidant enzymes, especially catalase, during chilling stress. Accelerated increases of ethylene production paralleled increases in ACC content after the squash were transferred from 4 °C, air to 20 °C, air. The treatments of 10% CO₂ effectively reduced these increase of ACC and ethylene. The level of ACC in non-chilled squash was low and remained unchanged after transfer to 20 °C.

1340-1440

S09-P-90

CHANGES IN COLOR AND COMPONENTS WITH TEMPERATURE TREATMENT IN HOT PEPPER

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This study was performed to improve red coloring and valuable components of hot pepper fruits with different coloring stages using variable temperature treatments. The coloring of 10% and 30% red-colored hot peppers was completed after 7 days after 20, 25, and 30 °C treatments, but not completed after 15 and 35 °C treatments in the same period. More than 50% red-colored hot pepper fruits in harvest time were completely colored red within 7 days after 20, 25, and 30 °C treatments, but not after 15 and 35 °C treatments, where red coloring was delayed by 2 or 3 days compared with other temperature treatments. The higher temperatures, up to 30 °C, accelerated coloring of hot pepper, but the decay of fruits was accelerated with the increase in temperature. The alternating temperature treatment had no significant effect on the red coloring of hot pepper. After treatment, capsaicin and beta-carotene contents of hot peppers were the highest after 15 °C treatments, but there was no statistical difference among other temperature treatments. Cryptoflavin rate was the highest after 15 °C, and cryptocapsin was the highest after 25 °C treatment.

1340-1440

S09-P-91

DELAYS TO COOL AFFECT VISUAL QUALITY, FIRMNESS AND GLOSS OF BELL PEPPERS AND EGGPLANTS

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Temperature management is key to marketing high quality produce, and it is generally recommended to "cool as soon as possible". Specific data is lacking for many fresh products. We evaluated the impact of water loss and delays to cool on quality attributes (visual appearance, gloss, weight loss, color change, decay development, and firmness) of stored mature-green bell peppers and Japanese eggplants. Objective measurements of gloss and firmness were highly correlated with subjective scores of both attributes. A weight loss of 2 to 4% reduced bell pepper firmness, gloss and visual quality. Average weight loss with cooling delays at 37 °C (35-38% RH) and 25 °C (48-50% RH) was 0.13 and 0.06% per hour, respectively. Significant decreases in gloss values occurred with cooling delays of 9 hours at both temperatures. Important decreases in firmness occurred after a 9 hour delay at 37 °C, but not until after an 18 hour delay at 25 °C. No color change occurred in the peppers held at 25 °C for up to 18 hours, but after 12 hours at 37 °C, some peppers began to color. Delays to cool should be less than 9 hours at 20-25 °C and less than 6 hours at 37 °C for mature-green bell peppers. For Japanese eggplants, visual quality scores were significantly decreased with a 3% weight loss, but differences in firmness were measurable with 2% weight loss. Gloss values were not significantly affected until weight loss exceeded 8%. Firmness and gloss were not affected as rapidly as the overall visual quality score by delays to cool. Firmness values decreased significantly after 9 and 12 hours at 37 °C and 25 °C, respectively. Gloss values decreased significantly after delays of 9 hours at either temperature. For Japanese eggplants, delays to cool should be less than 6 hours at 20-25 °C and less than 3 hours at 37 °C.

1340-1440

S09-P-92

MAINTENANCE OF FRUIT HEALTH AND QUALITY OF KINNOW UNDER COLD STORAGE: AN INTEGRATED APPROACH

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This study revealed that we can store kinnow fruit up to 80 days in cold storage without any significant losses in health and quality of fruits by using an integrated approach, which includes Bavistin @ 0.05% + Boric acid @ 1% +HDPE packaging. There were only 2.1, 3.11 and 4.60% spoilage losses after 30, 60 and 80 days of storage, respectively, in the fruits which received the integrated approach as compared to those fruits which received the individual treatment of higher doses of Bavistin, Boric acid and only HDPE packaging. As well, total soluble solids, reducing sugar and ascorbic acid contents were also higher in those fruits which received the integrated approach. From this experiment it was concluded that we can safely store the kinnow up to 80 days at cold storage by using integrated approach.

1340-1440

S09-P-93

SUGGESTIONS ON RATIONALIZED METHODOLOGIES TO INVESTIGATE KIWIFRUIT STORAGE LIFE

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Variation in storage life within and among fruit batches costs the kiwifruit (*Actinidia deliciosa* (A. Chev.) C.F. Liang et A.R. Ferguson 'Hayward') producers throughout the world millions of dollars each year. Investigation of the effects of preharvest factors and postharvest treatments on storage life of kiwifruit will contribute to both improved orchard management for higher quality fruit and improved postharvest management for reducing fruit loss. A rationalized methodology is proposed based on both research experience and literature to promote better and comparable results between research groups. Emphasis is placed on improvement of (1) sample preparation for mineral analysis; (2) temperature equilibration for firmness monitoring; (3) firmness measurement; (4) calculation of storage life based on fruit firmness monitoring data. Comparisons between different procedures in each of the four aspects are presented to demonstrate the improvements of the recommended methodologies.

1340-1440

S09-P-94

A STUDY ON MODIFIED ATMOSPHERE STORAGE OF STRAWBERRY

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The effect of polyvinyl chloride (PVC) stretch film thickness (12, 16 and 23 micron) on modified atmosphere (MA) storage of strawberry (*Fragaria x ananassa* Duch. cv. Tioga) fruits in polystyrene trays (350g/tray) was investigated. The fruits were stored at 0 °C and 90% R.H. Shelf life after harvest and during storage was studied at 20 °C and 75% R.H. Fruit parameters (quality, weight loss, firmness, SS, titratable acidity and pH) were examined during storage. PVC films at 16 and 23 micron maintained the fruit quality better than 12 micron. Effect of MA with 16 micron PVC was studied on 6 cultivars (Tioga, Douglas, Chandler, Aliso, Pajora and 216 'Dorit'). Tioga, Aliso and Chandler maintained their qualities better than other cultivars. The effect of PVC film was compared with P-Plus polypropylene (PP) films at different permeability on cvs. Tioga and Yalova 15. PP film maintained the fruit quality longer than PVC film. No significant difference was found between PP films. In cv. Yalova 15, MA packaging (MAP) reduced the weight loss to 2.5% with PVC film, and to 0.2% with PP film, compared to 8% in NA after 3 days at 20 °C. Weight loss reached 20% in control fruits, reduced to 3.5% in MAP with PVC and 0.2% in MAP with PP after 3 weeks of storage at 0 °C. MAP reduced the weight loss similarly in cv. Tioga. Therefore MAP significantly prolonged the storage and shelf life of strawberry fruits by maintaining fruit quality. For both cultivars, MAP with PVC and PP extended the shelf life to 4 and 5 days, respectively, from 2-3 days in control, and the storage life to 2 and 3 weeks, respectively, from one week in NA control.

1340-1440

S09-P-95

FORMULATION OF ZEIN COATINGS FOR APPLE FRUIT

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High-gloss coatings are often used to improve the appearance and sales of apple fruit (*Malus x domestica*, Borkh). The industry standard coating has been shellac, which has problems with low gas permeability, and association with non-food uses. There is also a problem with whitening that occurs after transfer of shellac-coated fruit from low storage temperatures to ambient marketing conditions, resulting in condensation of water vapor on the cold fruit surface. Zein, a natural corn protein, was used to formulate alternative, shiny coatings consisting of zein, propylene glycol (PG), alcohol and water. Coatings were evaluated on 'Galá' apples stored at 20 °C. At least 4% (by weight) PG, was necessary for adequate gloss, but higher levels of both zein and PG resulted in increased gloss. The gloss also varied due to zein content, with 10% giving about the same gloss as shellac-coated fruit. Whitening was low with zein content less than 11%. Permeability of CO₂, O₂ and water vapor was strongly dependent on the zein content in the coating. Internal gases of coated apples were modified to 3 to 12 kPa CO₂ and 19 to 5 kPa O₂, respectively, by increasing zein content in the coatings. An optimum formulation with 10% zein and 10% PG was developed and found to extend shelf life and to maintain overall fruit quality comparable to a commercial shellac coating.

1340-1440

S09-P-96

A STUDY ON MODIFIED ATMOSPHERE STORAGE OF SWEET CHERRY

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Sweet cherry (*Prunus avium* L. 'Merton Bigarreau') fruit were placed in polystyrene trays (350 g/tray) and wrapped with polyvinyl chloride (PVC) stretch film and P-Plus polypropylene (PP) films at different permeability or unwrapped (control, NA). In addition to retailer packs, the effect of P-Plus polyethylene (PE) bags at different permeability in carton boxes (in 3 kg packs) was investigated in cv. Lambert. The fruits under NA or different modified atmosphere (MA) conditions were stored at 0 °C. Shelf life after harvest and during storage at weekly intervals was studied at 20 °C. Fruit parameters (quality, weight loss, SS, titratable acidity

and pH) were examined weekly during storage. In cv. Merton Bigarreau fruits, MA packaging (MAP) reduced the weight loss to 2% with PVC film, and to 0.2% with PP compared to 9.8% in NA after 6 days at 20 °C. The weight loss reached 22.5% for control fruits, 4.5% for MAP with PVC and 0.3-0.5% for MAP with PP after 8 weeks of storage at 0 °C. In cv. Lambert fruits, MAP reduced the weight loss to 0.1% with PE films compared to 5% in NA after 6 days at 20 °C. The weight loss reached 21.7% in control fruits, and decreased to 0.8-0.1% for PE films after 8 weeks of storage at 0 °C. MAP with less permeable films not only dramatically decreased the weight loss, but also reduced the decay incidence. Therefore, the low permeable films (PP 90 for retailer packs and PE 120 for bulk packs) maintained the fruit quality better than high permeable one and doubled the storage life of sweet cherry to 8 weeks compared to NA.

1340-1440

S09-P-97

FORCED AIR COOLING AND PASSIVE MODIFIED ATMOSPHERE PACKAGING (MAP) OF APRICOTS

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Postharvest quality and physiology of apricots (*Prunus armeniaca* cv. 'Precoce de Tyrinthe') was studied after forced-air cooling (FAC) and passive modified atmosphere packaging (MAP). Apricots were harvested at 2 maturity stages: minimum maturity (MI: 9% SSC, orange color except suture), or export harvest maturity (MII: 10% SSC, completely orange color). Within a few hours after harvest, half of the fruits of each maturity stage were a) placed in a cold room at 0-1 °C and 90% RH for room cooling, or b) forced-air cooled at 600 cfm. All apricots were packed in MAP and stored at 0 °C for 7 d and then transferred to 20 °C (shelf-life) for up to 8 d. Another group of apricots were placed at 20 °C right after harvest to observe the shelf-life. Apricots were analyzed for fruit firmness, SSC, titratable acidity, color (hue angle), respiration, weight loss and evaluated for taste. Apricots from the two maturity stages benefited from forced-air cooling (FAC) at 0 °C. FAC increased the shelf-life and appearance of apricots from MI and MII when compared to room cooling at 0 °C. The cooling time of forced-air cooled apricots ranged between 86 min. (fastest) to 225 min. (slowest) compared to 431 min. recorded during room cooling. Apricots could be forced-air cooled to 0 °C and packed in MAP and then transported for a period of 7d in a refrigerated truck and still be able to maintain their quality even after additional 6-8 d shelf-life at 20 °C.

1340-1440

S09-P-98

MINIMALLY-PROCESSED LETTUCE QUALITY AS AFFECTED BY POLYMERIC FILMS EMPLOYED AS PACKAGING MATERIAL

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The use of minimally-processed vegetables has continued to increase in salad bars and fast food. Storage life of minimally-processed lettuce (*Lactuca sativa* L.) is influenced by their continued respiration and the biochemical activity associated with senescence. Enzymatic browning is one of the main causes of quality losses during postharvest storage. The use of modified-atmosphere packaging and low temperature reduce respiration and delay senescence, thus extending storage life. The objective of this work was to assess the suitability of a range of polymeric films for modified atmosphere packaging on butterhead, crisphead, latin and leafy lettuce types minimally-processed during storage at 5 °C for 9 days. Multilayered polyolefin RD-106, PD-900 and PD-961EZ with different gas permeability (oxygen permeability of 3000 to 11500 cm·m⁻²·4 h⁻¹, (1 atm at 23 °C) carbon dioxide permeability of 9800 to 30000, cm·m⁻²·4 h⁻¹ (1 atm at 23 °C) were tested. Phenylalanine ammonia lyase (PAL), polyphenol oxidase (PPO) and peroxidase (POD) activities, and phenolic compounds content were measured to relate them to overall visual quality, leaf edge browning and leaf surface browning. Enzymatic activities variability was related to lettuce type and packaging material permeability for O₂ and CO₂. In general, a low chlorogenic acid concentration and the best organoleptic quality was related to PD 900 packaging material, although leafy lettuce type had the highest chlorogenic acid concentration without quality losses by enzymatic browning. All leafy lettuce treatments packaged with multilayered polyolefins maintained consumer acceptability after 9 days of storage.

1340-1440

S09-P-99

A RESEARCH ON PROLONGING THE MARKETING PERIOD OF DRIED AND READY TO EAT TYPE FIGS (*FICUS CARICA* L.)

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Commercial fig drying is an important agricultural activity in the western part of Turkey. The region by itself provides 60% of the world trade. The research was carried out in 2000 and 2001 on inter-mediate moisture sun dried figs and rehydrated ready to eat type of fig fruits. After being sun-dried, figs were put in gas tight polyethylene packages. Some of the packages were heat sealed without any application as control, some of them were applied with vacuum whereas others were filled with N₂ or CO₂ (20% CO₂+ 80% N₂) after vacuum application. Another variable was cold storage (+4°C) versus ambient temperature conditions (20°C as the control parameter). Samples were derived at 45 days intervals and quality parameters as firmness (kgf), weight loss (%), dry weight (%), moisture content (%), water activity (aw), color (L, a, a/b), sugaring (%) and exudation (%) were analyzed. Dried figs were also rehydrated to 30% or higher moisture contents to prepare commercial packs for consumption as ready to eat. After rehydration, figs were put in gas tight polyethylene packages. Various package atmospheric compositions as air, N₂ or CO₂ (20% CO₂+ 80% N₂) were tested. The quality parameters as firmness (kg), weight loss (%), titratable acidity (g/100g), total soluble solids content (%), dry weight (%), water activity (Aw) and also organoleptic analysis such as taste, aroma and texture were performed at monthly intervals. The results proved that darkening of the fruit color and sugaring were the major quality attributes affected by the storage conditions. Vacuum applications are not recommended due to the exudation of the fruit juice.

1340-1440

S09-P-100

PREDICTING SHELF LIFE AND QUALITY OF RASPBERRIES UNDER DIFFERENT STORAGE TEMPERATURES

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'Killarney' raspberries were harvested twice at the full ripe stage and held for 7 days at 0, 5, 10, 15, or 20 °C. The objectives of this work were 1) to obtain quality curves for raspberries stored at different temperatures; 2) to identify, for each temperature, which quality parameter(s) limits raspberry marketability; and 3) to compare the quality curves and shelf-life of raspberries based on quality evaluations with those predicted by respiration rates reported in the literature. Raspberry weight loss, instrumental color (L*a*b*), visual color, firmness, shriveling, decay, taste and aroma were evaluated every day for a 7-day storage period. Darkening of the color was the primary limiting factor at 0, 5, 10 and 15 °C for raspberries from the first harvest, while darkening of the color, loss of firmness and objectionable aroma were simultaneously the primary limiting factors at 20 °C. For raspberries from the second harvest, darkening of the color, objectionable taste and aroma were simultaneously the primary limiting factors for fruits stored at 0 and 5 °C. Development of off flavor was the primary limiting factor for berries stored at 10 and 15 °C, and objectionable aroma was the primary limiting factor for those fruit stored at 20 °C. For each temperature, the shelf life of raspberries predicted based on the Q10 calculated from the respiration rates for raspberries found in the literature was on average 1 to 2 days longer at 0 °C, the same number of days at 10 and 20 °C and less than 1 day shorter at 5 and 15 °C when compared to the shelf life of raspberries obtained from quality evaluations. The quality curves obtained from quality evaluations for each temperature showed that a single quality attribute cannot be used to express loss of quality of raspberries over the normal physiological range of temperatures.

1340-1440

S09-P-101

QUALITY CHARACTERISTICS OF 'HORN OF PLENTY' AND 'MEDALLION' YELLOW SUMMER SQUASHES AS A FUNCTION OF THE STORAGE TEMPERATURE

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Two yellow summer squash cultivars, 'Horn of Plenty' and 'Medallion', were harvested from commercial fields in Homestead, Florida, and held for 14 days at 0, 5, 10, 15 or 20 °C (95 to 100% RH). The objective of this work was to obtain quality curves at chilling and non-chilling temperatures and to identify, for each temperature, which quality parameter(s) limits summer squash marketability. Quality characteristics of squash were assessed throughout the 14-day storage period by quantitative (weight loss, CIE-L*a*b*) and qualitative (visual firmness, shriveling, chilling injury symptoms, decay, and browning on abraded skin) evaluations. After 2 days at 0 or 5 °C both 'Horn of Plenty' and 'Medallion' showed minor symptoms of chilling injury such as surface pitting. Chilling injury symptoms rendered the squashes unmarketable after 5 days for 'Horn of Plenty' and after 3 days for 'Medallion' while all the other quality parameters evaluated remained acceptable. 'Horn of Plenty' squashes were less sensitive than 'Medallion' to chilling temperatures. At 0 and 5 °C, chilling injury and loss of firmness were simultaneously the primary limiting factors for 'Horn of Plenty' squashes, while for 'Medallion' chilling injury was the primary limiting factor. Loss of firmness was the primary limiting factor for 'Horn of Plenty' squashes stored at 10 °C and for 'Medallion' squashes stored at 10, 15 or 20 °C. Loss of firmness and development of browning on abraded surfaces were simultaneously the primary limiting factors for 'Horn of Plenty' squashes stored at 15 or 20 °C. However, pre-harvest factors related to high temperature in the field contributed to the development of 'warts' on the rind of 'Horn of Plenty' squashes, which reduced their shelf life at 10, 15 and 20 °C and masked the limiting factors.

1340-1440

S09-P-102

EFFECT OF SQUALENE ON CHILLING INJURY AND STORAGE QUALITY OF WHITE 'MARSH' GRAPEFRUIT

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The effect of squalene application on grapefruit chilling injury (CI) and maintenance of fresh fruit quality was studied in the 1999-2001 seasons. In the first experiment, all fruit were dipped with thiabendazole (TBZ) and Imazalil (IMZ). Six hours later, fruit were coated with squalene, wax (carnauba wax or polyethylene wax), or wax plus squalene. At 3 °C storage for 16 weeks, 20.7% of the fruit with squalene alone had chilling injury symptoms, but only 4.4 to 6.3% of the fruit with wax or squalene plus wax. At 10 °C storage, CI was zero except for the fruit treated with squalene, of which 4.3% had CI symptoms. Decay was close to zero after 16 weeks of storage in all treatments. However, after two further weeks of storage at 23 °C, decay increased to 5% in non-waxed fruit, approximately 2% decay in waxed fruit. In later experiments, attempts were made to identify which chemicals in the squalene formulation resulted in CI. Fruits were also treated with components of the squalene formulation (polysorbate or sorbitan). These studies showed that the squalene formulation resulted in the highest incidence of fruit with CI while fruit treated with sorbitan resulted in the lowest rate of fruit with CI. Surprisingly, all of the chemicals in the squalene formulation resulted in significant damage to fruit by CI after 10 weeks storage at 3 °C. Decay was generally lower than CI damage in all studies. The effects of squalene formulation on fruit shine, color development, weight loss, and internal gas concentrations are presented.

1340-1440

S09-P-103

POTENTIAL USE OF LYSOPHOSPHATIDYLETHANOLAMINE, A NATURAL LIPID, AS A POST-HARVEST DIP TO ACCELERATE RIPENING OF MATURE GREEN TOMATOES PACKED FOR FRESH MARKET

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Soluble solids content, titratable acidity, firmness, shelf life, color, and the rate of ripening are among the most important attributes to packers and brokers that determine tomato fruit value. Frequently, these qualities are compromised

due to weather, exposure to ethylene, shipping stress and maturity at harvest. Lysophosphatidylethanolamine (LPE) is a natural lipid present in cell membranes and found in high concentrations in egg yolk and soy lecithins. Recent studies demonstrate that LPE can add value to various fruits by enhancing desirable attributes. This study was conducted to determine the feasibility of improving ripening and quality of green tomatoes, in a commercial operation, using LPE. Tomatoes are harvested mature green (MG1-4) and exposed to ethylene prior to marketing. We used commercially harvested fruit. Fruit were dipped for 3 minutes in 50 ppm LPE solution added to the industry wash water pH 7 (plus sodium hypochlorite and ? acid). Control fruit were dipped in the same wash water alone. Fruit were dried, waxed and placed in ethylene chambers at 17 °C for 0, 2, or 4 days in a commercial setting. Ripening was monitored visually using the industry grading scale as well as a Minolta colorimeter. In general, LPE stimulated ripening of MG4 tomatoes with and without ethylene treatment. However, LPE had only moderate effect on MG1 and MG2 fruit, which required ethylene for stimulation of ripening. Ethylene is known to reduce tomato shelf life. LPE treatment reduced the ethylene requirement, improved fruit firmness, and mitigated some of the undesirable effects of ethylene. Our results show that LPE may be used as a post-harvest dip to accelerate ripening of mature green tomatoes packed for fresh market.

1340-1440

S09-P-104

EFFECTS OF MALEIC HYDRAZIDE AND TEMPERATURE ON ONION QUALITY DURING STORAGE

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In subtropical regions, loss of quality in onion bulbs (*Allium cepa* L.) is of great concern. Postharvest losses can be as high as 40% of total production or more and are due essentially to germination, decay, rooting and weight loss. Preharvest as well as postharvest factors such as temperature, humidity, cultural practices and growth regulators have been shown to affect onion quality postharvest. In this work we investigated the effect of foliar application of maleic hydrazide (MH) at 0, 3000, 6000 and 9000 ppm applied 15 days prior to harvest on quality of 'Rouge d'Amposta' onions during storage for 6 months at 3 °C, ambient temperature in a dark room and in traditional silos made with rock walls and straw. Dry matter content of the onions was in the range of 8-10% with no significant effect of either MH, temperature or method of storage (silo vs. ambient temperature). Weight loss was significantly inhibited by cold temperatures; germination was inhibited by MH and cold temperature; decay was reduced by cold temperature and MH; and rooting was reduced by MH but temperature effect was inconsistent. Aroma increased during storage with lower values at low temperature. After 6 months of storage, values of 72, 78 and 85 µmol of thiosulfinate/g dry matter were recorded, respectively, for storage at cold temperature, ambient temperature and traditional silo. MH had no effect on aroma. MH residues in the bulbs did not vary during storage but were always highest (4.3-5.0 ppm) for 9000 ppm and lowest (0.4-0.7 ppm) for 3000 ppm. The significance of these results for subtropical regions will be discussed.

1340-1440

S09-P-105

EFFECTS OF HYDROCOOLING ON RESPIRATION, GROWTH AND VITAMIN C CONTENT CHANGES IN SOYBEAN SPROUTS

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The practicality of hydrocooling soybean sprouts was tested. Soybean sprouts were precooled in 0 °C water for 1, 3, 5, 10, 30 min prior to storing at 4 °C, 12 °C and 20 °C, and resultant changes in respiration, growth and vitamin C content of sprouts were measured. Hydrocooling effectively decreased the sprout temperature (16.1 °C at harvest) down to 3 °C within 1 min and down to 1 °C within 3 min. Sprouts re-exposed to room temperature after hydrocooling exhibited slow temperature increase, indicating enough residual effects of hydrocooling required for sorting and packing prior to low temperature storage. Hydrocooling continuously decreased O₂ consumption and CO₂ production regardless of storage temperatures. Postharvest growth of sprouts, especially in root and total length of sprouts, were significantly suppressed by hydrocooling, while the length and thickness of hypocotyls were not affected. Hydrocooling longer than 1 min in-

duced no additional changes, suggesting 1 min of hydrocooling is enough for sprouts. Vitamin C content, a major nutritional factor of soybean sprouts, was not affected by hydrocooling. In conclusion, hydrocooling soybean sprouts for 1 min at 0 °C seems to be an effective method to enhance the shelf life and visual quality of soybean sprouts.

1340-1440

S09-P-106

EVALUATION OF QUALITY OF FRESH-CUT BUTTERHEAD LETTUCE IN PASSIVE AND ACTIVE MODIFIED ATMOSPHERE

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Fresh-cut lettuce is increasingly being used in salad bars and fast food restaurants in part because of the value added to the product during its preparation and delivery in a ready-to-eat condition. The primary factors of this added value are low temperature and modified atmosphere packaging. They are used to maintain freshness, extend shelf life, ensure safety and promote sale. This study was conducted to evaluate the effect of active and passive modified atmosphere with different temperatures on the keeping quality of fresh-cut 'butterhead' lettuce (*Lactuca sativa* L.). 'Butterhead' lettuce were harvested at the commercial maturity stage. External leaves were removed and the inner leaves selected, washed and packaged in multilayered polyolefin bags (PD 961-EZ) with passive and active (5% O₂, 5% CO₂) modified atmospheres. Bags were stored for 7 days at 1 °C, 7 °C and air temperature. Samples were taken for analysis at 0, 1, 4 and 7 days. The organoleptic evaluations included determination of visual quality and colour changes (a* value and hue angle). The O₂, CO₂ and ethylene concentrations in the packages were measured. Visual quality was not affected significantly in either modified atmosphere for every storage temperature. Colour changes of fresh-cut lettuce and ethylene concentration were similar in both modified atmospheres. Active modified atmosphere achieved O₂-CO₂ equilibrium after 24 h of storage period. Active and passive modified atmosphere at 1 °C were the best treatments in terms of keeping quality of fresh-cut 'butterhead' lettuce.

1340-1440

S09-P-107

POSTHARVEST LIGHT AFFECTS COLOUR DEVELOPMENT IN 'ROME' APPLES

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Red color is an important component of consumer acceptance of apples and is primarily a result of anthocyanins. We examined the effects of postharvest light quantity on the postharvest development of peel color. 'Rome' apples were bagged in the orchard during summer to obtain physiologically mature but anthocyanin-free fruit. Postclimacteric bagged fruit were harvested, and exposed to a gradient of light quantity from 0.5 to 50 $\mu\text{m} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ at 20 °C. The light source was continuous illumination with two 15 Watt cool white fluorescent lights. Color development was recorded every 2 days during storage. Color was correlated to anthocyanin production. The results showed that the quantity of light perceived by the apple peel is a strong determinant of color development. Apples receiving the most light produced the most anthocyanin, and in the quickest time. We related the rate of color change to the total level of light delivered. The results and implications of this experiment will be discussed in more detail.

1340-1440

S09-P-108

COLOUR OF RASPBERRY JAM AS INFLUENCED BY CULTIVAR, TEMPERATURE AND LIGHT DURING STORAGE

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Attractive red colour is one of the most important quality characteristics in raspberries for the processing industry. Fruit from four cultivars grown in the Oslofjord-area (59° 40'N) were used in the experiments. Jam was prepared from the cultivars 'Veten'- the most important cultivar for the Norwegian processing industry, 'Malling Admiral', 'Glen Ample' and 'Glen Rosa', the three latter being cultivars mainly for fresh consumption. The jam was stored for three months at 4 and 20 °C, in the dark and under fluorescent light (950 lux). The quality param-

eters assessed were mainly colour variables measured by means of Hunter L*, a*, b*, and reflectance measured at 400–700 nm, quantitative determination of total anthocyanin pigments, soluble solids and degradation index of pigments. The most important result, as evaluated by means of Principal Component Analysis (PCA), was obtained by storage at high and low temperature, explaining 50% of the total variation. Storage at 4 °C preserved the jam best. The second most important result were the differences between the samples as a result of pigment measurements, the L*-value and reflectance at 420 nm. Storage in light or dark surroundings did not affect the colour of the jam after three months of storage. Good correlation between measurements of pigments and reflectance at 420 nm, as measured by HunterLab was found, ($r = -0.78$). Optical colour measurements in raspberries should therefore be performed at 420 nm. The Norwegian cultivar 'Veten', had the highest amount of pigments, followed by 'Malling Admiral', 'Glen Rosa' and 'Glen Ample'.

1340-1440

S09-P-109

FRUIT SOFTENING AND HEAT TREATMENT OF PAWPAW FRUIT

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Pawpaw [*Asimina triloba* (L.) Dunal] is a highly perishable fruit, softening rapidly once ripening commences which may limit its marketability. Three enzymes—pectin methylesterase (PME), polygalacturonase (PG), and cellulase (CL)—are active during pawpaw fruit softening. PME activity is high at the earliest stages of ripening and declines as ripening proceeds. PG activity is not evident until fruit firmness begins its precipitous decline, peaks at mid-ripening, and declines in the later stages of ripening. CL activity also is not evident until softening starts but increases through late ripening. Heat treatment at 42, 46, and 50 °C for 15, 30, and 60 min delayed the loss of firmness, measured both externally and on the interior tissue. Respiration, but not ethylene production, was also reduced by heat treatment. Treatment at 50 °C for 30 and 60 min resulted in tissue injury, indicated by rapid skin darkening when it was returned to room temperature. The effects of heat treatment on the enzymes responsible for fruit softening will be discussed.

1340-1440

S09-P-110

POSTHARVEST QUALITY OF ARAZA FRUIT (*EUGENIA STIPITATA* MC VAUGH) TREATED WITH CALCIUM CHLORIDE SOLUTIONS AT TWO TEMPERATURES

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Arazá (*Eugenia stipitata* Mc Vaugh) fruit, harvested in mature-green stage, were treated with calcium chloride solutions (0, 0.36 and 0.72 mol·L⁻¹) at two temperatures (4 or 15 °C). Fruit were subsequently stored in air at 12 °C and 90% relative humidity for 2 weeks with or without an additional shelf-life period (3 days at 20 °C, 70% relative humidity). Shriveling increased during storage and the shelf-life periods without noticeable differences among treatments. Both calcium chloride treatments increased surface injuries but did not delay fruit softening, while control fruit did not develop surface injuries after storage or the shelf-life periods. The calcium concentration within the epidermal tissue increased at higher temperature or dip concentration, ranging from 0.065 ppm in control fruit to 2 to 3-fold more in fruit dipped with calcium chloride. Both treatments, particularly 0.36 mol·L⁻¹ calcium chloride at 4 °C, delayed ripening changes at 12 °C as indicated by better retention of sugars (mainly sucrose and fructose) and organic acids (malate and succinate). Anthracnose and, to a lesser extent, other diseases were exacerbated by calcium chloride treatments at 4 °C. Ascorbic acid decreased during the storage and upon transferring to shelf-life periods by 25%, but to a lesser extent in fruit treated with dips at 15 °C. In summary, calcium chloride treatments cannot be recommended because of surface injuries that were not alleviated by low temperature dips. Retention of malate and succinate levels was also higher in dips at 15 °C. In summary, calcium chloride treat-

ments cannot be recommended because of surface injuries that were not alleviated by low temperature dips. However, low temperature calcium chloride dips could be a promising treatment in order to retain overall internal fruit quality and modulate calcium absorption by the fruit.

1340-1440

S09-P-111

COLOUR DEVELOPMENT OF ARAZÁ FRUIT AS RELATED TO MODIFIED ATMOSPHERE PACKAGING

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Mature-green arazá (*Eugenia stipitata* Mc Vaugh) fruit were stored in air, or in macroperforated and unperforated low-density polyethylene (LDPE 38 micras) film bags at 7 or 10 °C to test the effects of modified atmosphere packaging (MAP) on fruit color development. Unperforated bags were also actively modified with 2% CO₂ and 21% O₂. Storage times were 15 d for treatments at 10 °C or fruit stored in air at 7 °C, or 20 or 25 d for fruit stored in macroperforated or unperforated bags at 7 °C, respectively. Fruit from all treatments were kept for a shelf-life period of 3 d at 20 °C in open bags. Steady state atmospheres were not reached in unperforated bags probably due to the onset of respiration within the bags. Atmospheres in active or passive bags at both temperatures were always above 6% O₂ and below 9% CO₂. Respiration showed a maximum value after 10 d in air at 10 °C (1880 mgCO₂, kg-1h-1) or after 6 d at 7 °C (3500 mg CO₂, kg-1h-1). Only arazá fruit at 7 °C in air or in macroperforated bags showed chilling injury symptoms (skin scald, inhibition of color development and increased susceptibility to anthracnose during the shelf-life period). Either MA reduced weight loss and extended fruit storage life particularly in nonperforated bags. Color changes during ripening were characterized by decreased Hue angle and increased chroma and lightness values. As expected, color changes were more noticeable at higher temperatures. Lightness linearly increased during storage and the shelf-life periods only at 10 °C, irrespective of the treatments used. Chroma values increased during storage in macroperforated bags at 7 °C compared with storage in air. After 1 week at 10 °C, either active or passive MA slightly delayed fruit color development as related to higher Hue angle values.

1340-1440

S09-P-112

QUALITY IMPROVEMENT IN FRESH-CUT TOMATO UNDER ACTIVE AND PASSIVE MAP

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Selected long-life 'Calibra' tomatoes, based on colour (65-78°Hue) and defect-free, were minimally fresh-processed into slices in a clean room at 5 °C. Tomatoes were washed in chlorinated (100 ppm) water, ambient air-drained and cut into slices of about 0.7 cm thickness. Slices were packaged in polypropylene (PP) trays heat-sealed with a 35 µm PP film. As a control, a macroperforated (9 holes of 0.7 mm diam(?) on 210 cm²) PP film was used. Packages were stored under passive and two active (3% CO₂ + 97% N₂ or 4% CO₂ + 3% O₂ + 95% N₂) modified atmosphere packaging (MAP) at 5 °C up to 14 days. Fresh-cut tomato was evaluated at harvest and after 14 days. Changes in gas composition within packages, microbial counts and sensorial and chemical quality attributes were evaluated. At the end of storage, gas composition was 10% O₂ and 12% CO₂ in passive MAP, while it reached 9% O₂ and 8% CO₂ and 6% O₂ and 9% CO₂ in active MAP, respectively. The level of C₂H₄ accumulated under passive MAP conditions (12 ppm) was double that under both active MAP treatments. Compared with control, MAP reduced microbial counts. After 14 days all treatments were safe, showing levels <105 CFU/g for Total Plate Count, <103 CFU/g for yeasts and <102 CFU/g for moulds. Based on sensorial quality evaluation, control tomato slices were unsuitable for consumption. Meanwhile slices under all MAP treatments kept their visual appearance, overall quality and texture, and

although a fair flavour was found, they were acceptable for commercial purposes.

1340-1440

S09-P-113

EFFECT OF POSTHARVEST HOT WATER TREATMENT, POLYETHYLENE BAG PACKAGING AND LOW TEMPERATURE STORAGE ON "SEMSORY" MUSKMELON FRUIT SUGAR CONTENT

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Several authors have reported that in muskmelon fruit the total sugar content does not increase after harvest and they suggest the fruit must be harvested at full ripe stage to obtain high sugar content. But full ripe fruit are very sensitive to postharvest losses. A study was conducted to determine if a noticeable increase in total sugar content (TSC) might occur after harvest in Iranian "Semsory" muskmelon fruit. Muskmelon fruit (*Cucumis melo* L. Group reticulatus, Cv. Semsory), harvested at first stages of yellow color development on fruit skin, were immersed in 55 °C hot water for 3 min. and or in 59 °C hot water for 2 min. and were placed in 10 µm and or in 30 µm Low Density polyethylene bags (4 fruit in a bag) and were stored at 2.5 °C or at 5.5 °C for 33 days followed by one day at 20 °C. Control fruit, that had not been treated with hot water nor been packaged in polyethylene bag, had a noticeable decrease in sugar content while fruit treated with hot water and packed in polyethylene bags showed a noticeable increase in TSC. Increase in fruit TSC was high in those stored at 2.5 °C and TSC reduction in control fruit was high in those stored at 5.5 °C. Hot water treatment alone or polyethylene bagging was effective in retaining fruit TSC. The combination of these two factors with the lower storage temperature was the most effective treatment. The 30 µm-thick polyethylene bag was more effective than the 10 µm thickness. The difference between the two hot water treatments was not significant. We found that under controlled conditions we can improve "Semsory" muskmelon fruit sugar content and consequently edible quality after harvest and we can harvest it at early stages of ripeness to be less sensitive to postharvest losses.

1340-1440

S09-P-114

POSTHARVEST TEMPERATURE AFFECTS COLOUR DEVELOPMENT IN 'ROME' APPLES

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Color is an important component of consumer acceptance of apples. We examined the effects of postharvest temperature on the postharvest development of peel colour. 'Rome' apples were bagged in the orchard during summer to obtain physiological mature but anthocyanin-free fruit. Postclimacteric bagged fruit were harvested, and exposed to a range of temperatures (-2, 0, 5, 10, 15, 20, 25, 30 and 35 °C). All fruit received the same continuous quantity and quality of cool-white fluorescent light to simulate anthocyanin production. Colour development was recorded every 2 days and ethylene production measured periodically during storage. Colour was correlated to anthocyanin production. The results showed that temperature is a very important component of color development in apples. Optimal colour development occurred at 20-25 °C, whilst at lower temperatures, colour development was significantly slowed. At higher storage temperatures (30 °C) anthocyanin accumulation was retarded, whilst at 35 °C, anthocyanin accumulation was completely prevented.

1340-1440

S09-P-115

QUALITY CHANGES OF PLEUROTUS OSTREATUS DURING MODIFIED ATMOSPHERE STORAGE AS AFFECTED BY TEMPERATURE AND PACKING MATERIAL

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Since Oyster mushroom (*Pleurotus ostreatus*) has experienced a continuous increase in fresh market sales, many methods have been examined to improve quality and extend shelf life during marketing. In order to study the effect of modified atmosphere package on keeping quality of oyster mushroom, whole mushrooms (200 g) were packaged with polyethylene film (PE, 60*µm), ethylene vinyl

acetate (EVA, 2%) and ceramic film (containing zeolite 5%), and were stored at 0, 5, 10, 20 °C. Weight loss, color, hardness, ethanol content, respiration rate, gas composition (O₂, CO₂) inside the package, microorganism, and sensory evaluation of MA-packaged mushrooms were examined. Mushrooms packed with conventional hardboard box (2 kg) lost marketability at an early of storage due to weight loss, shrinkage, browning and spore formation. The shelf life of oyster mushroom was about 8-11 days at 0 °C, about 4-6 days at 5 °C, about 2-3 days at 10 °C and about 1-2 days at 20 °C. During storage, film packaging could prevent or retard the deterioration of the mushroom in terms of appearance, texture and discoloration. This result may be due to the reduced respiration rate resulting from the elevated level of carbon dioxide and the reduced level of oxygen in the bag. At a constant temperature, ethanol production in the tissue increased slightly early in storage and rose considerably toward the end of the storage period. The ethanol content in oyster mushroom was higher in the stipe than in the pileus.

1440-1500

S09-O-116

ETHYLENE, ABA, AND 1-MCP IN FLOWER SENESCENCE AND ABSCISSION

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The wilting and abscission that results from exposure of flowers to ethylene is now commercially controlled by application of 1-MCP. However, only some floricultural crops show 'ethylene-dependent' senescence. For many others, natural senescence appears to proceed independently of the action of ethylene, so that 1-MCP has a minimal effect on the natural longevity of the flowers. Daffodil (*Narcissus pseudonarcissus* L.) is a good example of this latter response. Daffodil flowers held in air last almost as long as 1-MCP-treated flowers, but when they are exposed to low concentrations of ethylene (as little as 30 ppb), they senesce prematurely. Daffodil flowers treated with ABA also senesce rapidly, but senescence is not prevented by 1-MCP pre-treatment. Senescence of *Alstroemeria* flowers is associated with water-soaking of the petals and petal abscission. Treatment with ABA stimulated both these responses. Although 1-MCP pre-treatment prevented petal abscission in ABA-treated flowers, it was unable to delay the acceleration of water soaking. Treatment with 1-MCP allows the separate roles of ABA and ethylene in flower senescence to be distinguished.

1500-1520

S09-O-117

EFFECT OF 1-METHYLCYCLOPROPENE (1-MCP) ON PEAR MATURITY AND QUALITY

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Argentina is the most important pear (*Pyrus communis*) producing country of South America, with 'Williams' being the most widely planted pear, followed by 'Packham' and then by 'Beurre D'Anjou'. The potential for commercial application of 1-methylcyclopropene (1-MCP), an ethylene inhibitor, to maintain the quality of 'Williams', 'Beurre D'Anjou' and 'Packham' pears under cold storage conditions was investigated. The 1-MCP gas concentrations used were 0, 10, 100, 200, 400, 600 ppb, generated from measured amounts of SmartFresh powder. Fruit from each cultivar was removed from storage at 4 week intervals during 16 weeks, and evaluated after 1, 7 and 14 days at 20 °C. 1-MCP treatment slowed loss of firmness, titratable acidity, color changes and prevented development of several physiological disorders. These effects were concentration dependent: 10 ppb was not enough to delayed ripening, but 100, 200, 400 and 600 ppb prevented ripening. 'Williams' pears developed optimal quality in each evaluation, but required nearly 20 days when the fruit treated with 400 or 600 ppb was stored for a short period (90 days). Late harvested 'Williams' required higher 1-MCP concentrations to maintain fruit firmness, acidity and green color. When 1-MCP treatment was delayed for more than 20 days, very little or no response occurred. Retreating 'Williams' after 30 and 60 days showed some response when pears were treated at harvest with 100 ppb, but not when they were treated with 10 ppb. Treatment of 1-MCP with 400 and 600 ppb concentrations inhibited the normal ripening capacity of 'Anjou' and 'Packham' when stored for less than 7 months. 1-MCP was very effective in preventing the development of scald in 'Anjou' and 'Packham'. The results indicate that the efficacy

of 1-MCP is affected by the concentration used, the maturity of the fruit before application and the length of storage.

1520-1540

S09-O-118

THE ROLE OF 1-MCP IN THE EXPORT OF TROPICAL CROPS

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In the 98-99 season, Mexico exported 66% of vegetables and 19% of fruits of the total fresh produce imported to the USA. Growers are looking for new markets continuously. Reaching new distant markets (Europe and Asia) will depend on maintaining quality of the produce. To achieve that goal, SmartFresh® (1-MCP) effect on the quality and shelf-life of main exported crops was tested. Our main work focused on mangos, papayas, avocados, melons, tomatoes, peppers, and cucumbers. Different cultivars, doses, time of exposure, maturity stages, decay susceptibility, a combination of ethylene/1-MCP/wax either before or after each other, and storage temperatures were followed. Semi-commercial tests tied with growers, packinghouses and brokers are on-going trials. Data include physical, chemical, physiological, biochemical and decay incidence. Results on mango indicated a different response after 12 hr exposure on Kent and Keitt varieties. Rates of 180 ppb on Keitt were able to maintain firmness up to 5 days, without changes on flavor. Papaya fruits were more responsive to 12 hr 1-MCP treatment and clearly demonstrated inhibition of PG and Cx activity at rates up to 250 ppb and correlated with firmness. Works on tomato had been more intensive. 500 ppb of 1-MCP applied for 12 hr at green stage tomatoes was able to delay ethylene peak for 15 days, maintaining its firmness and green color until that time, reaching full red color by the 24th day. Roma tomatoes treated at breaker stage with 125, 250 and 500 ppb rates delayed maturity for 5, 7 and 9 days, respectively. Exposed turning Roma tomatoes for different times and rates showed better response at 500 ppb for 6 hrs. Greenhouse tomatoes applied at pink and light red stages for 24 hr at 500 ppb maintained color and firmness up to five days. Combination treatments (ethylene/1-MCP/wax) on cucumbers demonstrated the benefits on delaying yellowing and maintaining quality. The opportunity for fruit and vegetable growers to reach distant markets with the quality that consumers demand will be on hand with this novel technology.

1540-1600

S09-O-119

CREATIVE APPLICATIONS OF 1-METHYLCYCLOPROPENE

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1-Methylcyclopropene (1-MCP) has been extensively researched for postharvest applications on a diversity of crops. In previous studies we have shown that the rate of change in tomato color at all stages of ripening can be retarded with 1-MCP vapor treatment. Based on these responses, we evaluated the efficacy of pre-harvest applications of 1-MCP to concentrate fruit ripening and reduce the number of harvests in greenhouse grown tomatoes. An aqueous solution of 1-MCP was sprayed on 'Laura' tomato plants when approximately 5% of the fruits were at turning and a relatively large proportion of the remaining fruits (50-60%) were at mature green stage. A single spray of 1-MCP at this stage while delaying the ripening of MG and past MG fruits did not seem to affect the growth, development and ripening of immature fruits. The number of harvests was reduced from 6 in control to 1 in 1-MCP-treated plants. Fruit cracking was reduced by 60% with in the treated fruits. The crop cycle seemed to be unaffected by single spray of 1-MCP. The data collectively suggests that preharvest spray of 1-MCP may improve packout and reduce cost of greenhouse-produced tomatoes.

1600-1620

S09-O-120

SUCCESSFUL APPLICATION OF 1-MCP IN COMMERCIAL STORAGE FACILITIES

Edward Kostansek*

Agro-Fresh Inc., PO Box 904, Spring House, PA, USA, 19477-0904

The ripening, aging and eventual decay of many fruits and vegetables is con-

trolled by the simple plant hormone ethylene. Ethylene is produced by the plants themselves and is also found in the environment. AgroFresh Inc., a Rohm and Haas Company, is developing a technology to modulate the effects of ethylene. This unique technology works by diffusing parts per billion levels of 1-methylcyclopropene (1-MCP) in a storage room to make fruit less susceptible to the damaging actions of ethylene. The result is that freshness is maintained, which translates to higher quality produce for the consumer. In the case of apples, 1-MCP is released inside standard apple storage rooms using a proprietary delivery system. It is important to release 1-MCP completely and to diffuse the product uniformly and efficiently in a commercial environment. We have successfully treated commercial apple storage rooms as large as 3500 cubic meters (1 million kg of apples). This paper discusses the treatment technology, procedures used in the application of the product, and results of 1-MCP release and diffusion experiments in both the lab and commercial storage facilities.

1620-1640

S09-O-121

APPLES . . . AND BEYOND: FUTURE GOALS FOR SMARTFRESH

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In 2002, AgroFresh, Inc. commercially introduced SmartFresh' (1-methylcyclopropene) a new innovative postharvest tool for use in apples. SmartFresh' will be used by apple storage operators to maintain high quality during cold storage and the market life of their fruit. AgroFresh, Inc. is also actively developing use concepts in pears, avocado, tomato, melons, papaya and mango with emphasis on improving quality and market life. For example, tomato harvest can be delayed from the traditional green ripe stage to a pink stage which will improve quality, and SmartFresh' will delay ripening to provide sufficient time to transport and market the fruit. Active research programs are underway in banana, persimmon, stone fruit, Kiwifruit, green vegetables and exotic tropical fruits. SmartFresh' in combination with MA packaging has shown promise for extending the market life and quality of vine and tree ripe fruits and green vegetables. Also SmartFresh' holds promise for extending the market life of fresh cut melons and tropical fruit when applications are made to the whole fruit. These and other product concepts for SmartFresh' will be discussed in greater detail.

1640-1700

S09-O-121-A

TO BE ANNOUNCED

Thursday · August 15

1100-1120

S09-O-122

DETERMINING TISSUE DAMAGE USING MACHINE VISION TECHNOLOGY

Y. Luo*

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Tissue damage of fruits and vegetables during fresh-cut product preparation is a major factor of quality deterioration and shelf life loss. Developing a fast, accurate, and simple measurement of the tissue damage is highly needed for the fresh and fresh-cut fruit and vegetable industries to optimize harvesting, postharvest handling, and fresh-cut processing operations. This presentation describes a method developed to quantitatively measure tissue damage using machine vision technology. Images of damaged and not damaged tissues were acquired through a digital camera or video camera. The damaged areas and intensity were analyzed using the Image-Pro software program based on color differences of the damaged and not damaged tissues. For the samples showing no color difference between the damaged and not damaged, the tissues were stained by browning substrates via an accelerated browning reaction, followed by image analysis. Various fruits and vegetables were tested and this method proved to be fast, accurate, and easy to use. A series of browning substrates were tested for their usefulness in this method, and the results will be presented.

1120-1140

S09-O-123

VIS/NIR SPECTROMETRY TO PREDICT FRUIT RIPENESS

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A recently developed, non-invasive sensor based on spectral/optical technology (400 nm to 1100 nm) can be used to predict the fruit chlorophyll content, which provides a valuable information on the fruit ripeness stage. A potential benefit achieved from the fruit chlorophyll prediction is determination of the optimum harvest date and to non-destructively analyse the physiological fruit age during shelf life. Experiments were carried out on apples during 1999-2001 at 3 fruit growing locations (Jork and Werder, Germany; Skierniewice, Poland). The spectral-optical readings were carried out in freshly harvested 'Elstar' and 'Jonagold' apples. As a reference destructive measurements on SSC, starch and fruit firmness were applied. Apple ripeness stages can be predicted with a standard error of cross validation of 6 days using the spectral data. A second application was developed to discriminate bananas in different ripeness stages, which are commonly used commercially in the market. This apparatus will be shown during the presentation.

1140-1200

S09-O-124

FRESH CABBAGE SENSORY QUALITY: COMPONENTS AND THE IMPACT OF PRODUCTION FACTORS

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Strong anecdotal evidence suggests that sensory quality is a primary driver of consumer acceptance of fresh cabbage (*Brassica oleracea* var. capitata). Yet, little is reported about the extent to which individual components of fresh cabbage sensory quality contribute to consumer acceptance or how sensory quality may be influenced by major production factors. In 1999, we initiated a series of studies to address these gaps in the literature. Our goal has been to better understand mechanisms driving cabbage sensory quality, in part to develop production systems which maximize it. Results from 1999 and 2000 strongly suggested that cultivar and planting date impact perceptions of overall fresh cabbage sensory quality. Unstructured evaluation of forty varieties of spring- and summer-planted cabbage by a small number of experienced tasters showed a wide range in various traits among the samples. In 2001, twenty-one experienced but untrained panelists were asked to rate plain samples of 26 cultivars planted in May and June at the OARDC Vegetable Crops Research Branch in Fremont, OH. Panelists scored the overall desirability of samples and their acceptability based on flavor, aroma, texture, and color. Linear scales were also used to quantitatively describe flavor and texture components (hot, sweet, bitter, crisp) relative to a known reference (cv. Bravo) which was also included as a sample. Panelists correctly identified the reference and detected distinct quality differences among the cultivars. More importantly, multiple regression analysis revealed that variation in flavor acceptability explained 75% of the variation in overall sample desirability, while texture, aroma and color collectively explained less than 10% of the variation in overall sample desirability. The importance of individual flavor components varied with planting date. To our knowledge, this is the most comprehensive explanation to-date of the contribution of specific quality components and major production factors to fresh cabbage sensory quality.

1200-1220

S09-O-125

HEAT-SHOCK REDUCES WOUND-INDUCED TISSUE BROWNING IN FRESH-CUT LETTUCE BY REDIRECTING PROTEIN SYNTHESIS

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Wounding (e.g., fresh-cut lettuce) causes the production and propagation of a signal that induces the de novo synthesis of enzymes associated with phenolic metabolism, the accumulation of phenolic compounds, and subsequent

tissue browning. An important enzyme in stress-induced phenolic metabolism is phenylalanine ammonia-lyase (PAL, EC 4.3.1.5). Two wound-induced PAL mRNA appear after wounding and before the rise in PAL activity, and give rise to the synthesized PAL. A brief heat shock (45 8 °C for 90 sec) administered either before or after wounding suppresses the de novo production of PAL and tissue browning. The induced synthesis of specific heat-shock proteins (hsps) correlates with the reduced induction of PAL synthesis. The hsps synthesized in response to a number of stresses are thought to protect the cell from subsequent stresses. However, the exclusive production of hsps in relation to other proteins (e.g., wound-induced PAL) may itself be important. These data supply additional support for the hypothesis that the induced synthesis of hsps interferes with the translation of wound-induced PAL mRNA and thereby prevents tissue browning

1220-1240

S09-O-126

DOWN REGULATION OF ETHYLENE PRODUCTION IN APPLES

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Apples are an important agricultural commodity in the world. Most apples are produced for the fresh market and have to be stored under controlled atmosphere conditions to avoid softening. The softening of fruits is the result of structural changes in the cell walls. These structural changes are caused by the hydrolytic activity of such enzymes as polygalacturonase, cellulase and the diverse hemicellulases that are under the control of the ripening hormone ethylene. Ethylene is synthesized in plants from S-adenosyl-L-methionine by a short pathway that consists of two enzymes: 1-aminocyclopropane-1-carboxylic acid synthase (ACS) and 1-amino-cyclopropane-1-carboxylic acid oxidase (ACO). To interfere with ethylene synthesis in plants we have cloned two ACS genes from ripening 'McIntosh' apples. The gene showing the closest similarity to the ripening-related ACS gene in other fruits was used to make antisense constructs. 'Royal Gala' plants were transformed with these antisense constructs using an Agrobacterium-mediated transformation system. Transgenic plants were propagated on antibiotic-containing agar, transferred to the green house for conditioning, and later to the field. Transgenic 'Royal Gala' fruits which developed on these trees were evaluated for morphological characteristics, ethylene production, ACS activity and ripening parameters in the presence and absence of 1-methylcyclopropane (1-MCP) and ethylene. Data indicate down regulation of ethylene production and softening was achieved in some transgenic lines. 1-MCP (1 ppm, 24 h, 0 °C) completely prevented the development of any ethylene formation in transgenic 'Royal Gala' apples. Ethylene treatment (50 ppm, 3 h, 21 °C) did not affect the eventual onset and magnitude of ethylene formation in transgenic fruits.

1340-1440

S09-P-127

BANANA RIPENING: SUPPORTING THE ART WITH SCIENCE

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Banana ripening has developed over the years, from empirical observations by commercial ripeners of the effects of temperature and ethylene, to scientific studies of the postharvest physiology of this crop. While we have a good understanding of delaying or advancing banana ripening through manipulating ethylene, temperature and atmospheric oxygen and carbon dioxide, the industry is still facing a number of issues that result in disappointing commercial quality of banana. In particular, ripe life in the home is often very short, in the order of 3 days. Visual quality can be poor and dull in response to climatic stresses such as low temperatures in the field (in some production areas in Australia and Israel for example), excessive cloud cover and stormy weather. This paper will discuss postharvest management strategies that can be used to overcome these issues, including improved temperature management during ripening, using the anti-ethylene agent 1-MCP and modified atmospheres.

1340-1440

S09-P-128

CARBOHYDRATE CHANGES DURING FLOWER SENESCENCE OF EASTER LILY

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Flowers are composed of various organs which are at various developmental stages. In *Lilium*, changes in carbohydrates during flower development have not been investigated. Therefore, this research was initiated to examine changes in ethanol soluble carbohydrates and cell wall neutral sugar composition in various floral organs during tepal senescence of *L. longiflorum*, Easter lily flowers. Tepals began to lose their firmness and creamy-white color 6 days post-anthesis, turned brown (necrosis) 8 days post-anthesis, and flowers were considered senesced 11 days post-anthesis. Tepal fresh weight increased during the first 2 days after anthesis. However, the fresh weight of the stigma and ovary increased relatively slowly, reaching a maximum 7 days after anthesis. Exudate was produced beginning 4 days post-anthesis. Ethanol soluble (70%; v/v) carbohydrates and cell wall-related, non-cellulosic neutral sugars of various floral organs and floral exudates were analyzed. Glucose was detected during tepal senescence; however, sucrose was not. Arabinosyl and galactosyl residues were only detected in polysaccharides from exudates produced at latter stages of flower development. In tepals, soluble glucose level decreased, while sucrose and fructose levels increased immediately after anthesis and then decreased. The level of soluble sucrose of anthers was highest 2 to 3 days post-anthesis. On the contrary, the level of glucose and fructose reached their lowest levels, thus limiting available carbon sources in anthers after anthesis. The xylosyl, galactosyl, rhamnosyl, non-cellulosic glucosyl, mannosyl, and arabinosyl contents of cell wall materials decreased by 50% 3 days post-anthesis. Galactose content was the major cell wall neutral sugar component, and remained the highest compared to other cell wall sugar residues, during the entire period of flower bud development.

1340-1440

S09-P-129

ETIOLOGY AND PHYSIOLOGY OF STAIN, A 'FUJI' APPLE PEEL DISORDER

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Stain is a peel disorder of 'Fuji' apples that usually develops during storage. The disorder typically occurs on the blush side of fruit often at the margin of sunburn. Stain appears to be induced by sunlight as bagging reduces the incidence of stain. To determine when the injury leading to stain occurs, fruit were bagged at 14-day intervals from July through October, then bags were removed 14 days later. All fruit were harvested in late October and stored at 0 °C. The incidence of stain decreased relative to non-bagged fruit in fruit bagged in late September and October. Exposing fruit to UV-B light under laboratory conditions can induce stain-like symptoms. Fruit harvested at 14-day intervals from July through October, exposed to UV-B light then stored at 0 °C developed the most stain when harvested in late September and October. The development of stain following postharvest UV-B treatment is temperature dependent. Stain incidence increased as storage temperature decreased following postharvest UV-B treatment. A postharvest dip in 2 or 4% CaCl₂ or infiltration with 2% CaCl₂ significantly reduced stain during air storage. Other treatments (DPA, AVG, 1-MCP, methyl jasmonate) do not consistently reduce stain development. Storage in low O₂ (1-2 kPa) with up to 5 kPa CO₂ reduces stain development compared to fruit stored in air.

1340-1440

S09-P-130

PEROXIDASE ACTIVITY AND TOLERANCE/SUSCEPTIBILITY TO SUPERFICIAL SCALD DEVELOPMENT IN APPLES

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Superficial scald is believed to result from a deficiency in the antioxidant status/function of apples. To alleviate health concerns associated with the present scald-prevention method that involves dipping or drenching apples with a solution of diphenylamine, potential biochemical prediction strategies were explored. Peroxidase (POX) is a very common enzyme that can be detected with ease and rapidly. A tissue-printing method was developed to qualitatively determine the POX activity in the skin and hypodermal regions of apple fruits. Several common scald-susceptible apple varieties that included McIntosh, Red Delicious, Cortland and Idared, and scald-resistant varieties such as 'Empire', 'Gala' and 'Mutsu', were evaluated for POX reaction. In general, POX reaction resulted in the development of a near perfect ring of colour with varying intensities in the scald-resistant varieties, with 'Empire' showing the maximum intensity. By contrast, scald-susceptible varieties such as 'McIntosh', 'Cortland' and 'Idared' showed very weak POX reaction. The results were quite variable in 'Red Delicious', with fruits from some orchards showing high intensity of POX reaction. Apples showing colour development in the form of an intense ring was projected to possess resistance to superficial scald development. On this hypothetical basis, 'Red Delicious' and 'McIntosh' apples from over 40 orchards and from two seasons were evaluated for their predicted future scald development soon after harvest, and actual scald development after storage in air at 2 °C for four months. A positive correlation was observed between the POX reaction and resistance to superficial scald. Because of high variation, this technique could not be recommended as a reliable prediction strategy for superficial scald. Nevertheless, any technique that can increase the POX activity may potentially reduce the development of superficial scald.

1340-1440**S09-P-131****DEVELOPMENTAL REGULATION OF PHOSPHOLIPASE D IN TOMATO FRUITS**

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The catabolism of phospholipids, initiated by phospholipase D (PLD), is an inherent feature of developmental processes that include fruit growth and ripening. In cherry tomatoes, PLD activity increased during fruit development, which peaked at the mature green and orange stages. An increase in the activities of both soluble and membrane-associated forms of PLD could be noticed at these stages. The increase in PLD activity was associated with a similar increase in the intensity of a 90 kD band as demonstrated by Western Blot analysis using rabbit polyclonal antibodies raised against castor bean PLD. A full-length cDNA having 2430 bp and encoding a putative polypeptide with 809 amino acids, was isolated using tomato RNA, RT-PCR and 5' and 3' RACE. With the help of a transfer vector pBIN-mgfp5-ER, and a two-kilobase PLD cDNA fragment inserted in the antisense orientation between a CamV 35 S promoter and NOS terminator, tomato cotyledons were subjected to *Agrobacterium*-mediated transformation, tissue culture and selection of transformed plants in the presence of kanamycin. Transgenic plants obtained from "microtom" tomatoes were essentially similar to untransformed plants and set fruit as usual. The leaves and unripened fruits of transgenic microtom plants possessed lowered PLD activity and PLD protein as demonstrated by Western blotting. However, during ripening, PLD activity in the transgenic fruits increased just as in the control, which did not provide any added protection to membrane deterioration and the shelf life. This suggests that PLD gene expression is activated during the initiation of ripening and constitutive expression of the antisense PLD cDNA is unable to keep pace with it. The ripening characteristics of other transgenic tomato varieties are being evaluated.

1340-1440**S09-P-132****CONTROLLED ATMOSPHERE STORAGE REDUCES SCALD DEVELOPMENT IN 'GRANNY SMITH' APPLES**

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In this study, the effects of controlled atmosphere (CA) storage on scald development and postharvest quality of 'Granny Smith' apples (*Malus x domestica*

Burkh.) grown in Antalya, Turkey were investigated. The apples were harvested at optimal harvest time and stored in 1% CO₂ + 2% O₂; 2% CO₂ + 2% O₂ and 3% CO₂ + 2% O₂ at 0 °C and 90% relative humidity for nine months. At certain intervals samples were collected from each storage condition for physical and chemical analyses (e.g. weight loss, flesh firmness, amount of titratable acid, total percent soluble solids, skin color, scald development and decayed fruit). The percentage of scald was significantly lower in CA-stored apples than those stored in normal atmosphere. Apples subjected to CA were firmer and had substantially higher titratable acids and soluble solids than apples stored in air. CA-storage delayed the loss of chlorophyll and yellowing of the skin and also reduced incidence of decay. Flesh firmness, soluble solids, titratable acids, skin color and amount of decay were not different among tested CA concentration levels. No fruit injury or off-flavor production resulted in CA-storage.

1340-1440**S09-P-133****INVOLVEMENT OF THE ALTERNATIVE OXIDASE (AOX) IN SUPERFICIAL SCALD IN APPLE: ISOLATION AND SEQUENCE ANALYSIS OF THE APPLE AOX1 CDNA**H.P.V. Rupasinghe¹, K.C. Almquist¹, G. Paliyath², T.E. Elthon³, D.P. Murr⁴, A.C. Purvis⁵

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The alternative respiratory pathway in mitochondria provides a protective role against oxidative stress in preventing the generation of reactive oxygen species by avoiding over-reduction of the electron transport chain. We hypothesized that higher electron partitioning to the alternative respiratory pathway in apple (*Malus x domestica* Borkh) fruit could lead to resistance against development of superficial scald in apples during low temperature storage. As a first step in understanding the role of the alternative oxidase (AOX) in apple, a putative AOX gene was cloned and sequenced from the skin tissue of apple fruit. The cDNA clone (AOX1) contained an open reading frame of 1020 nucleotides encoding a putative protein of 340 amino acid residues. In comparison to AOX proteins found in other higher plants, the predicted amino acid sequence of apple AOX showed its highest degree of identity with proteins from *Vigna unguiculata* (71%), *Mangifera indica* (70%), and *Glycine max* (67%). The amino-terminal of the putative AOX1 protein from apple was highly divergent in length and amino acid composition when compared to the other higher plant AOX proteins but the carboxy-terminal was highly conserved. A potential mitochondrial-targeting signal sequence was found in the amino-terminal of apple AOX1. Two cysteine residues were found at positions 113 and 163, which are conserved in the sequences of higher plants and probably are involved in the regulation of the AOX enzyme activity. Antibodies raised against the *Sauromatum guttatum* AOX enzyme recognized two bands of approximately 31 and 32 kDa from the mitochondrial protein fraction of apple skin tissue. Evaluation of the expression of AOX1 in relation to superficial scald development in apple is in progress.

1340-1440**S09-P-134****INVESTIGATING METHYL BROMIDE SCALD OF 'FUJI' APPLES**

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'Fuji' apples have been exported from Tasmania to Japan since 1999. This required the development of a fumigation protocol to prevent the entry of codling moth into Japan. In the 2001 marketing season, methyl bromide (MeBr) scald developed on the fruit in several lines after fumigation and transport to Japan. This has the potential to lead to major restrictions in the marketability of fruit in Japan if the problem cannot be alleviated. The aim of this project was to conduct a comprehensive investigation on the supply chain of 'Fuji' apples exported in the 2001 season, and to examine the potential impact of each step in this chain on the appearance of scald. There is evidence that longer periods of time out of the cool-room between packing and transport to the fumigation centre reduced the

incidence of scald. In addition, fruit removal from the tempering room which heated fruit to the 17 °C fumigation temperature was often below temperature and free moisture in these rooms was high, which may have contributed to the occurrence of scald. There was no association between the fumigation process and the incidence of scald, suggesting that the actual fumigation protocol had no impact on scald incidence. Placement of apples into cold storage immediately after fumigation may have prevented the MeBr gas from dispersing from the apples, as MeBr is liquid at cold temperatures (4 °C). The post-fumigation cooling capacity was not adequate; as skin temperatures of the fruit in outside positions of the pallet (the coldest positions) were often above 9 °C upon loading for shipment to Japan. This study highlights the necessity for a comprehensive quality assurance system for the production and post-harvest handling of apples destined for export markets, included complete record-keeping in all stages of the supply chain to ensure complete trace ability of the product.

1340-1440

S09-P-135

STUDIES OF THE POSTHARVEST PHYSIOLOGY, BIOCHEMISTRY AND REDUCTION OF CHILLING INJURY BY INTERMITTENT WARMING ON PEACH

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If peaches are stored under low temperature for extended periods, they will develop chilling injury. Symptoms of chilling injury include: woolliness, loss of juice, browning, and insipid taste, which affect their commercial value. To prevent chilling injury, intermittent warming (IW) was used where fruit were exposed for 24hr at 20 °C following cold storage for 7 days, 14 days and 21 days. The results show that IW for 24 hr at 20 °C every seven days of storage can reduce chilling injury. However, the degree of fruit softening is high, which shortens the storage duration. Intermittent warming for 24 hr to 20 °C every 21 days does not reduce chilling injury. It appeared that chilling injury was irreversible if cold storage exceeded 14 days. In fruit with IW for 24 hr to 20 °C every fourteen days, during the period of storage, total soluble solids (TSS) increased over time. Titratable acidity (TA) decreased slowly and TSS: TA ratio was most similar with the optimal TSS: TA ratio. Water-soluble pectin increased, but protopectin and firmness of fruit decreased. These three physical indexes were linearly correlated. The activity of PE was inhibited, PG activity of PG did not change, and woolliness was not observed. The activity of peroxidase and polyphenol oxidase increased slowly, and loss of polyphenols and browning of the flesh was observed. Lipid peroxidation, as measured by appearance of MDA, and electrolyte leakage were lower in fruit with no chilling compared with chilling-injured fruit.

1340-1440

S09-P-136

GROWTH, MATURATION AND MATURITY INDEX OF 'MONTHONG' DURIAN

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During growth and maturation of 'Monthong' durian (*Durio Zibethinus* Murr) fruit, dry weight, soluble solids, total sugar and reducing sugar contents of the pulp increased to the highest level at 127 days after anthesis (DAA). However, starch content fluctuated during this period. Firmness increased to a maximum at 106 DAA then declined. Quality evaluation of durian fruit at unripe and ripe stages was done by scoring pulp color, odor and sweetness which were found to increase in parallel to their maturities. Judging from dry weight and total sugar content in pulp at 70, 80 and 90% commercial maturity, it was found that they were equivalent to 106, 113 and 120 DAA. The minimum maturity stage of durian should not be less than 106 DAA and contain at least 32% dry weight. The study on starch content with I2-KI staining showed that 2% I2-KI could differentiate durian maturity. At 78-92 DAA no color to light brown staining was observed. The color disappeared later after 6-10 minutes. Between 99-113 DAA the staining color was brown to brown-black and disappeared after 15 minutes. From 120 DAA onward the staining color faded from brown-black to brown. The time for color staining to disappear also declined to 8-13 minutes. It was concluded the I2-KI staining was not good enough to use for evaluating durian maturity.

1340-1440

S09-P-137

REDUCING INTERNAL BROWNING DISORDERS IN 'BRAEBURN' APPLES BY DELAYED CA AND SOME RELATED PHYSIOLOGICAL AND BIOCHEMICAL CHANGES

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'Braeburn' apples (*Malus x domestica*, Borkh.) have gained wide consumer acceptance because of its distinctive skin colour and high dessert quality. However, the storage duration is limited by the development of browning and cavity disorders when stored under CA conditions with high CO₂ and/or low O₂. This work was conducted to test the effectiveness of a delayed CA storage (21 days at 0 °C in air before CA storage) on the incidence of browning disorders and some related physiological changes like energy status and fatty acid metabolism in 'Braeburn' apples during CA storage. After delayed CA, fruits were stored for up to five months in 4% CO₂ + 1% O₂ at 0 °C. Fruits subjected to rapid CA establishment showed a high occurrence of internal browning and cavities, whereas in delayed CA-fruits a very low incidence of these disorders was found. No significant losses of firmness, acidity, colour and soluble solid contents between delayed and not delayed CA-fruits during storage time could be observed. Delayed CA-fruits showed higher ethylene production and respiration activity during the first two months of storage, which was associated with higher ATP concentrations in the flesh of fruit. Therefore, significant higher energy charge of delayed CA-fruits was found and remained high until the end of storage period. Delayed CA-fruits showed higher contents of fatty acids in the pericarp tissue than rapid CA-stored fruits.

1340-1440

S09-P-138

INVESTIGATING INTERNAL BROWNING OF TASMANIAN 'PINK LADY' APPLES

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Due to internal browning of 'Pink Lady' apples after storage and transport to markets, an investigation was conducted with thirteen lines from Tasmania by assessing incidence of internal browning, fruit quality measurements, fruit nutrient levels, fruit storage atmospheres and growing conditions in the orchards. Field trials and post harvest trials were established to ascertain the relative importance of the probable causal factors identified in the initial investigation. A large variation in the incidence of internal browning with 4 lines of fruit expressing less than 10% browning and 5 lines with greater than 40%. Affected lines were stored in low CO₂ (1.3%) and low O₂ (1.98%) conditions. Fruit lines with a low incidence of the problem had been stored in higher CO₂ (2.03%) and O₂ (2.25%) atmospheres. The level of tree vigour was also related to the incidence of the problem with vigorous trees being associated with a low incidence of internal browning. Non vigorous trees such as those on dwarfing rootstocks, on poor soils, or with heavy summer pruning and girdling were associated with an increase in the incidence of the problem. The lines of fruit with greater than 40% internal browning had significantly higher levels of fruit zinc. It should be noted that 4 of the 5 worst lines had received a zinc foliar spray compared with 1 in the best 4 lines of fruit suggesting that this activity is detrimental to fruit quality.

1340-1440

S09-P-139

HISTOLOGICAL FEATURES OF WATER CORE IN APPLE FRUIT

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Mechanisms of the development of the water core in apple (*Malus domestica* Borkh.) fruit have been examined by many researchers using biochemical and molecular techniques. However, no histological observations have been reported, since water core tissues and/or cells seem to alter during the dehydration procedure of a sample for light and/or electron microscopy. In the present study, we observed the water core tissue with Cryo-Scanning Electron Microscope (Cryo-SEM) which is useful for observing water-rich samples, because it does not need any dehydration procedure in preparation. Development of water core in fruits of

'Koutoku', 'Redgold' and 'Mutsu', either set on the trees or stored at 2 °C after harvest, were examined monthly from mid-September (1999) to mid-January (2000). Water core developed in fruits of 'Koutoku' and 'Redgold', but not in 'Mutsu'. Formation of the water core could be confirmed first in mid-October. Growth of the water core was maximum at harvest time, then reduced gradually in stored fruits. Tissues were excised from pith (water core area for 'Koutoku' and 'Redgold', and non-water core area for 'Mutsu') and cortex (non-water core area for all cultivars) of the fruits, cryo-fixed in Freon 22 at -160 °C, then stored in liquid nitrogen (-196 °C). The tissue was cracked horizontally with a steel blade in a freeze-edging chamber of Cryo-SEM (JSM-840A, JEOL, Tokyo), freeze-edged at -95 °C for 2 min, surface-coated with platinum, and then observed at -160 °C. The Cryo-SEM image showed that all the intercellular spaces were filled with ice crystals (water) in the water core tissue, but not in the non-water core areas. The surface of some cells in the non-water core tissue was covered with droplets of water. Water core tissue seems to be formed with water overflow in the apoplast.

1340-1440

S09-P-140

BORON APPLICATION AFFECTS RESPIRATION AND ENERGY STATUS OF 'CONFERENCE' PEARS DURING CA-STORAGE

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Internal flesh browning and cavities in 'Conference' pears occur frequently during CA-storage, mainly under high CO₂ and/or low O₂ concentrations. Although the reasons for the incidence of these disorders are not fully known, boron supply seems to alleviate the occurrence of browning injuries. Therefore, in three subsequent years the effect of pre-harvest boron sprays on several physiological parameters in pear fruits stored under high CO₂ CA-conditions was tested. Up to six times before harvest, trees of 'Conference' pears were sprayed with boron, alone or in combination with calcium. After harvest, the fruits were stored at -0.5 °C, 5% CO₂ + 2% O₂. During the subsequent 5-month storage period, the pears were monitored for physiological disorders, fruit quality, respiration, and energy charge of fruit tissue. The results showed that after storage, control fruits were more affected by brown heart, than those treated with boron. The lowest incidence of browning disorders, however, was obtained in fruits sprayed with boron in combination with calcium. At harvest, these fruits were also greener, firmer and less sour than control fruits. Boron-treated fruits evolved lower CO₂ and had lower O₂-uptake rates. At harvest and during the whole storage period, however, the energy status, expressed by ATP:ADP, ratio was higher in boron-treated fruits, which may be caused by a lower energy need resulting in a higher net amount of energy being available for maintenance of cell integrity and function.

1340-1440

S09-P-141

RELATIONSHIP BETWEEN THE RATIO OF ALPHA-FARNESENE TO CONJUGATED TRIENES, ANTIOXIDANT ACTIVITY AND SCALD DEVELOPMENT ON COOL-STORED APPLES

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'Starking' and 'Ralls' apples (*Malus x domestica* Borkh), harvested at different times and treated with diphenylamine (DPA) were used to study the changes of alpha-farnesene, conjugated trienes (CTs), the ratio of alpha-farnesene to CTs (RFC), and the relationships between RFC and scald development during cold storage. For late-harvested apples of both cultivars, the time of scald development and severity was delayed, and accumulation of alpha-farnesene increased. Accumulation of CTs in early- and late-harvested 'Starking' apples was similar, but markedly increased in 'Ralls' apples after 15 weeks of storage. alpha-farnesene was delayed and CTs decreased in apples treated with DPA (2.0 g·L⁻¹). DPA-treated apples did not develop scald while 86% of control apples did after 35 weeks of storage. It was shown that CT concentrations were not always correlated positively with scald development, whereas RFC values were strongly correlated with scald. RFC values of late-picked apples were much higher than those of

early-harvested fruit. DPA 2.0 g·L⁻¹ AT inhibited α-farnesene oxidation and gave much higher RFC values during apple storage. Oxidation of alpha-farnesene increased linearly with the rapid decline of RFC values, which corresponded to the changes in antioxidant activity. Superficial scald developed with the accumulations of CTs and when the RFC value reached about 10. After several years of study, it was shown that the relationship between scald development and RFC values fitted the equation $y = -5.78 + 173.71/x$ ($R = -0.93$) for 'Starking' apples, and $y = 133.34 - 17.04x + 0.57x^2$ ($R = 0.94$) for 'Ralls' apples. RFC may be a reliable and an easy predictor of scald development on apples during storage.

1340-1440

S09-P-142

THE ULTRASTRUCTURE OF EPICUTICULAR WAX OF COOL-STORED APPLES AND SUPERFICIAL SCALD DEVELOPMENT

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Scald is the most economically serious postharvest disorder of apples. The symptom of scald appears as a diffuse browning of the hypodermis of the fruit, somewhat roughened in severe cases, which becomes more extensive after a few days at room temperature. The lenticels are usually not affected, and leaving uninjured green spots. The wax ultrastructure of different degrees of scald development (skin with scald free, light browning, medium browning and dark browning) was studied by scanning electron microscopy. Homogenous and granular wax was found on the surface of skin without scald symptoms. When the skin appeared light brown, part of granular wax disappeared, and most of wax disappeared on skin with severe scald while heavy surrounded the lenticels. About 34% of total chloroform extractable wax decreased after severe scald. The data indicated that the disappearance of the wax was responsible for the loss of gloss of apples surface after scald developed and an apparent oxidative process was involved in wax layer during scald development.

1340-1440

S09-P-143

DIAGNOSTIC ASSAY OF INTERNAL BREAKDOWN SUSCEPTIBILITY FOR PEACH AND NECTARIN CULTIVARS

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Flesh breakdown associated with mealiness and flesh browning, is the main cause of peach and nectarine deterioration when stored at low temperatures. A diagnostic assay of susceptibility to this problem at harvest is required in the stone fruit industry. Three cultivars of peaches ('Elegant Lady', 'O'Henry' and 'Zee Lady') and two of nectarines ('August Red', 'Arctic Snow') were selected. Electrolytic leaking, extracted juice and respiration rate of the fruit, were measured at harvest and correlated with the incidence of mealiness and flesh browning after 8, 18, 26 days storage at 0, 5 and 10 °C plus a period of ripening at 20 °C. A high correlation ($r = -0.93$) was obtained between extracted juice at harvest on ripe fruit and the incidence of mealiness after 18 and 26 days storage at 5 °C. Electrolytic leaking at harvest on unripe fruit was positively correlated ($r = +0.86$) with flesh browning symptoms after 26 days of storage at 0 °C and a period of ripening. The susceptibility of the cultivars at different temperatures of storage is discussed in term of mealiness or flesh browning incidence.

1340-1440

S09-P-144

CHILLING INJURY IN BOTH PARTHENO-CARPIC VS POLLINATED CACTUS PEAR FRUITS

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Chilling sensitivity was evaluated in both parthenocarpic and pollinated fruits of two selections of red-colored cactus pear, 'Moradasa' and 'Solferino'. A combination of growth regulators, AG3 and TDZ was used in order to obtain parthenocarpic fruits while others were open pollinated. Ripe fruits were hand har-

vested and kept at 5 or 10 °C during 3, 6, 9, 12, 15, 18, and 21 days and then held at room temperature for 0, 2, 4, 6, 8, and 10 days. Membrane conductivity, ethylene evolution, weight loss, total soluble sugar, and titratable acidity were measured. At 10 °C /18 days of cold storage/10 days at room temperature, membrane conductivity was higher in parthenocarpic 'Solferino' fruit compared with the rest of the treatments. Ethylene evolution was of 2.2 $\mu\text{L}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$ in 'Solferino' vs 1.6 $\mu\text{L}\cdot\text{kg}^{-1}\cdot\text{h}^{-1}$ of Moradasa fruits. Parthenocarpic 'Solferino' fruit lost 20% of their fresh weight while 'Moradasa' fruit lost only 12%, regardless of cold storage treatment. Black spotting was observed in some treatments; however a clear pattern of this disorder was not found. There were no differences in total soluble sugar content nor titratable acidity among treatments. Under our conditions, the development of chilling injury was affected more by selection and type of fruit rather than by storage temperature. The use of growth regulators to induce parthenocarpic fruits may explain the differences found between parthenocarpic vs. pollinated fruits.

1340-1440

S09-P-145

BICARBONATE AND ASCORBATE ACTIVATE 1-AMINOCYCLOPROPANE-1-CARBOXYLATE (ACC OXIDASE)

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ACC oxidase (ACCO) catalyzes the final step in ethylene biosynthesis. ACCO requires ascorbic acid, bicarbonate, ferrous ion (FeII) and dioxygen for activity. Histidine(His)177, aspartate (Asp)179 and His234 are the binding sites for Fe(II) comprising a 2-His-1-Asp facial triad common to other mononuclear non-heme iron (II) enzymes. Fe(II) is the dioxygen binding site and the ACC- amino group is an iron ligand. Native and mutant ACCOs were expressed in *Escherichia coli*, purified and enzyme kinetics determined. Arginine(Arg)244, serine(Ser)246 and threonine(Thr)157 were determined to be binding sites for the ACC carboxyl group. Arg175 is the putative bicarbonate binding site, based on kinetic analyses of the Arg175Glu mutant and other Arg175 mutants. The data are consistent with bicarbonate binding by H-bonding/electrostatic interactions with the Arg175 guanidinium group. Collectively, our data indicates that His177, Asp179 and His234 are the iron ligands, the carboxyl group of ACC is H-bonded to Arg244, Ser246 and Thr157 and the ACC amino- group is an Fe(II) ligand. The guanidinium group of Arg175 is the putative bicarbonate binding site. An epsilon-amino group, of a conserved lysine residue, appears to be one of the ascorbate binding sites. Functional groups of other conserved amino acid residues capable of H-bonding/ionic interactions with ascorbate may also serve as binding sites for ascorbate. Whereas ACCO is not a pyridoxal-5'-phosphate(PLP)-dependent enzyme, PLP competes for an ascorbate binding site in ACCO. This is consistent with a lysyl residue being an ascorbate binding site. Our data suggest a kinetic model for bicarbonate and ascorbate activating ACCO by interacting with the ternary complex ACCO-Fe(II)-O-O-ACC.

1340-1440

S09-P-146

MOLECULAR CLONING OF UDP-GLYCOSYLTRANSFERASE GENES: DIFFERENTIAL EXPRESSION PATTERNS DURING APPLE FRUIT RIPENING

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Red skin color is an important factor for market acceptance of many apple cultivars (*Malus x domestica*). Red coloration is determined by anthocyanin levels. The main anthocyanin in apple fruit is cyanidin-3-galactoside, suggesting that a key enzyme genetically controlling red coloration is UDP-galactose:flavonoid-3-O-galactosyltransferase (UFGalT), but not UDP-glucose:flavonoid-3-O-glucosyltransferase (UFGlcT). To isolate the UFGalT genes in apple, a cDNA library using mRNAs extracted from 'Jonathan' apple skin at the mature stage was constructed. Because of sequence similarity between UFGalT and UFGlcT, the fragment obtained from 'Jonathan' that showed high similarity to the UFGlcT gene from 'Fuji' (accession number AF117267) was used as a probe.

Five positive clones were obtained from the 106 pfu by screening the library. All five cDNAs lacked the 5' ends, and these cDNA clones fell into two groups based on the nucleotide sequences. In the first group (one clone), the cDNA showed high similarity to the fragment used as a probe. In the second group (four clones), sequence similarities of the cDNAs to the probe sequence were less pronounced. Northern blot analysis was done using three apple cultivars which differed in skin coloration; a yellow skin type 'Orin', and red skin types 'Jonathan' and 'Fuji'. The expression of the clone from the first group increased only in the red skin types during fruit maturation, indicating the correlation with anthocyanin accumulation. On the other hand, expression levels of clones from the second group were quite low in immature fruit and increased during ripening in both skin color types. These results suggested that the two groups of the UDP-glycosyltransferase genes were differentially regulated during fruit ripening. To better understand the mechanisms of anthocyanin accumulation in apple fruit, an experiment to isolate the full-length genes encoding UFGalT is in progress.

1340-1440

S09-P-147

THE CHANGES AND EFFECTS OF SALICYLIC ACID IN KIWIFRUIT RIPENING

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For investigating the role of salicylic acid (SA) in fruit ripening, changes of endogenous free SA, LOX activity, rate of free radical production, relative electric conductivity, and ethylene biosynthesis were measured in ripening kiwifruit at 20 °C and the fruits treated with Aspirin (ASP) and stored at 0 °C. In the fruit stored at 20 °C, endogenous free SA declined while fruit firmness decreased, LOX activity increased, rate of free radical production accumulated, and the relative electric conductivity increased before the ethylene climacteric appeared. Less change of kiwifruit firmness and higher endogenous free SA content were observed when the fruit was stored at 0 °C. A notable relationship between the change of endogenous free SA and kiwifruit ripening was observed ($r = 0.9067^{**}$). ASP treatment maintained higher fruit firmness compared with control fruit by elevating both endogenous conjugated SA and free SA levels, inhibiting LOX activity, and decreasing free radical production. ASP treatment also lowered relative electric conductivity suppressed ethylene biosynthesis and delayed the onset of the ethylene climacteric.

1340-1440

S09-P-148

CHARACTERISATION OF THE 'PURPLE PATCHES' OBSERVED ON 'HAYWARD' KIWIFRUIT

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A disorder characterised by purple coloured tissue was observed on kiwifruit [*Actinidia deliciosa* (A. Chev) °C.F. Liang et A.R. Ferguson 'Hayward'] during storage and subsequent shelf-life tests for 2000 season fruit. This disorder resulted up to 25% fruit loss in some packed trays after long term storage. Patches were mainly observed on distal shoulder of some fruits, particularly those with a hue angle (measured by a Minolta chroma meter CR-200) less than 78 degree, high Ca and low K and P concentrations. Affected tissue had significantly higher N, P, Ca, and Mg concentrations but lower K concentration compared to adjacent healthy tissues on the same fruit. This indicates that the disorder is different from pitting which is associated with lower Ca, high K and P contents. Possible causes of the disorder are discussed and segregation of at-risk fruit by fruit colour is recommended.

1340-1440

S09-P-149

CHLOROPHYLL DEGRADATION, AUTOFLUORESCENCE AND DISTRIBUTION IN BANANA AND PLANTAIN PEEL AT HIGH TEMPERATURES

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Banana (*Musa AAA*) is a tropical fruit which is generally consumed as a ripe fruit. The turning of the peel from green to yellow is associated with the initial stages of ripening. Knowledge of the degreening process would enable sound horticultural practices to be developed that produce colour suitable for particular markets. At tropical temperatures (above 24 °C), the degreening of bananas is inhibited and chlorophyll concentration is retained. As a result, the peel is a pale greenish yellow colour. Plantain (*Musa ABB*), another group in the genus degreens rapidly and completely, even at high temperatures. In this experiment, we studied chlorophyll autofluorescence to determine chlorophyll activity in relation to peel colour change. We measured colour using an L*a*b* colour system and studied changes in the peel of bananas and plantains ripened at 20 and 30 °C. At day 4 after storage at 30 °C, a* value was still low (green) in banana. The bright red colour of chlorophyll autofluorescence was retained at day 4 of storage only in the peel of bananas at 30 °C. However, the autofluorescence occurred only at the surface of the peel, whereas initially it was present throughout the peel. Chlorophyll was distributed unevenly along the surface of the peel. The chloroplasts of bananas at 30 °C at day 4 of storage retained their thylakoids whereas in chloroplasts of plantains at 30 °C, they had disappeared. The retention of chlorophyll, which was found only at the surface of the peel of bananas ripened at 30 °C suggests that chlorophyll degrades from the inside to the outside of the peel. Therefore, bananas ripened at 30 °C have the capacity to degrade chlorophyll, at least in the deeper layers of the peel.

1340-1440

S09-P-150

EFFECT OF CITRIC ACID ON THE CONTROL OF POSTHARVEST BROWNING OF LYCHEE FRUIT UNDER COLD STORAGE

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Lychee 'Kom' fruits were dipped in 0.5 and 1 M citric acid solutions for 10, 20 and 30 minutes and then stored at 5 °C and 90-95% RH. The results showed that lychee treated fruits with 1.0 M citric acid had less browning than those with 0.5 M citric acid. Lychee fruits treated with 1 M citric for 10 minutes had the highest control of browning. In addition, total phenolic content, total anthocyanin content, pH of peel, rate of respiration and ethylene production of lychee fruits treated with citric acid occurred decreased but no effect on weight loss, total soluble solid content and sensory evaluation. However, the lychee fruits treated with citric acid had a pink-red color peel and had a storage life of 42 days.

1340-1440

S09-P-151

HARVEST DATE INFLUENCE SCALD DEVELOPMENT IN 'GRANNY SMITH' APPLES DURING LONG TERM STORAGE

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In this study, the effects of harvest date on scald development of 'Granny Smith' apples (*Malus x domestica* Borkh.) were investigated. Apples were harvested at 15 day intervals and stored at 0 °C with 90% relative humidity for 8 months. The percentage of scald was lower for late harvested (November 15) apples than apples harvested early (October 15). The fruits harvested early reached climacteric maximum earlier than the fruits harvested late. Amount of weight losses, titratable acids and soluble solids varied among different harvest dates. The loss of chlorophyll was faster for the fruits harvested late than apples harvested early. The percentage of decay was lower for the fruits harvested early.

1340-1440

S09-P-152

NEW DIRECTIONS FOR RESEARCH ON SCALD IN APPLES (*MALUS X DOMESTICA* BORKH.)

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Superficial scald, perhaps the most severe physiologic disorder known to occur in stored apples (*Malus x domestica* Borkh.) has been circumstantially associated with oxidative stress. The generally accepted hypothesis is that scald develops as a result of farnesene oxidation; farnesene is a naturally-occurring sesquiterpene hydrocarbon present in apple peel. Farnesene oxidation products presumably cause death of surface cells resulting in discolored fruit unsuitable for release through marketing channels. Prevention of scald is commercially achieved by diphenylamine (DPA) treatment of fruit destined for long-term storage. DPA, an antioxidant compound, inhibits the oxidation of farnesene. Scald development is also associated with the harvest of immature fruit, resulting in a dilemma for producers, as fruit harvested before the onset of ripening has a much better storage life. We believe that the crucial events associated with scald development occur before or immediately after harvest. Exposure of apple fruit to certain environmental conditions before or immediately after harvest may result in the accumulation of chemical species that are able to persist in the peel tissue. Once in storage, these species can combine with oxygen to generate singlet oxygen which is a much more toxic form of O₂. The use of spin-trapping reagents to identify intermediate chemical species in the scald reaction revealed the presence of reactive organic species associated with farnesene oxidation. Chemical identification of these intermediates allow us conditions to mimic the naturally-occurring scald response to facilitate molecular investigations. Recent information from our laboratory as well as from other scald investigations suggest that the oxidative stress associated with scald development attenuates a signal-transducing mechanism that involves ethylene reception to induce apoptotic cell death.

1340-1440

S09-P-153

AROMA VOLATILE BIOSYNTHESIS IN DIFFERENT TISSUES OF 'REDCHIEF DELICIOUS' APPLES (*MALUS X DOMESTICA* BORKH.) UNDER ANOXIC CONDITIONS

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Tissue disks from different tissues were obtained from 'Redchief Delicious' apple fruit (*Malus x domestica* Borkh.) and analyzed for the ability to metabolize 1-pentanol as well as synthesize constitutive esters and alcohols under anoxic and aerobic conditions. The skin tissue displayed a greater capacity to synthesize pentanal, pentyl acetate, pentyl propionate, pentyl butyrate, and pentyl hexanoate than the hypanthial and carpellary tissues during incubation with 1-pentanol. With the exception of pentyl acetate and pentyl propionate biosynthesis, the hypanthial tissue synthesized these compounds at a higher rate than the carpellary tissue. Anoxia inhibited both constituent and 1-pentanol derived ester biosynthesis. While anoxia inhibited ester biosynthesis, ethanol biosynthesis increased at a greater rate in tissue disks held under these conditions. Biosynthesis of 1-butanol, 2-methyl-1-butanol, and 1-hexanol was greater in tissue disks held in air during the first part of the measurement period and dropped off more rapidly than those transpiring in tissue disks held under anoxic conditions. The biosynthetic rates of all esters, both constituent and 1-pentanol derived, increased as a result of air exposure. While hypoxia or anoxia conditions may promote ethanol synthesis, these conditions also appear to inhibit the formation of the ethanol-derived esters partially responsible for the off-flavor in apples attributed to ultra-low O₂ controlled atmosphere storage.

1340-1440

S09-P-154

CHANGES IN NEUTRAL SUGARS AND PECTIN-RELATED MATERIALS DURING RIPENING OF SOUR CHERRY FRUIT

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Sour cherry (*Prunus cerasus*) fruit lose firmness in a few days, causing problems during mechanical harvesting and processing. We evaluated changes in cell wall composition during fruit development. Fruit were collected throughout development and ripening. Mesocarp tissues were extracted to yield phenol:acetic

acid:water (PAW) –soluble and other cell wall materials (CWM). Cell wall analyses showed several distinct changes in the mass of CWM, with a net increase becoming a sharp decrease at 36–40 days after pollination. These changes were associated with CDTA- and Na_2CO_3 -solubilized CWM, the pectin-related components, along with PAW-soluble materials. During development, arabinose was the major neutral sugar in CDTA and Na_2CO_3 fractions; other sugars were minor components. Using gel-filtration chromatography we analyzed neutral sugars and of PAW and CDTA-solubilized CWM. With ripening, pectins and neutral sugars increased in PAW, and these were present in a broad range of high to low molecules. Arabinose was the major neutral sugar in high fractions, but glucose was the major component of small fractions. In CDTA-solubilized CWM in young fruit pectins were broadly distributed across the range of eluted fractions. Later, however, small and intermediate pectins were sequentially solubilized, leaving only high pectins in mature fruit. Ripening thus involves removal of arabinose and glucose rich side chains from pectins, resulting in pectin depolymerization and increasing pectin-related solubility. These developmental and ripening related changes in cell walls are entirely consistent with changes in gene expression of a broad range of cell wall modifying enzymes.

1340–1440

S09–P–155

POLYGALACTURONASE ACTIVITY IN TOMATO FRUITS DURING RIPENING CORRELATED WITH CULTURE CONDITIONS

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Tomato fruit contains endogenous polygalacturonase (EC 3.2.1.15) that depolymerises the pectin. Because the quality of these fruits and also of processed tomato products depends on the extent of pectin degradation it is important to know how polygalacturonase activity evolves during ripening. The study was carried out in a glasshouse, using different tomato varieties. Together with polygalacturonase activity we determined the content of reducing sugars and the total amount of organic acids. These parameters were correlated with the cultural conditions, meaning temperature, light and nitrogen content of fertilizers.

1340–1440

S09–P–156

SPECIFICITY OF ALCOHOL DEHYDROGENASE IN APPLE PEEL

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Alcohol dehydrogenase (ADH) is a ubiquitous enzyme found in apple peel that is responsible for the interversion of acetaldehyde and ethanol. ADH is up-regulated in stressed tissue, particularly in anaerobic tissue and during controlled atmosphere storage of apples. ADH activity is important in aroma production and has been linked to the suppression of the long-term storage disorder, superficial scald in apples. ADH may play an important role protecting the fruit from chilling injury during storage of apples at low temperatures by reducing toxic aldehydes to alcohols. Apple peel ADH was isolated from 'Rome' apple peel and the substrate specificity was determined to a range of natural substrates. The results and implications of these experiments will be discussed in more detail.

1340–1440

S09–P–157

EFFECTS OF LOW OXYGEN ON ACTIVE OXYGEN METABOLISM AND INTERNAL BROWNING IN 'BRAEBURN' APPLE FRUIT

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'Braeburn' apple fruit were held in low oxygen (0.5kPa O_2 +0.05kPa CO_2) controlled atmosphere (CA) at 0 °C for two months, or sealed in polyethylene bags (PA) at 20 °C for 10 days to obtain anaerobic conditions. Control fruit (CK) were stored in air. Activity of xanthine oxidase (XOD), NADH and NADPH oxidase, superoxide dismutase (SOD) and the incidence of physiological disorders were investigated. The activities of XOD, NADH- and NADPH oxidase were highest in apples from the CA and PA treatments. SOD activity was similar in CA and CK fruit, but lower in PA apples. Acetaldehyde (AA) treatment (120 ppm, at 0 °C for 24 hr) prior to CA or addition of AA (1 ml of a 1%

solution) to polyethylene bags stimulated NAD(P)H oxidase activity. AA pre-treatment resulted in lower SOD activity, and this response was detectable through two months storage in CA. The physiological disorder, internal browning, occurred in apples stored in CA or PA, and the disorder development was enhanced by AA treatments. The results suggest that development of internal browning in 'Braeburn' apples may be associated with superoxide accumulation due to enhanced activity of XOD and NAD(P)H oxidase with reduced SOD activity under low oxygen or anaerobic conditions.

1340–1440

S09–P–158

CELL WALL CHARACTERISTICS ASSOCIATED WITH THE EASE OF TABASCO PEPPER FRUIT DETACHMENT

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Most cultivated cultivars of pepper (*Capsicum* sp.) are non-deciduous and the pedicel does not separate readily from the fruit. The processing industry wishes to understand how it can harvest fruits without the pedicel. In this study, cell wall characteristics in the detachment zone were examined in two tabasco pepper (*C. frutescens*) lines which differ in fruit abscission when ripe: 'McIlhenny Select' or easy pick (E) requires a low force to detach from the pedicel when ripe, and 'Hard Pick' (H) requires higher force. During ripening the uronide content of tissue extracted from the detachment zone (DZ) was similar in both lines, but pectin depolymerization and dissolution in water were higher in the E line as the fruit ripened. The degree of pectin esterification (DE) was lower in E in the most mature fruits. The pH measured with a microelectrode in the detachment area showed a high correlation with fruit detachment force (FDF). The pH of the E line decreased faster (from pH 6.4 to pH 4.9) than the H (down to pH 5.5 only) line as the fruit ripened, similar to the FDF. The effect of pH on polygalacturonase (PG) and cellulase (Cx) activities was also examined. PG and Cx activities from crude extracts increased during ripening but were not different between the two tabasco lines. PG was very active in the range of pH 5.0–5.7 and a half pH unit increase (from pH 5.5 to pH 6.0) reduced the enzyme activity approximately 50%. These results suggest that the DE and apoplastic pH may affect PG activity and cell wall degradation in vivo.

1340–1440

S09–P–159

STUDY ON RELATIONS BETWEEN SO₂ INJURY SENSITIVITY AND GRAPE PEEL STRUCTURE, PHYSIOLOGY AND BIOCHEMISTRY

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Experiments were performed using eight grape cultivars to study SO_2 injury to table grapes in normal and low temperature storage, and the relationship between SO_2 fumigation concentration, exposure time, storage temperature and injury extent of table grapes. The relationship between the peel structure, physiology and biochemistry and sensitivity to SO_2 injury was also researched. The result showed that the sensitivity to SO_2 was different in the grape cultivars and not dependent upon storage temperature. The sequence of sensitivity was: 'Ribier' > 'Hongbaoshi' > 'Red Globe' > 'Niunai' > 'Kyoho' > 'Muscate Hamburg' > 'Longyan' > 'Black Autumn'. The eight grape cultivars can be classified as, very sensitive to SO_2 ("Ribier", "Hongbaoshi", "Red Globe"), inferior sensitive to SO_2 ("Nunai"), inferior tolerant to SO_2 ("Kyoho", "Muscat Hamburg"), and most tolerant to SO_2 ("Longyan", "Black Autumn"). The sulfite residues of different parts of grapes varied greatly after fumigated with SO_2 from high to low in pedicel, stem, skin, brush and flesh. Data showed that stem, pedicel and skin were the two main pathways of SO_2 entrance into grape fruit. The large ration of the sulfite residues in skin and in pedicel of the sensitive grapes to SO_2 indicated that the grapes sensitivity to SO_2 had a close relation to their skin absorbing capacity of SO_2 . The skin bleaching index was strongly correlation with the temperature, fumigation concentration and time. The sensitive grapes ('Ribier', 'Hongbao shi', 'Red Globe', 'Niunai'), the fumigation concentration and time had significant effects on the bleaching index, but the fumigation time had insignificant effect on the SO_2 tolerant grapes ('Longyan', 'Black Autumn'). The effect of fumigation time on bleaching index had a negative correlation with the grape.

1340-1440

S09-P-160

EXPRESSION ANALYSIS OF GENES ENCODING CELL WALL MODIFYING ENZYMES DURING RIPENING IN PEAR FRUIT

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It is well known that pear (*Pyrus communis* L. cv. La France) fruit exhibit a rapid increase of ethylene production and decrease of flesh firmness during ripening. Previously we demonstrated by using 1-MCP, an inhibitor of ethylene action, and propylene, an analogue of ethylene, that ethylene production during ripening of pear fruit is under positive feedback regulation and that the fruit softening requires ethylene action not only for onset of softening but also for progression of softening. In order to study the cell wall modifying enzymes that are involved in the decrease of flesh firmness at the molecular level, we isolated cDNAs encoding cell wall modifying enzymes from ripening pear fruit; polygalacturonases (PC-PG1 and PC-PG2), endo-1,4-beta-D-glucanases (PC-EG1 and PC-EG2), and xyloglucan endotransglycosylases (PC-XET1 and PC-XET2). RNA gel blot analysis showed that mRNA accumulation of all cloned genes, except PC-EG1 was stimulated after the onset of fruit ripening. The accumulation of PC-PG1, PC-PG2 and PC-XET1 mRNAs was accelerated when pre-ripe fruit were treated with propylene and suppressed with 1-MCP treatment during ripening. This result indicates that the expression of these genes is regulated positively by ethylene during ripening. In contrast, PC-EG2 and PC-XET2 mRNA accumulation were not affected by 1-MCP or propylene treatment. While PC-EG1 mRNA accumulation was constitutive throughout the ripening period, it was not affected by either 1-MCP or propylene. These results suggest that the various cell wall modifying enzyme genes are involved in pear fruit ripening and that the change of PC-PG1, PC-PG2 and PC-XET1 mRNA accumulation correlate with the fruit softening suppressed by 1-MCP.

1340-1440

S09-P-161

IS MEALINESS OF 'FORELLE' PEAR A CONSEQUENCE OF CHILLING INJURY?

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'Forelle', a blushed pear cultivar grown in South Africa, is prone to develop mealiness during ripening. In the 2001 season fruit stored at 4 °C and 7.5 °C for 6 weeks and ripened at 15 °C for 7 days showed little to no mealiness in contrast to fruit stored at -0.5 °C. The firmness of fruit stored at 0.5 °C was constant over the 6 week storage period, and after 7 days at 15 °C firmness was 4 kg but 70% of the fruit were mealy. Firmness of fruit stored at 4 °C did not decrease by more than 0.5 kg during the storage period, which makes it suitable for export purposes. The firmness of fruit stored at 7.5 °C dropped rapidly after 3 weeks, and after 6 weeks of storage and 7 days at 15 °C. Fruit had a firmness of 2 kg. It appears that 4 °C satisfied the cold requirement necessary for subsequent ethylene production and resulting fruit were not mealy, while fruit stored at -0.5 °C for as little as 3 weeks resulted in mealy pears. These data suggest that mealiness is induced by chilling temperatures.

1340-1440

S09-P-162

HARVEST TIME, RIPENING PATTERNS AND QUALITY OF JAPANESE PLUMS

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'Pioneer' and 'Sapphire' plums (*Prunus salicina* Lindl.) were classified as having a climacteric ripening pattern, while 'Songold' and 'Angeleno' were classified as having a suppressed climacteric based on ethylene production. Fruit was harvested from each of the four cultivars 5-6 times during the picking period and stored at -0.5 °C for 5 weeks. Fruit were removed from storage weekly and evaluated immediately and again after 7 days at 15 °C. In all culti-

vars, the drop in firmness between harvest dates was not as great as expected. In the case of 'Pioneer' and 'Sapphire', a significant reduction in firmness occurred after 7 days at 15 °C without a cold storage period, whereas 'Songold' required cold storage in order to soften. Firmness of 'Angeleno' plums changed relatively little during storage at -0.5 °C and 7 days at 15 °C. It may be possible to use ripening patterns to predict postharvest responses and develop handling procedures for a wide range of plum cultivars.

1340-1440

S09-P-163

THE INFLUENCE OF LYSPHOSPHATIDYLETHANOLAMINE, A NATURAL LIPID, ETHYLENE PRODUCTION AND ACC OXIDASE ACTIVITY ON MATURE GREEN VS. RED TOMATOES

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Recent studies conducted at the Univ. of Wisconsin have demonstrated that lysophosphatidylethanolamine (LPE) is able to accelerate fruit ripening while at the same time prolong shelf life. Ethylene and activity of ACC oxidase are known to be integrally involved in the ripening of climacteric fruits such as tomatoes. We investigated the influence of LPE on ethylene production, ACC oxidase activity and respiration in pericarp tissue of tomato fruit at mature green 4 (MG4) and light red stages. Excised pericarp tissues were incubated in a buffer solution containing various concentration of LPE derived from egg yolk. In MG4 pericarp tissue, LPE resulted in an increase in ethylene production and in the activity of ACC oxidase. Respiration in this tissue was also slightly increased. However, in the pericarp tissue of light red tomatoes, LPE resulted in a decrease in ethylene production and in the activity of ACC oxidase. A slight decrease in the respiration of this tissue was also found. These results are consistent with the observed influence of LPE on stimulation of fruit ripening and on the prolonging of shelf life. Furthermore these results provide evidence that the influence of LPE on fruit tissue is dependent on the stage of development. These results show that in a mature fruit (ready to ripen) LPE can stimulate ripening while in a ripened fruit LPE can inhibit ethylene production and thereby prolong shelf life and fruit firmness. These responses of LPE involve the modulation of ACC oxidase.

1340-1440

S09-P-164

STUDIES ON THE RELATIONSHIP OF THE MICROSTRUCTURE OF RED GLOBE GRAPE EPIDERMIS, ENZYME ACTIVITY, AND SO₂ DAMAGE

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'Red Globe' grape epidermis is sensitive to SO₂, resulting in bleach spots on the fruit surface whereas 'Longyan' grape epidermis is resistant to SO₂. The epidermis is the main entrance of SO₂ into the fruit. The epidermis microstructure of 'Red Globe' grape and the microstructure of SO₂ damage was observed with a scanning electron microscope. The epidermis structure had a close relationship to SO₂ sensitivity. 'Red Globe' fruit had a loose epidermal wax structure and some holes in them. 'Longyan' grape had a tight epidermis wax structure. The epidermis wax structure was destroyed and was heaped together so that epidermis was uncovered when the epidermis wax structure was exposed to SO₂. The peel of 'Red Globe' fruit had a lower concentration of superoxide dismutase (SOD) than that in the peel of 'Longyan' grape. Catalase (CAT) decreased rapidly at the first stage of storage in the peel of 'Red Globe'. MDA concentration in the peel of 'Red Globe' fruit increased higher than that in the peel of 'Longyan' fruit which were resistant to SO₂, indicating a greater amount of lipid peroxidation in 'Red Globe' fruit.

1340-1440

S09-P-165

DIFFERENTIAL EXPRESSION OF TWO BETA-D-XYLOSIDASE GENES DURING FRUIT DEVELOPMENT AND RIPENING IN TOMATO

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The plant cell wall is modified during almost all plant developmental processes such as seed germination, fruit development, fruit ripening and abscission. Modifications to the cell wall are thought to be mediated by cell wall hydrolases, including a beta-D-xylosidase that participates in the breakdown of xylan. We have cloned two beta-D-xylosidase genes, designated LeXYL1 and LeXYL2, expressed in tomato fruit. The deduced amino acid sequence of LeXYL1 shows 74% identity with that of LeXYL2. Accumulation of mRNA for the two beta-D-xylosidases was examined during fruit development and ripening. LeXYL2 mRNA was relatively highly expressed during early fruit development and decreased gradually after the onset of ripening. In contrast, LeXYL1 mRNA was not present during fruit development, but was present later during ripening. LeXYL1 and LeXYL2 each showed diverse patterns of expression during fruit development and ripening. We studied the transcription of LeXYL1 and LeXYL2 in wild type ('Ailsa Craig') fruit and ripening-impaired mutants, Nr2, nor, and rin. In the ripe fruits of the mutants, there was no expression of LeXYL1, whereas mRNA abundance of LeXYL2 was similar to that in mature-green wild-type fruit. These two beta-D-xylosidase genes are subject to distinct regulatory control during fruit development and ripening. These results suggest that the product of the LeXYL1 gene is responsible for ripening-associated cell wall changes.

1340-1440

S09-P-166

THE EFFECT OF HEAT TREATMENTS ON QUALITY AND CHILLING INJURY OF SATSUMA AFTER LONG-TERM STORAGE AT LOWER TEMPERATURE

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Satsuma fruits (*C. unshiu* Marc.) were dipped in hot water for three minutes (HWD) or wilted at room temperature till 3% weight loss before storage at 3 °C for 6, 8 and 10 weeks. In comparison to control, HWD's at 48 and 50 °C showed significantly lower weight loss after 6 weeks of storage and total weight loss (storage + 7 d of shelf life). After 8 and 10 weeks of storage, there were no significant differences in storage and total weight loss. Hot water dipping at 46, 48 and 50 °C showed significantly lower weight loss after 6 weeks of storage, but after 10 weeks, that was true only for HWD at 48 °C. Storage time significantly increased weight loss after storage, but for weight loss after shelf life and total weight loss that was true only for 6 and 8 weeks of storage. Wilting increased juice content after 8 weeks and after 10 weeks for HWD's at 46 and 48 °C. TSS and TA was decreased by HWD's at 48 and 50 °C after 8 weeks. All treatments decreased TSS after 10 weeks. HWD at 48 °C decreased TSS/TA ratio after 6 weeks and increased it after 8 and 10 weeks. There were no significant difference in percentage of fruits with chilling injury CI between control and treatments after 6 weeks, but there were 32.5 and 50.0% CI—control fruits after 8 and 10 weeks, respectively. HWD's at 46, 48 and 50 °C resulted with lower incidence of CI. Contrary to the reports in literature, HWD at 52 °C showed no effect on CI after 6 weeks; however, after 10 weeks this treatment increased CI incidence.

1340-1440

S09-P-167

RELATIONSHIP BETWEEN ANTHOCYANIN CONTENT AND PERICARP BROWNING OF LYCHEE PERICARP

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Pericarp browning is the main postharvest problem of lychee fruit, resulting in an reduced shelf life and reduced commercial value of the fruit. Lychee pericarp browning index increased while anthocyanin content decreased with storage time. There was a good negative correlation between anthocyanin content and pericarp browning index, when a pH-differential method was used to determine anthocyanin content. However, there was no significant change in anthocyanin content while lychee fruit browned, when an acidific-methanol method was used. To understand the difference between the two analytic methods in determining the anthocyanin content, a detailed comparison was carried out. Acidific-methanol can extract anthocyanin as well as brown compounds, which were insoluble in 1% HCl and had a high absorption at 510-530 nm, thus interfering with the results and resulting in a high value for anthocyanin content. According to anthocyanin solubility in water, 1% HCl was used as extract solution in the pH-differential method, thus making the

results more reliable because it does not extract brown compounds. Additionally, the pH-differential method could eliminate interfering compounds in the determination of other chemical constituents.

1340-1440

S09-P-168

CONTROL OF POSTHARVEST BROWNING AND DECAY IN BABY CORN

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Control of browning and decay of three cultivars of baby corn (*Zea mays* L.) were studied in relation to their postharvest changes and quality. Baby corn cv. Chiang Mai 90, had greater browning than cvs. CP45 and Pacific No.5. The browning appearance of baby corn did not correlate with L value, while it did with weight loss and total phenolic content. Baby corn cv. CP45 had the greatest decay after 6 days of storage at ambient temperature. Sodium hypochlorite at 100, 200, and 300 ppm completely controlled decay of 'CP45' for the first 4 days of storage and had the least decay by the end of storage compared to the control. Sodium hypochlorite treatment had no significant effect on color and total sugars of baby corn. Ascorbic acid and Eribate at 0.05, 0.1 and 0.2% and calcium chloride at 0.5, 1.0 and 2.0% were also tested for control of browning in CP45. Only Eribate at 0.2% effectively reduced browning.

1340-1440

S09-P-169

EFFECT OF LOW TEMPERATURE ON THE DEVELOPMENT OF SENESCENT SPOTS IN 'KLUAI KHAI' BANANA

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Senescent spotting of banana (*Musa* AA group) cv Kluai Khai developed during the latter phase of ripening. Total phenolics, total sugars, ethylene production, respiration, phenylalanine ammonia lyase (PAL) and polyphenol oxidase (PPO) activities increased, while firmness of peel and plup decreased during ripening. Continuous exposure of bananas at color index 4-5 to 12, 15 and 18 °C reduced significantly senescent spotting, total phenolics, total sugars ethylene production and respiration, while low temperature treatments increased activities of PAL and PPO of bananas. Exposure of bananas to 12 °C after the development of senescent spots did not inhibit further senescent spotting.

1340-1440

S09-P-170

ANTIOXIDATIVE ABILITY OF CELL WALL COMPONENTS IN FRUIT AGAINST ASCORBIC ACID OXIDATION

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Ascorbic acid (AsA) oxidizes rapidly in an aqueous solution and/or in the presence of copper ions. UV absorbance of an aqueous solution of AsA decreased remarkably with time and had nearly disappeared after 12 hrs. When the fraction extracted with water from alcohol-insoluble residue of fruit flesh was added to an AsA solution, the decrease in UV absorption slowed in comparison to the control. Among 18 varieties of fruits, the fraction from the flesh of melon, loquat and strawberry demonstrated remarkable effect in maintaining UV absorbance (higher antioxidant activity), while that of grape, mango and kiwifruit showed lower activity. Among the fractions extracted with water, hot water, HCl and KOH successively, water and hot water soluble fractions showed activity, while no activity was found in the HCl and KOH soluble fractions. In apple and pear fruit, the activity varied with cultivar, and increased with maturity, and by storage in apple. Using fractionation by gel permeation chromatography, water and hot water soluble fractions from apple flesh were separated into four subfractions, and antioxidant activity of each subfraction was evaluated. The highest activity was found in the subfraction which included lower molecular-weight substances. In an AsA solution with added CuSO₄, UV absorbance decreased quickly and had nearly disappeared within 15 min. In a mixture of hot water fraction, CuSO₄ and AsA, UV absorbance decreased slightly

at a slower rate than in comparison to the solution without the hot water fraction. In an AsA solution with pectin from apples and lemons, the decrease in UV absorbance was noticeably inhibited. Pectins with a low rate of esterification displayed a relatively higher level of activity than those with a high rate of esterification. These results suggest that pectic compounds can include antioxidant components.

1340-1440

S09-P-171

NUTRITIONAL QUALITY OF CANOLA SEED SPROUTS AND GREEN FOLIAGE

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Our objectives were to study the nutritional quality of seed sprouts and green foliage of canola (*Brassica napus* L.) to determine the potential of developing alternate uses for this crop. In the first experiment, canola sprouts were harvested 2, 3, 4, 5, and 7 days after initiation of the experiment in which seeds were placed on filter paper kept continuously moist. In the second experiment, nutritional quality of pre-flowering foliage (canola greens) was compared to that of mustard and turnip greens. The oil contents of sprouts decreased with age from 40 (2 days) to 5 (7 days) percent. The relative content of saturated fatty acids in the oil in sprouts decreased with age from 5.1 (2 days) to 4.5 (7 days) percent. The relative content of 18:3 fatty acid increased with age from 6.8 (2 days) to 8.5 (7 days) percent. The canola oil is considered healthy for human consumption because of its low content of saturated fatty acids (about 6%) as compared to 9% in safflower oil, 13% in olive and corn oil, and 14% in sesame oil. The saturated fatty acids in canola sprouts were even lower than those in the seed (5.1 to 4.5%), indicating that canola sprouts may be even more desirable as human food as compared to oil. The oil content of canola greens was 3.4% as compared to 2.2% in mustard and 3.4% in turnip greens. The mean total saturated fatty acid content of canola greens was 18.8% which was intermediate between mustard (5.0%) and turnip (23.3%). Canola greens had considerably higher content (43.8%) of omega-3-fatty acid (18:3) as compared to mustard (9.0%) or turnip greens (28.00%). The canola greens had higher protein content than mustard and turnip greens (30.6, 29.3, and 16.8 percent, respectively) whereas all three types of greens were similar in K, Mg, P, and Zn contents. These results indicated that alternate uses for canola seeds and foliage can be developed.

1340-1440

S09-P-172

POLYPHENOLIC CONTENT AND ANTIMUTAGENICITY OF SWEETPOTATO LEAVES IN RELATION TO COMMERCIAL VEGETABLES

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Our previous study has indicated that sweetpotato (*Ipomoea batatas* L.) leaves are rich sources of nutrition and can become a potential functional food. The physiological functions are considered to be one of the important factors for developing new uses of sweetpotato leaves. Polyphenol is one of the physiologically functional components that prevent aging, cancer, and cardiovascular disease. Therefore, polyphenol content and antimutagenicity in the leaves of 10 varieties of sweetpotato was compared with 12 kinds of commercial vegetable to evaluate the use of sweetpotato leaf as a functional food. There was a remarkable varietal difference in the polyphenol content of the sweetpotato leaf and the sweetpotato leaf had much higher polyphenol content than other commercial vegetables. Antimutagenicity was investigated using *Salmonella typhimurium* TA 98 and various kinds of mutagens. The ethanol extract from the sweetpotato leaf effectively inhibited the reverse mutation induced not only by Trp-P-1, Trp-P-2, IQ, B[a]P, and 4-NQO, but also by dimethyl sulfoxide extracts of grilled beef. These results suggest that sweetpotato leaves have a high polyphenolic content, which may influence the antimutagenicity properties of the leaves. In addition, HPLC analysis indicated that the sweetpotato leaf contained several polyphenol components and antimutagenicity is being examined for each purified component.

1340-1440

S09-P-173

ANTIOXIDANT ACTIVITY AND TOTAL PHENOLICS IN POST-HARVEST ICEBERG LETTUCE (*LACTUCA SATIVA* L.)

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Phenolic compounds are found in most fruits and vegetables and have been reported to possess antioxidant function. Iceberg lettuce has been popular because of its fresh-like quality and the increased consumption in fast foods and prepared salads. Though it was found that lettuce mainly contains hydroxycinnamic acids, little is known about antioxidant quantity and quality of lettuce during post-harvest storage and processing. This study was to investigate changes in total phenolics and antioxidant activity of iceberg lettuce during storage at 4 °C for 14 days. The outer, middle parts and core of the lettuce leaves were sampled respectively for analysis of total phenolics and antioxidant activity, measured by coupled oxidation of beta-carotene and linoleic acid. Total phenolics were measured by the Folin-Ciocalteu reagent using chlorogenic acid as a standard. At harvest total phenolics in the core were 125mg/100g fresh weight, 4.5 and 4.2 times as much as the outer part (28 mg/100g fresh weight) and middle part (30 mg/100 g fresh weight) respectively, while the antioxidant activity in the core was 3.9 and 3.6 times as much as the outer and middle parts respectively. Total phenolics in the outer and middle parts increased by 25.0% and 23.3% during the storage duration of 14 days, while the antioxidant activity increased by 25.5% and 22.8% respectively. The antioxidant activity in the core increased and then declined during storage, while total phenolics demonstrated a similar trend.

1340-1440

S09-P-174

ASCORBATE METABOLISM IN TWO CULTIVARS OF POSTHARVEST SPINACH DIFFERING IN THEIR SENESCENCE RATES

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We have shown that rapidly declining levels of ascorbate (vitamin C) are associated with advancing senescence and postharvest quality loss. To further explore the association between ascorbate metabolism and senescence, two cultivars of spinach (*Spinacia oleracea* L.) previously shown to differ in their postharvest senescence rates were grown under controlled conditions (18 °C, 14:10 L:D) and leaves harvested 6 weeks after planting. Detached leaves of Spokane F1 (relatively fast senescence rate) and BJ412 Sponsor (relatively slow senescence rate) were bagged and placed in the dark at 10 °C. Samples were removed on days 0, 7, 14, 21, 28, and 35 and analyzed for activities of galactono-gamma-lactone dehydrogenase, ascorbate free radical reductase, monodehydroascorbate reductase, dehydroascorbate reductase, ascorbate peroxidase and levels of ascorbate (reduced and oxidized) and malondialdehyde (estimator of lipid peroxidation). Differences in ascorbate metabolic properties between these two cultivars will be discussed.

1340-1440

S09-P-175

JUST BECAUSE IT LOOKS GOOD, IS IT STILL GOOD FOR YOU?

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Nutrition scientists sometimes appear to regard fresh fruit and vegetables as having a fixed complement of dietary nutrients. As post-harvest scientists we are well aware that this is not the case. Vitamin C levels are greatly affected by both pre- and post-harvest factors, a fact which has been used in a marketing campaign for frozen peas in New Zealand ("freezing at harvest locks in the nutrients..."). Our research has investigated the effects of good and bad storage regimes on the retention of some vitamins (A, C and E) and dietary polyamines in a wide range of fresh vegetables. Capsicums are a rich source of vitamin C (higher content than oranges per gram fresh weight) and we found that, unlike in peas,

vitamin C levels were maintained even after three weeks' storage and four days' shelflife (maximum ten percent loss). Vitamins A and E were also stable throughout this period, which is less surprising as the lipid-soluble vitamins are regarded as less labile. Dietary polyamines are not universally recognised as nutrients; they are essential for cell division but the body is normally capable of producing adequate quantities for itself. However in the elderly or in recuperating patients, dietary polyamines may be critically required for normal cell division in e.g. the intestinal epithelium. Only the true polyamines, spermine and spermidine, are useful in the diet; putrescine is a diamine and is broken down in the stomach. We found that the polyamine content of red, yellow and orange capsicums rose during storage but this was entirely accounted for by an increase in putrescine. Broccoli had a much higher level of polyamines at harvest than capsicums, in keeping with the fact that this is an immature tissue; polyamine contents generally decline with maturity of fresh produce; putrescine was rapidly metabolised in the first 24 hours after harvest, but spermine and spermidine were more stable. Our work with lettuce, tomatoes, silver beet, snow peas, pak choy, asparagus, broccoli and capsicums is shedding light on the complex interaction between storage regimes and vitamin and polyamine retention in vegetables and demonstrates that it is not enough to know that fresh produce still looks good after storage and shelflife; to know whether it is still good for you, you must measure its content of dietary nutrients.

1340-1440

S09-P-176

CHEMOPROTECTIVE PROPERTIES OF GLUCOSINOLATE CONTAINING PLANTS EVALUATED UTILIZING AN *AGROBACTERIUM TUMEFACIENS*-POTATO ASSAY

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The chemoprotective benefits associated with the consumption of broccoli (*Brassica oleracea* L. [Botrytis Group]) have been linked to metabolites derived from glucosinolates (GS). Glucosinolates are catabolized into isothiocyanates (ITC) and other breakdown products. Isothiocyanates induce the production of detoxifying phase 2 enzymes, which protect tissues from malignancy. To screen GS-containing plants for chemoprotective activity, an *Agrobacterium tumefaciens*-potato disk assay was performed. Seed of sixteen species of GS containing plants, representing two families and six genera, were extracted with 90 °C-deionized water. Extracts were centrifuged and filter-sterilized. Potato disk were cut from white Russet Burbank potatoes and placed on petri plates containing water agar for hydration. Extracts were applied to the surface of the potato disks. Myrosinase, an enzyme that breaks down GS into ITCs, was also added to the potato disks. Disks were incubated at 25 °C for 24 hr. Disks were then inoculated with *A. tumefaciens* to illicit tumor formation and incubated for 20 days. After incubation, disks were stained using diluted Lugol's solution and tumors were counted. All plant extracts provided significant inhibition of tumor formation ($P < 0.01$). Upland cress (*Barbarea verna* L.) extract provided the most protection with 74% inhibition of tumor formation. Brussels sprouts (*Brassica oleracea* L. [Gemifera group]) exhibited the least amount of inhibition at 44.6%. A compound known to inhibit growth of human cancer cells, cAMP, demonstrated 60% inhibition.

1340-1440

S09-P-177

CHANGES IN THE ASCORBATE SYSTEM IN LETTUCE SEEDLINGS

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Vitamin C (L-ascorbic acid; AsA) acts as a potent antioxidant and cellular reductant in plants and animals. As plant-derived ascorbate is the major source of vitamin C in the human diet, it is desirable to improve techniques which increase ascorbate levels in plants. In order to obtain fundamental knowledge of the ascorbate control mechanism in plants, we investigated the ascorbate metabolic system in dark-grown lettuce seedlings. L-Galactonolactone dehydrogenase (GLDH) activity is high in the 1st and 2nd day after seeding when the ascorbate level is increasing. In the 3rd and 4th day after seeding, GLDH activity decreases; however, ascorbate levels remain high. Ascorbate peroxidase activity is highest in the 1st and maintains this level until the 4th day after seeding. Dehydroascorbate

reductase (DHAR) activity increases during seedling growth, and reaches the highest level in the 3rd day. These results suggest that, in lettuce seedlings, GLDH contributes much in de novo synthesis of AsA in earlier stage of germination, and then DHAR acts in an important role to maintain the AsA levels in later stages. We have generated transgenic lettuce expressing GLDH cDNA constitutively, which we cloned from sweet potato. Although a large amount of GLDH protein accumulation was observed by Western blotting analysis, AsA level in this transgenic lettuce leaves was similar to that of non-transgenic, even when L-galactonolactone was supplied exogenously. The change in the ascorbate system in seedlings of this transgenic lettuce will be discussed.

1340-1440

S09-P-178

RADICAL SCAVENGING ACTIVITIES, ANTHOCYANIN AND POLYPHENOLIC COMPOSITIONS IN SWEETPOTATO (*IPOMOEA BATATAS* L.) LEAVES

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The consumption of sweetpotato (*Ipomoea batatas* L. Lam.) greens as fresh vegetable in many parts of the world indicates that they are acceptable as edible vegetables like other traditional leafy vegetables. Recent experiments revealed that sweetpotato leaves are an excellent source of polyphenols, including anthocyanins. These antioxidative compounds are considered to play a vital role in preventing ageing, cancer and other cardiovascular diseases. An experiment was conducted to investigate the radical scavenging activities, anthocyanin and polyphenolic contents and compositions of sweet potato leaves using three cultivars 'Simon No. 1', 'Kyushu 119' and 'Elegant Summer'. The anthocyanin and polyphenolic compositions were determined by NMR, FAB-MS and RP-HPLC analysis. The anthocyanin compositions were YGM-0a, [cyanidin 3-O-sophoroside-5-O-glucoside]; YGM-0f, [cyanidin 3-O-(2-O-(6-O-(E)-p-coumaroyl-beta-D-glucopyranosyl)-beta-D-glucopyranoside)-5-O-beta-D-glucopyranoside]; YGM-1a, [cyanidin 3-(6,6'-caffeylp-hydroxybenzoylsophoroside)-5-glucoside]; YGM-1b, [cyanidin 3-(6,6'-dicaffeylsophoroside)-5-glucoside]; YGM-2, [cyanidin 3-(6-caffeylsophoroside)-5-glucoside]; YGM-3, [cyanidin 3-(6,6'-caffeylferulylsophoroside)-5-glucoside]; YGM-4b, [peonidin 3-(6,6'-dicaffeylsophoroside)-5-glucoside]; YGM-5a, [peonidin 3-(6,6'-caffeylp-hydroxybenzoylsophoroside)-5-glucoside]; YGM-5b, [cyanidin 3-(6-caffeylsophoroside)-5-glucoside] and YGM-6, [peonidin 3-(6,6'-caffeylferulylsophoroside)-5-glucoside] The polyphenolic compositions were chlorogenic acid, caffeic acid, 3,5-di-O-caffeylquinic acid, 4,5-di-O-caffeylquinic acid, 3,4-di-O-caffeylquinic acid, 3,4,5-tri-O-caffeylquinic acid. Results suggested that the polyphenol content was positively correlated with radical scavenging activities of sweetpotato leaves.

1440-1500

S09-O-179

FLOWER BUD OPENING OF CUT "NELSON" CARNATIONS AS AFFECTED BY PHOTOSYNTHETIC PHOTON FLUX DENSITY

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For each flower bud opening (FBO) treatment, six bud-cut "Nelson" carnations were placed in a transparent cylindrical container (0.33 m in diameter, 0.50 m in height; 25 °C) ventilated at 300 L·h⁻¹ under a photosynthetic photon flux density (PPFD) of 30 (P30), 120 (P120) or 250 (P250) μmol·m⁻²·s⁻¹ (at the bud-top level) with continuous light from white fluorescent lamps installed outside the container. The stem cut-ends of the carnations were placed individually in flower opening solution (FOS) containing 25 mg·L⁻¹ AgNO₃ + 200 mg·L⁻¹ 8-hydroxyquinoline citrate (8-HQC) with 30 g·L⁻¹ sucrose (S30; combined with P30, P120 or P250) or without sucrose (S0; combined with P250). All the carnations in each treatment were removed from the container as 5 out of 6 buds opened fully, and were placed in a growth chamber 25 °C) for 10 d flower-quality evaluation (FQE) with their stem cut-ends in deionized water. The required time for FBO was significantly reduced by increasing PPFD in the S30 treatments (60 h in P30-S30 (control),

48 h in P120-S30, 36 h in P250-S30). The time for FBO in P250-S0 (120 h) was 2.0 to 3.3 times longer than that in the S30 treatments. There was no large difference in flower quality among the S30 treatments during the 10 d FQE, whereas P250-S0 was already lower in flower quality than in the S30 treatments at the beginning of the 10 d FQE. The results indicate that PPFs of 120 and 250 mmol·m⁻²·s⁻¹ each combined with 30 g·L⁻¹ sucrose in FOS were effective for reducing the required time for FBO compared to the control, and that 30 g·L⁻¹ sucrose in FOS cannot be eliminated for FBO treatment even when increasing PPF from 30 to 250 mmol·m⁻²·s⁻¹. Net CO₂ exchange and absorbed sucrose during the FBO treatment were almost the same among the S30 treatments, suggesting that a certain amount of carbon uptake might be essential for full opening of bud-cut carnations regardless of the required time for FBO.

1500-1520

S09-O-180

PHOSPHORUS FERTILIZATION, LYCOPENE LEVELS AND PROCESSING QUALITY OF TOMATOES

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The quality attributes of two cultivars of tomatoes (*Lycopersicon esculentum* Mill), 'Heinz 9478', a processing cultivar, and 'Celebrity', a fresh eating type of tomato, were analysed in relation to phosphorus fertilization. In addition to the phosphorus fertilization at normally recommended levels (250 kg of 5:20:20 per hectare), phosphorus supplementation, either through soil (Superphosphate, 0:20:0, supplied at 120 kg/hectare and 240 kg/hectare) or through foliar spray, (hydrophos, and seniphos, Phosyn U.K.), were tested. Phosphorus supplementation appeared to increase the yield of both cultivars marginally. Phosphorus supplementation through hydrophos spray caused a 15% increase in the yield of 'Heinz 9478' tomato. The processed juice was evaluated for various processing characteristics including pH, titratable acidity, precipitate weight ratio, total solids, serum viscosity, gross viscosity, colour, lycopene levels and flavour volatiles. Soil phosphorus supplementation, at a low level over regular phosphorus fertilization, enhanced lycopene levels by nearly 30%. As well, phosphorus supplementation enhanced the Brix value, acidity, and ash content in the processed juice. The pH, colour, gross viscosity, serum viscosity and precipitate weight ratio were increased in response to various phosphorus supplementations. The volatile compounds emanating from the processed juice of both 'Heinz 9478' and 'Celebrity' tomatoes were qualitatively identical with differences in their relative amounts. Phosphorus supplementation increased the levels of major flavour volatiles such as hexanal, 6-methyl-5-hepten-2-one, and that of 2-isobutylthiazole, 1-penten-3-one and 2-octenal (E) to a lower degree.

1520-1540

S09-O-181

EXOGENOUS APPLICATION OF PUTRESCINE AFFECTS MANGO FRUIT QUALITY AND SHELF-LIFE

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Short shelf life of mango fruit limits its export to distant markets. The effects of pre and postharvest applications of putrescine on fruit ripening, quality and shelf life of 'Kensington Pride' mango were investigated. Aqueous solutions of different concentrations of putrescine (0, 0.5, 1.0, 2.0 mM) containing surfactant Tween-20 (0.01%) were applied as preharvest sprays on to trees 7 days prior to the harvest and as a post-harvest fruit dip treatments for 6 minutes. One lot of the treated fruits was allowed to ripen at room temperature (21 °C) and the second stored at 13 °C (85% RH) for 20 days. Fruit ripening at ambient temperature revealed that putrescine treatments reduced ethylene production and the response was more pronounced in the postharvest dip treatment than in the preharvest application. Ethylene production was decreased as the concentration of applied putrescine increased. Pre and postharvest application of putrescine increased fruit firmness, TSS, acidity, total carotenoids, ascorbic acid and decreased sugars and colour development compared with controls. After 20 days of storage, pre and postharvest treated fruits had higher firmness and TSS/acid ratio whilst acidity, sugars, total carotenoids contents and eating quality scores were reduced compared to controls. Preharvest treatments resulted in higher fruit levels of TSS

and ascorbic acid. In conclusion, both pre and postharvest putrescine application retarded mango fruit ripening and improved shelf-life quality and longevity.

1540-1600

S09-O-182

ANTIOXIDANT ENZYME ACTIVITIES DURING TOMATO FRUIT RIPENING AND IN RESPONSE TO PHOSPHORUS NUTRIENTS

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Changes in activities of antioxidant enzymes such as superoxide dismutase (SOD), peroxidase (POX) and ascorbate peroxidase (APX) were determined in cherry tomatoes and processing tomatoes during fruit development. In cherry tomatoes, activities of SOD and POX were the highest at the orange stage, and were the lowest at the red stage, and were nearly similar at the initial stages of development. By contrast, APX activity was the highest at the red stage and was the lowest at the mature green stage. Native PAGE and enzyme activity staining of the gels showed three isozymes of SOD. The staining intensities of the two slow-migrating isozymes were nearly the same at all developmental stages. The third fast-migrating isozyme was present at the young, intermediate and mature green stages, but declined considerably at the orange and red stages. Peroxidase activity was localized in two isozymes, a major fast-migrating isozyme and a minor slow-migrating isozyme. The staining intensity of both these isozymes at all stages was nearly the same. APX was characterized by two isozymes, a minor, fast-migrating isozyme and a highly intense, slow-migrating isozyme. The staining intensity of the slow-migrating isozyme increased considerably at the orange and red stages, in parallel with the activity estimations. A nearly similar profile of antioxidant enzymes was detected in processing tomatoes. In general, soil and foliar phosphorus fertilization enhanced the antioxidant enzymes as revealed by their in vitro activity and activity staining. The maintenance of these enzyme activities during the ripening stages may potentially help in the detoxification of active oxygen species that are generated during catabolic activities and maintain the quality of fruit longer.

1600-1620

S09-O-183

WATERMELON: A RICH SOURCE OF THE ANTIOXIDANT LYCOPENE

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Lycopene pigment provides the red color found in some fruits, notably tomato, and is found only in plants. Lycopene is a highly effective oxygen radical scavenger and has been indicated in many epidemiological studies as having efficacy against cardiovascular disease and some cancers, particularly prostate. Human uptake of lycopene from tomato based products is thought to be more effective after heat and processing treatments. Watermelons contain as much or more lycopene than tomato but have been little studied as a consumer source of lycopene. We have done a number of studies with watermelon to determine maturity, storage, and minimal processing effects on lycopene levels. Additionally, feeding studies with watermelon juice and tomato juice have been done to determine uptake in humans. Twenty varieties of melons, including seeded and seedless types, had average values of 36 to 78 µg·g⁻¹ lycopene, and only red-fleshed watermelons had significant amounts of lycopene. Underripe and overripe melons had as much as 20% less lycopene than fully ripe melons, with maturity effects dependent on the variety. Storage of whole or cut melons for 2 to 10 days reduced lycopene by 6 to 10%. Assays of human plasma after lycopene ingestion indicate that lycopene was as effectively obtained from watermelon juice as from tomato juice. Thus, watermelon fruit contains considerable lycopene, the pigment is maintained effectively in germplasm and with postharvest handling, and human uptake of lycopene from fresh watermelon is as effective as that from a heated and processed tomato product.

1620-1640

S09-O-184

POSTHARVEST BIOLOGY AND QUALITY OF FRUITS KEPT IN SUPERATMOSPHERIC OXYGEN ATMOSPHERES

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Oxygen concentrations greater than 21 kPa may influence postharvest biology and quality of fresh intact fruits and their fresh-cut products either directly (via the action of free radicals on the fruit tissue and/or decay-causing fungi) or indirectly (via altered carbon dioxide and ethylene production rates and/or actions). Sensitivity to oxygen toxicity varies among species, cultivars, and developmental stages of the fruit. There is no clear relationship between tolerance of fruits to high oxygen concentrations and their total antioxidant activity. Ripening of mature-green, climacteric fruits may be slightly enhanced by exposure to 30 to 80 kPa oxygen, but levels above 80 kPa may retard their ripening and induce oxygen toxicity symptoms on some fruits and aggravate chilling injury symptoms on fruits such as avocado and banana. Exposure to 80 kPa or higher oxygen concentrations can induce fermentative metabolism and associated undesirable flavor in fruits. Elevated oxygen atmospheres enhance many of the effects of ethylene on fruits, including color changes (chlorophyll degradation and biosynthesis of carotenoids and anthocyanins) and softening. Exposure of intact fruits to 40 to 80 kPa oxygen-enriched atmospheres before cutting or exposure of fresh-cut fruit products to such atmospheres has little or no effect on rates of browning and softening of the fresh-cut products and their post-cutting life. While superatmospheric oxygen concentrations retard the growth of some fungi, they are much more effective if combined with elevated (15 to 20 kPa) carbon dioxide as a fungistatic treatment; however, the combination of elevated oxygen and elevated carbon dioxide is often no better than elevated carbon dioxide alone.

1640-1700

S09-O-185

TOTAL PEROXIDES, LIPID SOLUBLE ANTIOXIDANT LEVELS AND ANTIOXIDANT ENZYME ACTIVITIES OF WHOLE 'SPARTAN' APPLES DURING TREATMENT IN AIR, 1 AND 100 KPA OXYGEN AND THEIR RELATION TO SLICE QUALITY

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Total tissue peroxide levels, lipid soluble antioxidant levels and antioxidant enzyme activities were monitored in 'Spartan' apples during treatment in air (21 kPa oxygen), 1 kPa oxygen and 100 kPa oxygen. Lipid peroxide levels were lowest and lipid soluble antioxidant levels were highest in apples during pretreatment under 100 kPa oxygen. The 100 kPa oxygen treatment also resulted in an increase in catalase (CAT) activity and reduced activities of peroxidase (POD), polyphenol oxidase (PPO) and superoxide dismutase (SOD) in crude extracts from whole apples. Slices made from this treatment developed the lowest level of browning and had the best firmness retention as compared with slices made from apples from the other two treatments. Apples held in the air pretreatment showed lower catalase activity, higher POD and SOD activities and similar PPO activity as compared with the 100 kPa oxygen pretreated apples. The 1 kPa oxygen pretreatment resulted in lowest catalase activity, highest SOD activity, intermediate POD activity and the lowest PPO activity compared with the other two pretreatments. A model is presented to relate these responses to effects on deteriorative processes responsible for quality loss in apple slices which were made from treated apples. The hypothesis is that short duration pretreatment with high oxygen induces an antioxidant acclimation in the tissue against active oxygen species thus preventing cellular breakdown after cutting into slices. This results in lower levels of cut surface browning and reduced rates of softening in the slices.

1700-1720

S09-O-186

POSTHARVEST RESEARCH AND DEVELOPMENT IN CANADA

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In Canada, postharvest research and development is conducted by the Federal government, two Provincial governments and eight universities across Canada which have a Faculty of Agriculture. The Federal government postharvest research is conducted at several of Agriculture and Agri-Food Canada's Research Centres located across Canada, primarily at the Atlantic Food and Hor-

ticulture Research Centre (AFHRC), Kentville, NS; Centre de recherche et de développement en horticulture (CRDH), St.-Jean-sur-Richelieu, QC; and Pacific Agri-Food Research Centre (PARC), Summerland, BC. Postharvest research exists at various levels in all 8 Canadian universities which have an agricultural faculty (UBC, Univ. of Alberta, Univ. of Sask., Univ. of Man., Univ. of Guelph, McGill Univ. (Macdonald Campus), Univ. de Laval and NSAC). The provincial governments have divested themselves of in-house research capability, except for Alberta and Quebec, and now provide support for horticulture research, including postharvest, mainly through collaboration with university and/or federal government researchers. The Directory of Canadian Horticultural Research Organizations and Professionals (http://res2.agr.gc.ca/kentville/pubs/chropdev_e.htm) provides more specific information on the institutions and individuals currently active in postharvest research and development. Research and development accomplishments in preharvest and postharvest handling, transport, storage technology and methods to maintain product quality will be highlighted. Postharvest research activities will depend on the nature of the regional horticultural industry and will be summarised by region, i.e., Atlantic provinces, Quebec, Ontario, Prairie provinces and British Columbia.

Friday · August 16

0800-0900

S09-P-187

MODELS TO PREDICT POTATO TUBER INFECTION AND LESION EXPANSION IN STORAGE BY PYTHIUM ULTIMUM

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Leak, caused by *Pythium ultimum*, is one of the important postharvest diseases of potatoes. Models were developed to predict the potential of leak development from important factors influencing infection and lesion expansion, so that they could be used as a tool to manage leak in potato after harvest. 'Russet Burbank' potato tubers were surface sterilized, wounded and inoculated with 20 mL of 104 sporangia/mL suspension of *P. ultimum* and incubated in mist chambers placed in growth chambers. For the infection study, inoculated tubers were kept at 4, 8, 12, 16 and 20 °C. After 3, 6, 12, 24 and 48 h of incubation time samples of 5 tubers were removed, dried and stored at 12 °C and 95% RH. After 30 d of storage tubers were removed and the disease severity was assessed. For lesion expansion study, inoculated tubers were maintained in mist chambers for 24 h, at 16 °C, for the establishment of initial infections, and then, the tubers were dried in laminar flow, and stored at 4, 8, 12, and 16 °C, for 15, 30, 45, 60, 75 and 90 d, at 95% RH. At the end of the storage time, 6 tubers were removed and the disease severity was assessed and transformed to proportion of volume diseased (PVD). A cubic model to predict infection potential from incubation temperature and duration of wetness explained 96.75% of the variation in PVD. A cubic model to predict lesion expansion potential as a function of storage temperature and duration explained 99.5% of the variation in PVD.

0800-0900

S09-P-188

TRIACYL GLYCEROL AND SAPONINS WITH ANTIFUNGAL ACTIVITY OF PITHECELLOBIUM DULCE SEEDS (GUAMÔCHIL) AGAINST POSTHARVEST PATHOGENIC FUNGI

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Up to date, natural products may offer a new approach for control of postharvest diseases horticulture. *Pithecellobium dulce* Benth (common names: guamuchil, manila tamarind, madras thorn) is an evergreen tree indigenous to America widely distributed in Mexico. We have previously reported significant antifungal activity or powder and aqueous extracts from the seed and leaves. The objective of this

work was identify the active fractions and compounds through guided fractionation of the hexane-dichloromethane and methanol-water seed extract. Seeds of guamuchil were extracted with hexane-dichloromethane (8:2) and methanol-water (8:2). *P. dulces* seed powder (10 mg/mL) after extracts different removal stimulated the mycelial growth of *Penicillium digitatum*, *Fusarium oxysporum*, *Pestalotiopsis spp.*, *Rhizopus stolonifer* and *Alternaria spp.* These results suggest that several fungicidal compounds were present in the extracts. In order to identify the active compounds present in the hexane-dichloromethane extract, a biodirected chromatography was performed. The fractions were tested against three fungal species. The most sensitive was *F. oxysporum*, eleven fractions retarded its growth with exception of two fractions, while nine of the fractions retarded development of *R. stolonifer*. The less sensitive species was *P. digitatum*. The NMR spectrum of the most active fraction indicated the presence of a triacyl glycerol. In the case of the methanol-water extract, five CC fractions afforded several saponins which retarded mycelial growth of *Pestalotiopsis spp.*, *R. stolonifer* and *C. gloeosporioides*. Our study was centred only on in vitro studies. However, having in mind that fungi behaviour can dramatically change when experiments are carried out in situ than in plant further investigation should be undertaken to determine the effects of these compounds with applied studies on fruit.

0800-0900

S09-P-189

THE EFFECT OF DIPPING TEMPERATURES ON BRAMLEY'S SEEDLING APPLE STORAGE QUALITY

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Bramley's Seedling apple is the main apple produced in Northern Ireland (35K tonnes per year). The bulk of the apples are processed and require long term storage to keep the processing market continuously supplied. Bramley apples are routinely dipped in fungicide and diphenylalanine (to prevent scald) prior to long term storage. Preliminary investigations indicated that dipping the apples in warm water prior to storage significantly reduced disease development during storage. Subsequent experiments confirmed that increasing the normal dipping temperature from 10 °C to 20 °C or greater, significantly increased the hardness of the apples while reducing both low temperature breakdown and senescent breakdown. Since only quality apples are put into storage, levels of initial disease were quite low and remained low during the six months period in low oxygen stores. However, analysis of the combined diseases showed that the warmer temperatures significantly reduced disease (50%) and enhanced fungicide efficacy (25% greater at 20 °C). It was difficult to determine if these effects were simply due to washing the apples or due to an alteration of the surface texture. The apple surfaces were examined using scanning electron microscopy and it appeared from the photographs that the warmer temperatures had softened the wax scales sufficiently for them to collapse onto each other, producing a smoother surface—which would have made infection more difficult. Examination of the apple surfaces using a Fourier Transformed Infrared Spectrometer confirmed changes in the wax structure when the apples were dipped at higher temperatures. The results indicate that altering the apple surface using warm water has the potential for reducing fungicide treatments without compromising storage quality. This in turn has important implications for the potential reduction of residues in apples.

0800-0900

S09-P-190

EVALUATION OF THE FUNGICIDAL POTENTIAL OF TWO NATURAL OCCURRING COMPOUNDS TO REDUCE ANTHRACNOSE OF PAPAYA DURING STORAGE

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One of the limitations of extending papaya fruit shelf life is the incidence of postharvest rots. In previous in vitro studies, the efficacy of chitosan and papaya seed extracts to reduce *Colletotrichum gloeosporioides* development and other fungi of this fruit was demonstrated. The objectives of this work were to evaluate the effect of chitosan and papaya seed aqueous extract on *C. gloeosporioides* development on papaya after five days ambient storage and to determine fruit quality. Fruit were dipped in the following treatments for 20 min: 1.- chitosan 0.5%, 2.- chitosan 1.5%, 3.- papaya seed extract (2:10 w/v), 4.- chitosan 0.5%+pa-

paya seed extract, 5.- chitosan 1.5% + papaya seed extract and 6.- control. Three experiments were carried out: 1-treatments were applied before artificial inoculation by *C. gloeosporioides*, 2-treatments were applied after inoculation and 3-treatments were applied without previous artificial inoculation. Percentage infection was evaluated at the end of the five-day storage period. Physiological parameters such as solid solubles content (SSC), firmness and mass loss were evaluated at the end of the storage period. Results indicated significant ($P < 0.001$) less fruit infection with chitosan (1.5%) or chitosan combined with papaya seed extract (infection of 40% and 47%, respectively) and when treatments were applied before inoculation. The highest infection was observed when fruit was treated after inoculation for all treatments (range infection of 95%-100%). In the non-inoculated experiment, percentage infection for all treatments was not significantly different from that of the control fruit (range infection of 60%-75%). The main fungus isolated was *Phomopsis*. No differences were observed between treatments and the frequency of the fungi isolated. There was a tendency of higher firmness in fruit treated with the chitosan solutions and seed extract. No significant differences were observed between SSC and mass loss.

0800-0900

S09-P-191

EFFECT OF ALPHA-FARNESENE AND ITS METABOLITES ON MEMBRANE PROPERTIES OF RED DELICIOUS APPLES

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The sesquiterpene alpha-farnesene and its metabolites have been implicated in the development of superficial scald development in apples. SPME-GC analysis of head-space volatiles of whole normal and scalded fruits did not show any differences in the alpha-farnesene levels. By contrast, analysis of head-space volatiles from the normal and scald-developing sides of the apples independently revealed a 3-fold lower level of farnesene evolution from the scald-developing side by comparison to the normal side. HPLC analysis of hexane-soluble hypodermal tissue extracts showed nearly three-fold lower level of farnesene in scald-developing tissues. Several other components were present in the hexane extracts, some of which have been identified as potential catabolites of farnesene. The content of alpha-farnesene was seven-fold higher in the hypodermal tissue as compared to the epidermal wax layer. The levels of the putative farnesene catabolite, 6-methyl-5-heptene-2-one, were very low in both normal and scald-developing tissues and detectable only through monitoring the selected-ion profile. To evaluate the potential effects of alpha-farnesene and its catabolites on membrane properties, several authentic components that include alpha-farnesene, methyl heptenone and methyl heptenol were incorporated into the microsomal membrane of apples and phase transition properties determined. There was no significant difference in the phase transition temperature between the membrane from normal apples and scald-developing apples. As well, addition of farnesene or its catabolites to the normal membrane did not change the phase transition temperature or energy of activation. The results suggest that farnesene or its metabolites do not possess membrane-destabilizing properties.

0800-0900

S09-P-192

ETHANOL VAPOURS TO COMPLEMENT OR SUPPRESS SULFITE FUMIGATION OF TABLE GRAPES

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Preliminary studies showed that ethanol vapours reduced berry shatter in Chasselas table grapes. We then tested the effect of various doses: 0, 4 and 8 g ethanol/kg fruit for various cold storage lengths: 2, 4 and 6 weeks. We measured the berry shatter, stem browning, Botrytis incidence and sensory appreciation by tasting panels. We also ran an experiment in which various doses of ethanol were applied for short periods (less than 6 hours) at the end of the cold storage time, prior to packing. The results will be discussed in the light of antioxidant properties of ethanol.

0800-0900

S09-P-193

CHARACTERIZATION OF EXTRACELLULAR LYTIC ENZYMES PRODUCED BY THE POSTHARVEST BIOCONTROL AGENT *CANDIDA OLEOPHILA*

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The enhancement of biocontrol activity of biocontrol agents may be the most important factor in their success in controlling postharvest fruit diseases. In our efforts to identify genetic traits of the yeast *C. oleophila* and determine the potential to enhance its biocontrol activity, we have been studying the yeast's ability to produce fungal cell wall degrading enzymes. This study has focused on four enzymes secreted by the yeast *C. oleophila*: exo-glucanase, endo-glucanase, chitinase and protease. The influence of the type of growth and carbon sources on the production of these enzymes by the yeast antagonist was determined by using calorimetric assays and plates containing the septic substrates. SDS-PAGE and activity gels of partially purified enzyme preparations were used to study the isozyme profiles. In addition, a full length gene of secreted 1,3- β -glucanase of this yeast (CoEXG1) was cloned and analyzed. Sequencing analysis revealed that CoEXG1 carries the signature pattern of the 5-glycohydrolases family, has a putative secretion leader, and has a high degree of identity to other yeast 1,3- β -glucanases. *C. oleophila* transformants harboring 2 copies of the CoEXG1 and its putative promoter region exhibited increased production (at least 2-fold) of β -1,3-glucanase. Cloning and sequence analysis of chitinase genes from *C. oleophila* is underway.

0800-0900

S09-P-194

EFFECT OF BLANCHING, FREEZING AND THAWING ON SOME QUALITY FACTORS OF SWEET PEPPER (*CAPSICUM ANNUUM* L.)

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The study covers research on the cooling treatment of peppers well known for their high taste values and content of natural substances showing high antioxidant activity (e.g. ascorbic acid, tocopherols, carotenoids). As the influence of blanching, freezing and thawing methods on some quality factors of peppers were studied. The experimental materials consisted of five cultivars of pepper fruits. The blanching was performed in water at temperatures of 85, 95 °C for 0, 1 or 1.5 min. The blanching efficiency was assessed on the basis of peroxidase activity tests (POD). Freezing was performed in a freezing cabinet, in nitrogen cryostat, as well as with an immersion method in liquid cryostat and in liquid nitrogen, all which altered the freezing rate. The temperature changes of the samples throughout the freezing and thawing were recorded by electronic thermometer with a thermocouples kit NiCrNi at ± 0.05 K accuracy. The measurements were performed until the product temperature reached below -18 °C. The frozen pepper was then thawed in the air at temperature ranging from 15 to 20 °C, each time evaluating drip loss after a static weigh test. The sensory analysis of all material after thawing was made according to 9-degree scale as well as evaluation of texture change development on the grounds of cutting tests by testing machines Zwick Z020 and INSTRON 4302. The results from the experiments allowed the determination of optimum conditions of blanching and pretreatment of pepper fruits as well as to establish a freezing method and parameters. Moreover, thawing protocols adequate for the material was ascertained in order to obtain the best quality pepper after the treatment.

0800-0900

S09-P-195

AROMA VOLATILE DIFFERENCES IN COMMERCIAL ORANGE-FLESHED CANTALoupES, THE INBRED PARENTAL LINES, AND STORED FRESH-CUTS

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Substantial differences exist in cantaloupes (*Cucumis melo* L. Reticulatus Group) regarding flavor and fresh-cut processing quality. We are attempting to discriminate volatile compounds that can be used as reliable breeding indicators for melon quality. Analysis of two commercially available varieties, and both their inbred breeding lines, may indicate hereditary linkages and help pinpoint quality. Cantaloupes were grown commercially in Arizona in 2000 and 2001 on raised beds with standard cultural practices and furrow irrigation. Fruit from two commercially available varieties ('Athena' and 'Sol Real') and both homozygous inbred parental breeding lines were harvested (all 3/4-slip) in June and analyzed for aroma and flavor differences. Fruit were sanitized, uniformly peeled, and cubes prepared. Cubes from numerous fruits (4 to 6 minimum per replicate) for each variety were randomized and roughly 300 g was placed into 24 ounce clamshell containers that were stored at 4 °C and analyzed after 0, 2, 5, 7, 9, 12 and 14 days storage. Volatiles were determined in rapidly homogenized juice via solid phase microextraction (SPME) by GC-MS (HP6890/5973). In 2000 melons, many flavor-related compounds increased during storage, whereas flavor-related aldehydes often decline during storage. Abrupt decreases in some flavor-related compounds were observed at or approximately concomitant with unacceptable subjective scores. For example, benzyl acetate dropped off markedly in SR-M, Athena, Athena-M and Athena-F after 12 or 14 d storage, while other volatiles were absent by d 12 or 14 in some varieties.

0800-0900

S09-P-196

COMMERCIAL PACKAGING OPTIONS FOR BEIT ALPHA CUCUMBERS GROWN UNDER PROTECTED CULTURE

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Beit Alpha-type cucumbers show promise as a new greenhouse crop. They are significantly smaller than European greenhouse types (125 to 175 mm in length, 22 to 30 mm in diameter), have a thin, delicate epidermis, and are seedless, firm and flavorful. Although retailers have shown interest in marketing Beit Alpha types, lack of commercial handling recommendations has led to significant postharvest losses. Chilling injury occurs during storage below 10 °C. 'Sarig' cucumbers were stored at 12.5 or 15 °C for 21 d in five commercial packages: * mineral-oil based wax in waxed, corrugated carton; unwaxed on stretch-film overwrapped tray (OWT); unwaxed in small (n=3) (SC) or large (n=6) (LC), rigid, "clamshells". Acceptable quality was maintained up to 14 d in all treatments; by 21 d, all fruits remained firm, but had a "grassy" off-flavor, and unwaxed fruits stored at 15 °C developed bitterness in locular gel. Small, corky growths also appeared by 21 d, irrespective of treatment or temperature. Unwaxed fruits stored at either temperature lost up to twice the fresh weight (2.0 to 2.3%) as those stored in SC, LC or OWT, and about 50% more than waxed. In all treatments, after 14 and 21 d, external color became slightly more yellow (lower hue angle) and brighter (higher chroma value). Internal color (cross-section) became more yellow after 7 d at 12.5 °C, but did not change up to 21 d at 15 °C. Slight condensation in SC, LC and OWT did not promote decay. For small operations, the clamshell was considered the best option, minimizing weight loss and providing protection during handling.

0800-0900

S09-P-197

PASTEURIZATION ALTERS THE QUALITY BUT NOT THE ACCEPTABILITY OF FRESH APPLE CIDER

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In response to new federal and state regulations, some apple (*Malus domestica*) growers and processors in eastern USA have adopted pasteurization as a means to ensure the microbiological safety of fresh (not fermented) apple cider. Because this heat-based process may denature naturally-occurring enzymes which affect cider color and flavor, cider makers have been concerned about the effect of pasteurization on the consumer acceptability of this economically important commodity. In a sensory evaluation trial, 331 judges recruited from the general population of potential apple cider consumers compared fresh and pasteurized samples

of a commercially blended cider. Results from triangle (discriminability) tests indicated that judges were adept at distinguishing differences among the two cider samples. Although consumers detected quality differences between samples, hedonic scores (2.7 and 2.6, respectively, corresponding to the descriptor "like moderately") and preference frequencies (i.e., 149 and 158 panelists, respectively) for fresh and pasteurized ciders were nearly identical. Similar results for hedonic ratings (range of 2.8 to 3.1) and preference tests (61:66) were uncovered in a second consumer trial involving 144 judges, primarily apple cider producers and their families, evaluating fresh and pasteurized samples of an in-house cider blend. In both tests, fresh ciders were characterized as being fresh, tart, apple-like crisp and clean whereas pasteurized ciders were found to exhibit good flavor balance (i.e., to be more sweet than tart) and intensity. Overall, our data suggests that, although pasteurized ciders differ slightly in quality when compared to their fresh counterparts, these differences are not likely to decrease consumer acceptance. Chemical analysis and QDA (trained panel) sensory evaluation of these products complemented the findings above.

0800-0900

S09-P-198

YIELD AND QUALITY OF STEMS CHICORY (*CICHORIUM INTYBUS* L.) FOR FROZEN AND "READY TO USE" PRODUCTS

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Stems chicory (SC), also known as 'catalogna' or 'asparagus' chicory, are cultivated in southern Italy mainly for their tender stems and leaves, eaten both raw and cooked. A substantial increase in its cultivation would result from the introduction of frozen and/or ready to use (RTU) products the consumption of which has progressively increased in the past few years. This research provides information on the suitability to prepare frozen and ready to use products. Two years trials were carried out in Bari (41°N). Seedlings of two cultivars: 'Galatina' and 'Brindisina', were transplanted each year in September with a density of 55.600 plants/ha and harvested 90, 110, 120 and 135 days after planting. For each harvest the most important morphological and yield characteristics were determined; all data were processed by ANOVA. To prepare RTU products, stems were trimmed and then stored in sealed plastic bags at 4 °C for 15 days. For freezing, stems were blanched in boiling water for 1, 2 or 3 minutes, frozen at -40 °C and then stored for 3, 6 or 9 months. Panel tests were made on the frozen and RTU products during the storage period to evaluate organoleptic attributes; results were graphically represented by QDA profiles. Colour measurements according to CIELAB system, were taken on fresh and frozen stems, using a Minolta Chroma Meter CR-200. In both years, total yield, plant weight, weight and number of stems and processing yield increased with delayed harvests. 'Galatina' had higher yields than 'Brindisina'. Stems from the second harvest, blanched for 2 minutes and stored for 6 months, were more appreciated for their organoleptic characteristics than were stems from the other treatments, fibre content was higher in stems from the final harvest. After 3 months storage, browning were observed on frozen stems blanched for 1 minute. Quality of RTU products were progressively worse through 9 days storage.

0800-0900

S09-P-199

QUALITY ASSESSMENT OF DICED ONION USING AN ELECTRONIC NOSE

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Cutting of bulb onions initiates biochemical, physiological and microbiological processes that reduce shelf life. Cut onion spoilage can be monitored by sensory and analytical methods, but these are costly, time-consuming and complex. Evaluation of diced onion quality using a 32-conducting polymer sensor electronic nose was investigated. Diced brown onion (ca. 6 cubic mm) was sealed in 50 micron thick polyethylene bags and stored for 3, 6 or 9 days at 4 °C. Electronic nose sensor response (%dR/R) did not change significantly ($P > 0.05$) during 6 days of storage. However, %dR/R significantly ($P < 0.05$) fell from 1.91% for initial (day 0) assessment to 1.70% on day 9. Mahalanobis distance (D-square)

statistics for separation of headspace volatile data set clusters increased with sampling time; being 3.6, 5.8 and 7.0, respectively, with reference to day 0. Pyruvic acid concentration reduced significantly ($P < 0.01$) by 11.6, 13.3 and 26.6% on days 3, 6 and 9, respectively. Greatest reduction in dry matter content from 18% to 16% was recorded between days 0 and 3. Time to maximum lachrymatory potency (hotness) increased from 34 s on day 0 to 42 s on day 3, and was $>>42$ s on day 6. Total soluble solids content did not change during 9 days of storage. A strong positive linear correlation was found for pyruvic acid concentration (Y) vs. %dR/R (X); where $Y = -6.1 + 7.5X$; $r = 0.8$; $n = 4$. Collectively, these findings suggest that the conducting polymer sensor electronic nose has potential application to monitor quality of minimally processed onions.

0800-0900

S09-P-200

EMPIRICAL MATHEMATICAL MODELING OF RHEOLOGICAL PROPERTIES OF MILK DRINK FLAVORED WITH DATE DIBBS

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Rheological properties were investigated for milk-dibbs using a viscometer equipped with a cone probe at temperatures of 5-65 °C, added dibbs of 2.5-15 mL/100 mL milk, dibbs from three date cultivars (Khlass, Nuboot Seif, and Sukkari), and a shear rate of 0-500 s⁻¹. Values of apparent viscosity ranged between 0.02 to 1.06 Pa.s based on the variables studied. Apparent viscosity increased with the decrease of temperature and the addition of dibbs. However, a sharp increase in apparent viscosity was observed at 5 °C and 15 mL dibbs/100 mL milk for dibbs from the Sukkari cultivar. This can be attributed to the high content of sucrose compared to other date cultivars. Results showed that the influence of temperature can be expressed by Arrhenius Equation, where activation energies ranged between 17437 to 24616 kJ/kg.kmole depending on added dibbs, shear rates, and date cultivars studied. Two models (exponential and power types) were utilized to present apparent viscosity as a function of added dibbs. The exponential-type model was found to be more adequate, in which the correlation coefficients (0.943 to 0.989) were higher than that of the power-type model. In addition, two other models were used to include the influence of temperature, shear rate in addition to added dibbs on the apparent viscosity of milk-date dibbs. Results showed that those two models fit well with the experimental values, in which the correlation coefficients ranged between 0.927 and 0.998.

0800-0900

S09-P-201

CONSUMER EVALUATION AND QUALITY MEASUREMENT OF FRESH-CUT SLICES OF 'GOLDRUSH', 'GOLDEN DELICIOUS', AND 'GRANNY SMITH' APPLES

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Fresh-cut apple slices are desired as a convenient snack for general consumers and as a component in school lunch programs. Development of fresh-cut products requires reconsideration of cultivar selection as well as storage and preparation methods, particularly for products like apples that are stored for a relatively long time before fresh-cut preparation. We compared the eating quality of a new apple cultivar, GoldRush, with Golden Delicious (one of its parents) and Granny Smith (currently used for fresh-cut slices). We also compared a commercial preservative treatment (NatureSeal for Apples) with an in-house treatment (calcium ascorbate and other active ingredients). Apples stored about 6 months were sanitized, cut into wedges without peeling, and served to 120 consumers (ARS staff volunteers who like apples, eat them frequently, and had no knowledge of the treatments). Panelists rated the acceptability of appearance, flavor, and texture. Subsamples were measured for color and firmness. Both NatureSeal and the in-house treatment maintained cut surface L^* , a^* , b^* values similar to values at the time of cutting. NatureSeal was rated slightly better for texture than the in-house treatment; but there was no significant difference in appearance or flavor. GoldRush scored highest for texture. Acceptability of texture was closely related to slope and area of force/deformation curves, but not to maximum force. Granny Smith scored highest for acceptability of appearance. GoldRush and Granny Smith were scored similarly for acceptability of flavor and Golden Delicious scored lower.

The results indicate that GoldRush is a promising cultivar for fresh-cut apple slices.

0800-0900

S09-P-202

EXTRACTION TEMPERATURE ALTERS PHYTOCHEMICAL CONCENTRATIONS AND QUALITY OF MAYHAW JUICE

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Research has demonstrated that antioxidants contained in fruit can provide protection against certain human degenerative conditions associated with oxygen free radical damage. Phenolics contribute substantially to the water-soluble antioxidant complement of many ripe fruit which are red, purple, or blue in color. An increasing public awareness of the benefits of antioxidants necessitates the determination of optimum processing practices for extracting juice with minimal loss in quality. Fruit of 'Royal Star' and 'Texas Star' mayhaws were collected from plots at the Calhoun Research Station in Calhoun, LA in May and frozen at -60 °C. Fruit were thawed overnight and incubated for one hour at 2, 20, 40, 60, 80, and 100 °C prior to hand-pressing to extract the juice. Titratable acidity, Brix, and pH were determined on freshly pressed juice. Juice was assayed for total phenolics, anthocyanin content, and soluble carbohydrates. Antioxidant activity was determined using the Ferric Reducing/Antioxidant Power (FRAP) assay. Increasing temperature from 2 to 100 °C had no significant effect on juice pH of 'Texas Star' but reduced the pH of 'Royal Star'. Titratable acidity initially increased as the extraction temperature increased, but then decreased at the highest temperatures. Total phenolics and FRAP increased from 2 °C to 60 °C, peaking at 60 °C, but then declined at higher temperatures. The lowest phenolic concentration and FRAP was measured in extracted juice from the lowest temperature treatment. The effect of temperature on the soluble carbohydrate profile will be discussed

0800-0900

S09-P-203

DIFFERENTIAL DISPLAY ANALYSIS OF GENE EXPRESSION IN LIGHTLY PROCESSED PAPAYA FRUIT

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Fruits stored as lightly processed (LP) tissue deteriorate much more rapidly than their intact counterparts. In the case of papaya, for example, LP tissue exhibits optimum storage conditions of 4 to 8 days compared with the 2 to 3 weeks for intact fruit. The objective of this study was to isolate and identify genes possibly involved in the deterioration of LP tissue by means of differential display RT-PCR. Ripe papaya fruit (skin color: 60-70% yellow) were processed under sanitized conditions at 5 °C, and fruit pieces along with intact fruit were both stored for 12 hours at 5 °C. Total RNA was isolated from intact and LP papaya fruit and treated with DNase I to eliminate genomic DNA contamination. Total RNA (0.2 µg) was used in a reverse transcription reaction with three different one-base-anchored oligo dT primers. High stringency PCR was performed using eight different 18-mer arbitrary primers in combination with the fluorescent-labeled one-base-anchored oligo dT primers. The PCR fluorescent labeled products were separated on a 6% polyacrylamide sequencing gel and scanned with a fluorescent scanner. Confirmation of true positive bands was performed by Northern blotting. The comparison of mRNA transcripts between intact and LP fruit revealed that 12 genes were differentially expressed in response to lightly processing. The differentially expressed genes were cloned into PCR-TRAP cloning vector. The cloned genes will be sequenced for comparison with known gene sequences already published in the database.

0800-0900

S09-P-204

REDUCTION OF FLOWER ABSCISSION AND LEAF SENESCENCE IN CUT PHLOX INFLORESCENCES BY THIDIAZURON

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The attractive and long-lasting clusters of dense flowerheads of perennial phlox (*Phlox paniculata* L.) have great potential as a cut flower crop. Our studies

indicated that the key determinants of postharvest performance of cut flower clusters in phlox are flower abscission, opening of additional flower buds during vase life and the quality of the leaves on the inflorescence axis. We report here on a novel effect of thidiazuron (TDZ), a phenylurea derivative with strong cytokinin-like activity, in reducing flower abscission and delaying leaf senescence in cut flowerheads of 'John Fanick' phlox, a recently identified superior selection for Texas landscapes. Freshly harvested flowerheads were put in glass vases containing either water or the desired concentration of TDZ (5-45 µmol) at 22 ± 1 °C under light. Observations on flower abscission, flower bud opening, and parameters related to leaf senescence such as chlorophyll and soluble protein content were performed for up to 2 weeks. In phlox, onset of flower abscission is initiated via shedding of funnel-shaped corolla with fused stamens. Other parts of the flower, such as calyx and gynoecium, are not shed. Shedding of corolla may be initiated within 72 hours, whereas yellowing of leaves is seen only after 8-10 days. The leaves on the flowerhead axis kept in TDZ, in comparison to control, continued to retain dark green color, exhibited high pigment level and less degradation of proteins. Treatment with TDZ also greatly reduced the shedding of flowers and, depending upon the concentration used, induced opening of a significant number of additional flower buds during vase life. TDZ also counteracted the strong flower abscission-accelerating and leaf-senescence promoting effect of abscisic acid. These results indicate that TDZ may prove highly useful in improving postharvest performance of phlox cut flowerheads.

0800-0900

S09-P-205

EFFECT OF NITRIC OXIDE ON POSTHARVEST PERFORMANCE OF PERENNIAL PHLOX CUT INFLORESCENCES

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Nitric oxide (NO*) is a highly bioreactive molecule that targets either a redox or an additive chemistry, and accordingly reacts with metal- and thiol- containing proteins including signalling proteins, receptors, enzymes, transcription factors and DNA. In many plant systems, by downregulating ethylene production, NO* delays senescence. Its involvement in the regulation of a wide spectrum of cellular functions via signal transduction pathways is also quite impressive. As ethylene is involved in flower abscission and leaf senescence of cut flowerheads of phlox, this investigation was initiated to evaluate the effect of NO* on postharvest performance of phlox cut inflorescences. Sodium nitroprusside (SNP) was used as the source of NO* donor. Freshly harvested flowerheads of 'John Fanick' phlox were placed in glass vases containing water or SNP solution (10-200 micromole) at 22 ± 1 °C under fluorescent lamps. In phlox, flower abscission may be initiated within 72 hours, whereas visual yellowing of leaves is observed after 8-10 days. During flower abscission only the funnel-shaped corolla with fused stamens is shed. With an increase in the concentration of NO* a concomitant rise in flower abscission was clearly evident. At high concentrations (50-200 micromole), within a week, toxicity symptoms in the form of development of blackening of leaves, usually starting on the lower leaves and moving progressively upward, were also clearly visible. However, the flowers did not exhibit any toxic symptoms, and the new buds continued to open even at relatively high concentrations. Preliminary results indicated that the deleterious effects of NO* could be greatly counteracted by a simultaneous application of thidiazuron in the solution. Experiments are in progress to further elucidate the action of these chemicals in postharvest performance of cut phlox flowerheads.

0800-0900

S09-P-206

THE USE OF LYSOPHOSPHATIDYLETHANOLAMINE (LPE), A NATURAL LIPID, TO ENHANCE THE OPENING AND RETENTION OF FLOWERS ON BEDDING PLANTS EXPERIENCING WATER STRESS DURING RETAIL SALES

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Spring bedding plants sold at retail outlets are regularly exposed to less-than-ideal growing conditions. These plants are often not watered enough to maintain the health of the plant. They are subjected to periods of drought stress, are watered excessively, and the drought cycle is repeated. The marketability of these bedding plants is seriously compromised by these cycles of water stress.

Water stress reduces the opening and retention of flowers. We investigated the influence of a spray application of LPE on the marketable quality of bedding plants subjected to cycles of water stress. The number of flowers per plant was used as an indicator of marketable quality. Six-week old seedlings of Super Elfin Rose and Dazzler Salmon impatiens were transplanted into 12-04 cell packs. After one week the plants were sprayed to drip with a solution containing LPE at the rates of 100 and 200 ppm LPE. The plants were given 14 hours of fluorescent light at room temperature. The impatiens were put under drought stress by withholding water, and allowed to dry to wilt between waterings. The number of open flowers per four-pack was recorded daily. Following a water stress cycle, LPE sprayed plants consistently had a greater number of open flowers as compared to control. With subsequent stress cycles, the differences between LPE and control became larger and more significant. In most cases LPE treated plants had more than two times the number of open flowers per four-pack and recovered more quickly from periods of stress than did those in the control. These results show that LPE has the potential to enhance the opening and retention of flowers on bedding plants undergoing water stress cycles during marketing.

0800-0900

S09-P-207

EFFECTS OF TRANSPORT IN (CA) CONTROLLED ATMOSPHERE AT SUBOPTIMAL TEMPERATURES ON CUT FLOWERS OF THE ROSE 'FIRST RED'

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The growing world-wide importance of cut flower production in regions far from the main purchase sites has involved the necessity to improve conveyance and package systems for the flower products, to assure satisfactory qualitative standards. The most decisive factor to keep a satisfying quality at the consumer is a low (close to 0 °C) temperature during storage and transport. In practice, however, this low temperature cannot always be realised. As opposed to vegetable and fruit produce, the data available in literature on the use of controlled atmosphere (CA) for cut flowers are scarce. Thus experiments have been conducted on cut flowers of the rose 'first red' with the aim to study the effect on postharvest physiology of different transport conditions for 5 days of flowers in CA [(O₂) 0.5-21%; (CO₂) 0-10%] at suboptimal temperatures (4-12 °C). During the period of transport simulation in CA, the respiration rate and the production of ethylene were measured in the flowers while during the vase life, transpiration rate, water uptake, diameter and longevity of the flowers were recorded. In single petals, fresh weight and area were measured daily. We found no positive effects on longevity of high CO₂ concentrations. At low O₂ concentrations, respiration rate and ethylene production during storage were lowered. The moment at which fresh weight of flowers started to decrease during vase life was somewhat delayed in low O₂-stored flowers. Low O₂ concentrations during storage resulted in poor flower opening afterwards. Petal growth was not inhibited by the low O₂-storage, but instead the outer petals showed a greater increase in surface area and fresh weight after treatments at O₂ concentrations of 1%. For the inner petals of the bud the differences in surface increase were less obvious. The negative after-effect of low O₂ concentrations could not be annulled by a GA3 pulse treatment (20h) following the transport simulation.

0800-0900

S09-P-208

IMPROVING THE VASELIFE OF WOODY CUT STEMS

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Three studies were conducted to determine postharvest life of three woody species that have value as cut foliage (*Myrica cerifera*, *Ilex crenata*, and *Buxus sempervirens*). In the first experiment, six treatments were used: 1-MCP, a 10% sucrose pulse, cool (20 °C) distilled water, warm (50 °C) distilled water, cool (20 °C) tap water, and warm (50 °C) tap water. In the second experiment, cut stems were held in 0, 2 or 4% sucrose solutions, with or without foam. In the third experiment, cut stems were held at 5 °C for 0, 1, 2, or 3 weeks before being moved to 20

°C to simulate a typical home environment. Data were collected weekly on visual quality, fresh weight, solution pH and solution uptake. In Expt. 1, visual quality of *Myrica cerifera* dropped rapidly between week 1 and week 2, and stems treated with a 10% sucrose pulse had the lowest fresh weights. In Expt. 2, a negative correlation existed between percent sucrose and visual quality in *Myrica cerifera*. All stems held in 2% and 4% sucrose treatments were considered dead by week 3. The stems with longest vase life were held in 0% sucrose and without foam. Results for *Ilex crenata* and *Buxus sempervirens* will also be presented.

0800-0900

S09-P-209

POSTHARVEST HANDLING OF CUT CAMPANULA FLOWERS

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Various postharvest treatments were applied to evaluate and improve the longevity and quality of cut *Campanula medium* L. 'Champion Blue' and 'Champion Pink' stems. Stems could be stored at 2 °C either wet or dry with no difference in vase life, percent flowers opened or quality ratings at 9 d; however, flowers stored dry had a slightly greater percentage of senesced flowers at termination and lower quality ratings 3 and 6 d after placement in the postharvest area. Increasing storage duration from 1 to 3 weeks decreased vase life and quality ratings. Stems pretreated for 4 h with 38 °C deionized floral solution [water amended to pH 3.5 with citric acid and 200 mg·L⁻¹ 8-hydroxyquinoline citrate (8-HQC)] followed by a 5% sucrose pulse solution produced the longest vase life (10.3 d) and maintained high quality even at 6 d (4.2, with 5.0 as best). Flowers opening after treatments commenced were paler than those flowers already opened and a 24-h pretreatment with 5 or 10% sucrose did not prevent the color reduction in flowers opening after treatment. Stems had an average vase life of only 3.3 d when placed in floral vase foam but lasted 10.0 d without foam. Optimum sucrose concentration was 1.0 to 2.0% for stems placed in 22 °C floral vase solution without foam and 4% for stems placed in foam. High (110 μmol·s⁻¹·m⁻²) or low (10 μmol·s⁻¹·m⁻²) light levels did not affect postharvest parameters, but the most recently-opened flowers under low light conditions were paler than those under high light conditions.

0800-0900

S09-P-210

VASE LIFE OF BIRD-OF-PARADISE FLOWERS INFLUENCED BY PULSING AND TERM OF COLD STORAGE

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Bird-of-paradise flowers were harvested at the commercial stage and stored at 10 °C for 7, 14, 21 and 28 days. The flowers were recut 2 cm from the stalk base and pulsed with 40% sucrose for 24 hours before or after cold storage, and control stalks were treated with distilled water. Long term storage reduced flower longevity in vases for all treatments, with lower drop for those flowers pulsed with sucrose immediately after cold storage. Pulsing treatment following storage for 7 and 14 days improved flower quality by increasing the number of open florets, once placed in the vase. Storage for 28 days at 10 °C induced chilling injury symptoms in the bracts and sepals, and allowed the development of *Penicillium* sp. in the petals. Flowers presented excellent post-storage longevity after storing up to 14 days at 10 °C, followed by pulsing treatment with 40% sucrose for 24 hours.

0800-0900

S09-P-211

FRUIT QUALITY EVALUATION OF STRAWBERRY CULTIVARS GROWN IN ARGENTINA

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Fruit quality of different strawberry (*Fragaria x ananassa* Duch.) cultivars was evaluated in Tucumán (Argentina) from June to August (2001), a period when

fruit prices are the highest of the season. Cold-stored plants of 'Aromas', 'Camarosa', 'Gaviota' and 'Selva', and fresh plants of 'Camarosa', 'Earlibrite', 'Gaviota', 'Rosa Linda', 'Sweet Charlie' and 'Tud New' were grown in a winter production system. Fruit were harvested periodically and samples of 15 fruit (with more than 75% red color) per cultivar were analyzed weekly during June and July (cold-stored plants) and August (fresh plants). Fruit quality was evaluated in terms of fruit weight, external and juice color (L^* , hue, chroma), firmness, soluble solids content (SSC), acidity, ratio (SSC/acidity) and ascorbic acid content. Within cold-stored plants, 'Camarosa' and 'Selva' had the highest external chroma values, while 'Gaviota' and 'Aromas' had intermediate and the lowest external chroma values, respectively. Levels of acidity were different within cultivars, with 'Camarosa' the most acid of the group. Within fresh plants, 'Tud New' had high fruit weight, firmness, ascorbic acid content, and low values of external and juice hue, which is desirable in terms of quality; however, L^* (external and juice color), SSC and SSC:acidity ratio were low. 'Camarosa' had relatively high values of firmness, SSC and acidity and low values of external hue and juice. 'Earlibrite' had relatively high values of fruit weight, firmness, SSC, acidity and ascorbic acid. 'Sweet Charlie' had high SSC, intermediate firmness, and low acidity and ratio. Although production patterns of cold-stored and fresh plants were not the same and both groups were not fruiting simultaneously, 'Camarosa' and 'Gaviota', which were included in both groups, produced smaller fruit from cold-stored than from fresh plants, but firmness and SSC were the highest. These differences could be related to the particular background of each kind of plant and/or to the environmental conditions during the fruiting season.

0900-0940

S09-O-212

BIOLOGICAL CONTROL OF POSTHARVEST DISEASES OF FRUITS AND VEGETABLES: CURRENT ACHIEVEMENTS AND FUTURE CHALLENGES

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World trends are moving toward reduced pesticide use in fresh fruits and vegetables. In response to this trend, several physical and biological approaches have been evaluated as safer alternatives to the use of chemical fungicides. In particular, the use of microbial antagonists for the control of postharvest diseases has been extensively investigated. Most of the reported antagonists, yeasts, bacteria, and filamentous fungi, naturally occur on fruit or other plant surfaces. Currently, there are only two biological products registered by the U.S. Environmental Protection Agency (EPA) for postharvest use. They are commercially available under the trade names, Aspire™, and Biosave 110 and 111, and are recommended for the control of postharvest rots of both citrus and pome fruit. Additional microbial agents are being developed and some have reached the stage of semi-commercial testing and are currently undergoing evaluation by governmental regulatory agencies for registration. The implementation of biological control practices for postharvest diseases is lagging behind expectations. Among the reasons for the limited use of the technology is that the available products confer only a protective effect and often do not provide control of previously established infections to an extent similar to synthetic fungicides. Recent attempts to overcome the variable performance of microbial antagonists have led to the development of a combination of complementary approaches such as combining antagonists with the use of sodium bicarbonate or chitosan. As we learn more about the mode of action of biocontrol agents, new approaches of combining complementary biological and physical approaches will emerge that will lead to additive and/or synergistic effects. Initial results obtained by using various combinations of biological, chemical, and physical control methods have demonstrated the potential of this multifaceted approach as a viable alternative to synthetic fungicides. The potential and limitations of the 'first and second generations' of postharvest biocontrol products will be discussed and avenues of future research will be presented.

0940-1000

S09-O-213

AN INTEGRATED APPROACH TO POSTHARVEST DISEASE MANAGEMENT IN CITRUS

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The use of chemical fungicides for postharvest disease control is under pressure due to both fungal resistance potential as well as the consumer desire for fungicide free fruit. Alternative biological control methods have not provided acceptable commercial control. Citrus fruits contain antifungal compounds which decrease in the rind after colour break. The decrease is more rapid in some orchards than others, leading to increased waste. The objective of the work was to investigate the potential to enhance antifungal compounds preharvest, and combine this approach with biological postharvest control measures plus risk management through development of a prediction technique for postharvest decay potential. Spray application of phosphorus acid and a commercial phytoalexin-enhancing compound within two weeks of harvest did increase antifungal phenolics in the fruit. Neither this nor postharvest application of *Cryptococcus albidus* alone were able to control growth of *Penicillium digitatum* in fruit inoculated with 106 spores per mL. In combination, however, commercial control could be achieved. A technique for risk potential was developed by separating components of a rind extract by thin layer chromatography, spraying the plate with *P. digitatum* and observing fungal growth inhibition in the zone of antifungal compounds. It is concluded that the use of an integrated approach to decay management can potentially replace chemical fungicides for citrus decay management.

1000-1020

S09-O-214

INTERACTION OF OZONE AND NEGATIVE AIR IONS TO CONTROL MICROORGANISMS

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The control of microorganisms on fresh produce is very important to the food industry in order to maintain quality and ensure safety. *Pseudomonas fluorescens* and *Erwinia carotovora* pv. *carotovora* are plant pathogens that cause decay of many fresh fruits and vegetables during storage. Strains of *Escherichia coli* are pathogenic to humans and have been found on contaminated produce. In this study, dilute cell suspensions of *P. fluorescens*, *E. carotovora* pv. *carotovora*, and *E. coli* were inoculated onto potato dextrose agar (PDA) and subsequently exposed to 100 nL x L-1 ozone and/or 106 negative air ions (NAI) x mL-1 to determine the effect of these treatments on cell viability. Treatment with NAI alone had no killing effect on any of the bacterial cells of all three species. However, ozone was effective in killing all three species and the addition of NAI enhanced this killing effect. *P. fluorescens* was most susceptible to the combined treatment; viability was reduced to 0.7% after 6 h, while 76% of the cells remained viable when exposed to ozone alone. Viability of *E. carotovora* pv. *carotovora* was reduced to 4% after 6 h in the combined treatment compared with 69% when exposed to ozone alone. *E. coli* was more resistant to the combined treatment; viability was reduced to only 40% after 11 h compared with 70% in the ozone alone treatment. Other factors, including the culture media used, influenced the effectiveness of ozone and NAI to kill bacteria and requires further study. The synergism of NAI with ozone may provide an effective method to reduce microbial contamination resulting in produce with less decay and risk of food borne disease.

1020-1040

S09-O-214-A

TO BE ANNOUNCED

1400-1440

S09-O-215

PHYSICAL AND CHEMICAL CONTROL STRATEGIES TO REDUCE POSTHARVEST DECAY OF APPLES AND OTHER FRESH FRUIT WHILE MAINTAINING QUALITY: REDUCING DEPENDENCE ON PESTICIDES

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Growing consumer concern about pesticide residues on the surface of fresh produce along with the development of pathogen resistance to approved pesticides are prompting the development of alternative methods of maintaining produce quality during storage. One of these methods, Ca infiltration of apples, decreases the incidence of bitter pit, scald, water core, and internal breakdown, maintains fruit firmness and quality, and reduces naturally occurring and wound-inoculated pathogen-induced decays. While rather effective at controlling decay, this treatment has received little commercial attention for a number of reasons among which is the relative inability to rapidly access and precisely adjust Ca absorbed from one lot of fruit to another. Another alternative method that has received considerable research attention is prestorage heat treatments. Exposing apples to 38 to 42 °C for 2 to 6 days suppresses softening and reduces decay incidence and development caused by postharvest pathogens. Heat treatment, however, offers little to no residual protection, and enhances some ripening characteristics, e.g., peel degreening and lowering acidity. A new rapid hot water brushing (HWB) method has been developed to simultaneously rinse and disinfect fresh fruit. The HWB method decreases the incidence of pathogen-induced decay, seals potential pathogen invasion sites, and/or slows some ripening characteristics in citrus, sweet peppers, lichee, corn, melon, mangos, and other fresh fruit. Still, the method does not offer adequate residual protection on its own so HWB is now being tested in combination with reduced levels of pesticides or other alternative methods. A new, low toxicity, gaseous inhibitor of ethylene action, 1-methylcyclopropene (1-MCP), has recently been developed to suppress ethylene-mediated ripening of many climacteric fruit especially apples. We found that 1-MCP treatment of preclimacteric 'Golden Delicious' apples has little to no effect on the incidence of decay but decreases decay development caused by wound-inoculated *Penicillium expansum* Link, *Botrytis cinerea* Pers.:Fr., and *Colletotrichum acutatum* Simmonds (teleomorph *Glomerella acutata* J.C. Guerber & J.C. Correll sp.nov.) to about the same degree as controlled atmosphere (CA) storage, while more effectively inhibiting ripening than CA. Some 1-MCP dosages can prevent apple ripening, and occasionally 1-MCP treatments have been associated with surface and internal injury of apples, especially after prolonged CA storage. Other gaseous and natural chemical inhibitors of decay incidence and development in apples have been reported. It is unlikely that any of these alternative methods alone will be as effective as pesticides. However, the development of a strategy combining several of these methods could result in the desired level of control. An example of the beneficial effects of various combinations of chemical, physical, and biological control methods in apples will be presented.

1440-1500

S09-O-216

USE OF COMBINED UV-C AND HEAT TREATMENTS TO IMPROVE POSTHARVEST LIFE OF STRAWBERRY

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Since strawberry is a highly perishable fruit, much of the postharvest research on strawberry is devoted to the development of methods to improve its postharvest life. Physical treatments involving a low UV-C dose (0.4600 Jc m⁻²) and heat treatment (45 °C, 3 h in air) have been applied both separately and combined on strawberries (*Fragaria x ananassa* cv. Seascape) at a 70-80% surface red stage. After treatments, fruit were kept at 20 °C for 2 d and fruit quality characteristics such as surface color and lightness, anthocyanin content, total phenol and sugar content were measured. Also, development of surface fungal infections and a parallel 'in vitro' germination assay on conidia of *Botrytis cinerea* and *Rhizopus stolonifer* were conducted to quantify treatments' effect. For both the heat and combined treatments, development of surface hue was delayed, which agreed with the reduction in the anthocyanin content; for these same treatments, lightness loss was also delayed. Fruit treated with the combined physical treatments showed a stable phenol content during storage, compared with a decrease in the separate treatments. No significant differences among treatments were observed in the total sugar content, while an increased content of reducer sugars was recorded for the combined treatment. Over the experimental time (7 d after harvest), the combined physical treatment

reduced drastically surface fungal infections and delayed markedly 'in vitro' germination rates (over 10 h). Based on these results, for most parameters studied a potential synergistic effect from the combination of both appear to provide a positive synergistic benefit to most of the characteristics studied. This suggests an innovative physical method to improve postharvest life which appears to be cheap, simple and market-appealing.

1500-1520

S09-O-217

EVALUATION OF PLANT ESSENTIAL OILS AS NATURAL POSTHARVEST DISEASE CONTROL OF TOMATO (*LYCOPERSICON ESCULENTUM* L.)

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The overall objective of this project is to investigate plants producing extracts high in biologically active compounds. Essential oils of thyme, oregano, sage, rosemary, sweet basil, cinnamon basil, dill, spearmint, cilantro, and lemongrass were tested on *Rhizopus stolonifer*, *Botrytis cinerea*, *Alternaria arborescens*, and *Geotrichum candidum*. The fungicidal activity of major compounds of each essential oil were also tested. Vapors of white thyme oil and its main compound, thymol (45%), inhibited spore germination and stopped growth of all fungi. Thyme and oregano oils incorporated into potato dextrose agar (PDA) inhibited spore germination of *Botrytis*, *Alternaria*, and *Rhizopus* at 500 mg·L⁻¹. Lemongrass was fungicidal on *Botrytis* and *Geotrichum* at 1000 ppm, but had only a growth retardant activity on *Alternaria* and *Rhizopus* at that concentration. *Botrytis* was also controlled in vitro by vapors of cinnamon basil and spearmint, and their major compounds, methyl cinnamate and l-carvone. However, those oils and compounds were fungistatic and their effects lasted only 4 to 6 days. Vapors of dill oil, which contained 35% of d-carvone had no effect on *Botrytis*, but d-carvone alone was fungistatic. Alpha-terpineol, which is a compound found in most of the Labiateae oils, was also fungistatic as a vapor. Tomatoes at the breaker stage were inoculated with *Botrytis* or *Alternaria* and dipped for 5 or 10 min. in emulsions of thyme or oregano oils with polysorbate 20. Thyme controlled *Botrytis* disease development at 5,000 mg·L⁻¹ and 10,000 mg·L⁻¹. Oregano controlled *Alternaria* above 1,000 mg·L⁻¹, although when dipped 10 min. at 10,000 mg·L⁻¹, tomatoes showed signs of phytotoxicity. Lemongrass oil was phytotoxic on tomato at the breaker stage and could not be used as fumigant or in dip treatments.

1520-1540

S09-O-218

MITIGATION OF PHYTOTOXICITY OF FUNGICIDE (BRAVO) ON CRANBERRY FRUITS AND FLOWERS BY LYSOPHOSPHATIDYLETHANOLAMINE (LPE), A NATURAL LIPID

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Fruit rot caused by fungi is considered to be one of the most yield-limiting problems in cranberry production. Multiple fungicide applications starting at bloom are considered necessary to mitigate this problem. Bravo is one of the widely used fungicides to control cranberry fruit rot. However, application of Bravo has been reported to cause a reduction in fruit set, yield and fruit size as well as scarring damage on fruits. We investigated the potential use of LPE to mitigate undesirable effect of Bravo on cranberry (*Vaccinium macrocarpon* Ait. cultivar Stevens) yield, fruit set and size. For this purpose 1 m x 2 m plots were established in cranberry beds at four separate locations with five replications. Plots were sprayed with recommended dosage of Bravo and LPE (100 and 200 ppm) combinations at 20 and 80% bloom. LPE was applied either 3 hours prior to Bravo or mixed together with Bravo. At late season, fruits and flowers on 50 cranberry uprights were counted from in each plot to determine the fruit set. At harvest all fruits were removed with a hand rake to determine total yield and other fruit quality parameters. Bravo applications resulted in a 10% decline in fruit set as compared to untreated control. Bravo also resulted in 7% decrease in total yield. Combination of LPE and Bravo mitigated this decline in fruit set and total yield. Application of LPE alone (without Bravo) gave the highest overall fruit set and total yield. The result of the present study shows that LPE can mitigate injury to cranberry flowers and fruits by Bravo.

1540-1600

S09-O-219

CHANGES IN MICROBIAL AND SENSORY QUALITY OF FRESH PROCESSED UV-C TREATED 'LOLLO ROSSO' LETTUCEA. Allende*¹, E. Padilla¹, F. Artes²

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Shelf life of most fresh processed vegetables is commonly not longer than 10 days, and even shorter for minimally processed lettuce. Currently several methods are used for keeping microbial and sensorial quality and extending shelf life, but industry still needs new advances to guarantee safe and tasty products. Ultra-violet-C (UV-C) radiation has been applied in order to reduce microbial growth and improve quality of fresh processed lettuce. Red pigmented 'Lollo Rosso' lettuce, freshly processed following standard industrial methods, was exposed to

UV-C radiation from 17 germicidal lamps before modified atmosphere packaging. Three intensities were applied: 0.81 kJ·m⁻², 4.06 kJ·m⁻², and 8.14 kJ·m⁻², depending on distance (60 cm) and exposure time (1, 5, and 10 minutes). The microbial growth of spoilage flora was studied and effects of UV-C radiation on microorganisms and quality attributes of the product were determined. A panel test of 12 people evaluated sensorial quality. Throughout shelf life changes in gas composition within bags were monitored. Results showed that microbial growth was usually reduced by UV-C radiation except for lactic acid bacteria. Compared to control lower microbial counts were found for total psychrotrophics, coliforms, and yeast on UV-C treated lettuce. However only the highest UV-C intensity was efficient to reduce mould growth. Higher CO₂ and lower O₂ concentrations were generated within bags containing 'Lollo Rosso' treated with higher UV-C radiation, which means that treatment increased the respiration rate of lettuce pieces. Only slight differences in overall appearance were found between 1 and 5 min treatments and control. However, the UV-C treatment for 10 min induced damage in 'Lollo Rosso' tissues.