Report of ISHS XII International Controlled & Modified Atmosphere (CAMA) Research Conference, Warsaw, Poland – 18 - 22 June 2017, by Richard Hurndall, Hortgro Science & Anél Botes, Agricultural Research Council

Content

1. Introduction

The CAMA conference is held every 4 years. The conference was held in an airport hotel and conference centre in Warsaw.

Apart from the authors, the South African contingent also comprised of Lohan Bester and Daniel du Plessis of Kromco, and Jaco Moelich of Fruitways.

Anél Botes, Richard Hurndall, Lohan Bester, Daniel du Plessis

2. Objectives of visit

1. Obtain postharvest research, controlled atmosphere storage and quality management information of relevance to the industry
2. Introduce Anél Botes to leading postharvest researchers and to the postharvest research community in general
3. Observe new trends in postharvest research
4. Build relationships with international researchers

3. CAMA Research Conference presentations

Progress in Production and Storage of Fruit and Vegetables in Poland – Francizek Adamicki (Poland)

- Poland produces 3600 thousand tons of apples and 80 thousand tons of pears
- Apple production is increasing to 4 000 – 5 000 thousand tons
- Idared is the largest apple variety preferred by apple producers
- Apart from Europe and surrounding markets, they are targeting North Africa, Vietnam and China for the future
- Dynamic Controlled Atmosphere (DCA) capacity consists of 100 thousand tons

Keynote Presentation - Physiological Disorders of Apples in a World of 1-Methylcyclopropene (1-MCP) and Controlled Atmosphere Storage – Christopher Watkins (USA)

- He is writing a chapter in book with Dr Jim Mattheis of WSU
- He illustrated a 1-MCP matrix with its positive and negative effects, which is cultivar dependent
- This depends on the role of ethylene in susceptibility of fruit to a particular disorder
- 1-MCP reduces bitter pit, diffuse flesh browning and core flush, but increases CO_2 injury and diffuse skin browning
- Delayed CA, DPA and maintaining low CO_2 concentrations reduce browning
- Harvista & Retain increases CO_2 injury
- CA and 1-MCP reduces bitter pit
- Omic (genomic, proteomic and metabolic) technologies are now being used to predict or identify physiological disorders by using biomarkers to reduce fruit quality losses
- Future: increase our understanding of disorder development and interactions with different technologies

Respiratory Quotient (RQ)-Based DCA Storage May Prevent Internal Browning in 1-MCP Treated Braeburn Apple Fruit – Niels Besselmans (Belgium)

- Braeburn browning disorder is related to gas transport in fruit cortex tissue
- The lower oxygen limit was found to be 0,2%
- RQ-DCA + 1-MCP at 625 ppb resulted in higher ethanol levels and lower internal browning than regular CA + 1-MCP

The Effect of Temperature on Quality and Internal Breakdown of 1-MCP-Treated 'Deveci' Pear Cultivar during Storage – Mustafa Sakaldas (Turkey)

- 1-MCP stimulates internal browning in pears at a storage temperature of 2 – 3°C
- Storage at lower temperatures of 0 – 1°C prevented internal browning, even with 1-MCP treatments of 312 and 625 ppb

Effects of Repeated Low Oxygen Stress (RLOS) and DCA-CF on Superficial Scald Development on 'Granny Smith' Apples – Anél Botes (South Africa)

- In one season RLOS+ULO was effective in preventing superficial scald on pre-optimum and optimum fruit for 10 months. DCA and RLOS+CA was effective on pre-optimum fruit up to 8 months. On the optimum fruit RLOS+CA and DCA-CF was effective for 8 and 10 months, respectively
- In the second season all the low O_2 treated fruit had superficial scald at various shorter periods
- In seasons with high potential for superficial scald, RLOS alone would not be effective enough to prevent this physiological disorder on Granny Smith

Effects of Storage Conditions on Storability and Quality of 'Shampion' Apples – Krysztof Rutkowsky (Poland)

- CA + 1-MCP maintains firmness, but induces dark russeting in 'Shampion' apples
- New technologies may reduce flavour but retain firmness, poliphenols and antioxidants
- DCA plus 1-MCP produces a good storage result
- Extend bags provide an additional 40 – 50 days in RA storage

Disorders of Pome Fruit Related to Pre- and Postharvest Factors – Kazimierz Tomala (Poland)

- Lower calcium levels occur in large fruits
- Calcium in the fruit decreases as distance from pollinator increases
- Calcium levels are lower in green leafed rootstocks
- Calcium increases with tree age
- Light cropping results in lower calcium
- Fruit exposed to sunlight and heat, followed by lower night temperatures result in more water core, followed by internal breakdown
- There is a link between CO_2 and internal breakdown
- Hot dry weather in the last two months before harvest, coupled with a low calcium results in superficial scald
- Store at very low O_2 (0,6%) to reduce internal breakdown risk
- 1-MCP is correlated with dark russeting
- Flesh browning occurs at lower storage temperatures

Plant Growth Regulator Effects on Fruit Maturity and Storability of CA-Stored Fuji Apples – Nurdan Gunes (Turkey)

- Fuji CA storage regimes were 2% O_2; 2% CO_2; 0,5°C
- Harvista plus Retain resulted in the lowest greasiness levels

Risk of Braeburn Browning Disorder Based on Weather and Orchard Factors - Roy McCormick (Germany)

- The aim of the 'Big apple' project is to predict storage disorders such as internal browning (IB)
- With the 'Bid Apple' they want to manage and optimise apple harvesting by means of data based prognosis models to enhance fruit quality
- Orchard monitoring to create a databank – 'Big data'
- Connect pre-harvest growth factors and development processes with physiological defects
- Focus on prediction of storage behaviour and not the explanation thereof
- Types of data e.g. orchard temperature, calcium levels, crop-loading and harvest dates, are more important than volume of data
- High temperatures during cell division – high IB
- Larger cells and low crop load – labile cells – more IB
- 2 – 3°C warmer/colder– no differences

CO_2 Injury on 'Honeycrisp' and 'Empire' Apple: Dose Response to DPA – Randolf Beaudry (USA)

- Elevated CO_2 and low O_2 suppresses ethylene action – which reduce softening, respiration and slows loss of sugars and titratable acids
- DPA prevents CA injury to Honeycrisp
- The concentration to completely suppress CO_2 injury was 100, 250 and 1000 ppm for 0,5 and 10% CO_2
- 1000 ppm DPA protects IB up to 10 – 20% CO_2 in Honeycrisp and Empire
- CO_2 injury in Honeycrisp at 0% CO_2 may be the result of low O_2 in combination with low amounts of CO_2 that accumulate in the interior of the apple
- Injuries are due to elevated CO_2, and to a lesser extent, low O_2
- Internal ethylene causes 10% IB at 0% CO_2
- There is still a need for non-chemical means to control CO_2 injury
- Chilling sensitivity requires conditioning treatment
- CA injury can occur in air storage
- CA injury requires at least one of the following for CA storage:
    - Do not use CA – rather store in air with 1-MCP
    - Delay CA – 30 days before CA <1% CO_2
    - High temperature conditioning followed by CA
    - DPA treatment followed (in 3 days) by CA

Keynote Presentation – Atmosphere Control in Packages and CA Rooms – Randolf Beaudry (USA)

- Oxygen necessary for formation of disulphide bonds for ethylene synthesis
- CO_2 suppresses ethylene
- 'We need to find out how low O_2 inhibits ethylene'
- Future developments:
    - Maybe new applications for MAP or CA
    - New sensors and monitoring systems to improve control
    - Improve our understanding of postharvest biology

Labpod: A High Precision System for Controlling Storage Atmospheres and Measuring Respiration – David Bishop (UK)

- LabPod is a self-contained system for CA from 0.1% to 21% O_2 and 0.1% to 20% CO_2
- Automatic measurement of respiration rates
- Up to 65 kg produce capacity
- Multiple pod's in one cold room
- The control system manages 32 CA cabinets, down to 0,002% O_2 and 0.004% CO_2 – sufficient to measure respiration
- It does multistep respiratory quotient (RQ) measurements
- A 60 kg capacity Safepod can be placed in a CA room for respiration and RQ measurements

Cultivar- and Oxygen level-Dependent Responses of Apple Fruit to CA Storage – Pietro Tonutti (Italy)

- DCA capacity consists of 700 000 m^3 in Italy
- Pink Lady tolerates 50 – 70 ppm ethanol, and Granny Smith 70 – 100 ppm
- Different metabolic behaviour was observed between Granny Smith and Red Delicious under hypoxic conditions

Antimicrobial Efficacy of Gaseous Ozone during Commercial Cold Storage of Fuji Apples – Ines Hanrahan (USA)

- Listeria monocytogenes is a human soil borne pathogen can survive in a CA room
- Ozone has been used in CA storage to mitigate microbial growth
- Results indicate that long-term CA storage, with or without a continuous low dose of ozone gas application can be an additional hurdle for controlling Listeria
- USA Fuji industry standard 33°F; 4% O_2; 0,9% CO_2

Metabolomics and Metabolic Flux Analysis of Fruit during Postharvest Storage – Bart Nicolai (Belgium)

- Fruit exposed to severe low oxygen stresses during CA storage adapt by reducing their metabolism – measure respiration rate versus gas diffusivity
- There is a link between respiration and ethylene biosynthesis but we do not know what or how
- There is a relationship between fruit size and anoxic conditions
- Large pears are more susceptible to low oxygen and high CO_2 conditions = IB
- A little alcohol fermentation is good
- Temperature conditioning allows fruit to adapt to low oxygen

Influence of 1-MCP on the Quality of 'Conference' and 'Williams' pears – Severine Rebeaud (Switzerland)

- 1-MCP-treated Williams stored at 2% CO_2; 2% O_2 for 3 months storage – 0,3 ppb softened, but not 0,6 ppb
- 1-MCP limited skin marks and senescent browning (brown core) when pears were stored at 0,5°C
- Combine ethylene with 1-MCP to achieve softening

- Black spots on Conference coincide with ethylene evolution during shelf life

Potential of Volatile Organic Compounds (VOC's) Emission of Conference Pear for DCA Storage Bert – Bert Verlinden (Belgium)

- Typical Conference storage conditions are -1°C: 2,5 – 3% O_2; < 0,7% CO_2
- Since chlorophyll fluorescence measures stress while RQ and alcohol measures respiration, it is proposed to measure volatiles in the cold room instead of respiration or stress
- VOC's are measured by IR spectroscopy
- RQ DCA for Conference is comparable to ULO – no browning

Going beyond the lower oxygen limit during the storage of Conference pears: Impact on fruit quality, volatile emission and fruit physiology – Laia Torregrosa (Spain)

- RQ is different between DCA-stored and ILOS treated fruit (ILOS treated fruit showed RQ < 0,7 while RQ under DCA-CF showed values between 0,8 -1,4)

3D Pore Structure Maps of Whole Apple using High Resolution X-CT – Siem Janssen (Belgium)

- Spatial porosity maps were used to understand gas diffusivity
- Large spatial gradients occur in porosity
- Low porosity around the ovary
- Low porosity in certain parts of the Braeburn apple is causing a barrier for gas transport, resulting in the occurrence of brown spots during long-term storage

Comparative Study of RQ-DCA and DCA-CF Technology for Storage of 'Golden Delicious' Apples – Niels Bessemans (Belgium)

- The various techniques measure bio-responses of the fruit
- RQ-DCA reached a minimum of 0,2% O_2, whereas DCA-CF stress occurred at 0,4% O_2
- Apart from DCA-CF fruit being more greasy after 14 days of shelf-life, there were no differences between DCA-CF and RQ-DCA on GD

Ripening in 'Summerred' Apples (as measured by I_{AD} Index) Stored in Low Oxygen Atmosphere – Eivind Vangdal (Norway)

- Maturity was measured with a non-destructive, portable chlorophyll DA meter
- While it was difficult to compare different orchards and seasons, good correlations with maturity indices were found (r^2 = 0,89 for firmness and r^2 = -0,86 for starch conversion)

Application of DCA Storage by measurement of Respiratory Quotient (RQ) – Alex van Schaik (Netherlands)

- A 0,81 correlation was found between RQ and ethanol production
- No clear relation between fruit characteristics and fermentation (RQ)
- RQ for several varieties between 1,2 – 1,5 – still needs to be determined for some cultivars

ACR: Dynamic CA in Practice – Rob Veltman (Netherlands)

- Need gastight room and multipoint calibration (7 data points for O_2 and CO_2)
- Bring the cold room to overpressure to avoid oxygen entering the room
- Switch off cooling for 4 – 5 hours
- No use of lime permitted
- Do not use a half empty room
- Algorithms to calculate the RQ of non-standard varieties still need to be established

Modular Sensor System for Real-Time Monitoring of Respiration Rate for Controlled and Modified Atmosphere Application – Pramod Mahajan (Germany)

- There is a requirement for a sensor system to measure continuous real-time respiration rate
- They developed a sensor that can be placed inside a jar, MAP package or CA cabinet
- A modular respiration sphere was then developed **–** the size of an apple
- This sphere has a O_2 sensor, CO_2 sensor, temperature and humidity sensor
- Data capture intervals can be varied from 60 seconds to 60 minutes

Variability of the Respiratory Response of Apples to Low Oxygen Storage – Richard Colgan (UK)

- Braeburn was cooled to 1,5 – 2°C (rapid 7 days or delayed 14 days)
- Rapid cooling was better for core flush and delayed cooling at 0,6% O_2 was better for IB
- Rapid cooling produces more ethanol
- Storing fruit at 0,3% led to larger amount of alcoholic fruit
- Storing fruit at 0,6% limited alcohol accumulation
- Low O_2 storage can reduce IB and core flush in Braeburn
- Fruit exhibiting lower RQ responses are less prone to low oxygen disorders

New Recommendations for CA Storage of 'Rocha' Pear – Domingos Almeida (Portugal)

- Best practice includes:
- Load cold room in less than 5 days
- Cool the fruit pulp temperature to -1 – 0°C within 5 days of first load
- Establish the CA regime immediately after cooling
- Pull down O_2 to < 3% within 24 hours and to 0,5% after 5 days
- Relative humidity 93 – 95%
- Pears treated with 1-MCP at 312 ppb should be stored at 3,5% O_2 and 0,6% CO_2 with a 6 – 8 week delay in the establishment of CA regimes

4. Posters

Effect of Repeated Low Oxygen Stress on Superficial Scald Incidence on Packham's Triumph Pears – Anél Botes (South Africa)

- In both seasons the RLOS treatments were effective in preventing superficial scald for 10 months
- RLOS treatments resulted in firmer fruit with better skin colour retention than the RA treatment
- No off-tastes were detected
- This study showed that RLOS inhibits superficial scald development on 'Packham's Triumph' pears during long term storage

Dynamic Controlled Atmosphere Based on Respiratory Quotient Allows to Increase the Storage Temperature of Gala Mutants – Auri Brackmann (Brazil)

- Storage under DCA – RQ allows a storage temperature of 2,5°C without firmness loss while reducing flesh browning

Has Ozone any Value in the Treatment of Apple Fruits for Quality Preservation within Long-Term Storage – Karina Juhnevica-Radenkova (Latvia)

- Ozone treatment between 0,8 – 3 ppm accelerates the natural ageing of waxes on the fruit surface, thereby facilitating a greater rate of transpiration and weight loss

EUFRUIT Thematic Network – Dirk Köpcke (Germany)

- A 1,8 million € research consortium of 21 partners from 12 countries
- The consortium will focus on 4 thematic areas for competitiveness and innovation potential:
    - New cultivar development
    - Minimise residues in fruit and the environment
    - Optimise storage and fruit quality
    - Enhance sustainable production systems

Storage Disorders in the Time of Software Based Systems – Daniel Neuwald (Germany)

- Driven by the need to correctly identify storage disorders and to understand storage disorder development

- Frudistor is the development of a software based identification system (App) for pome fruit
- Online platform and an application for smart mobile devices
- Photos will be linked to text

The Effects of Preharvest 1-MCP (Harvista) Treatments on Harvest Maturity of 'Deveci' Pear – Mustafa Sakaldas (Turkey)

- Harvista applications of 150 – 200 g/ha were found to be the most positive applications in preventing fruit drop and minimising changes in quality parameters
- Harvest maturity was prolonged for 28 days

Energy Conservation in Long-Term Fruit Storage Due to Different Fan Motorisation – Marc Spuhler (Germany)

- At full fan speed, an electronically commutated (EC) fan had a 21% lower energy consumption than an alternating (AC) fan

Impact of Low O_2 during DCA Storage on Apple Fruit Physiology – Angelo Zanella (Italy)

- If both 1-MCP and DCA-CF are applied, the fruit must first be conditioned after 1-MCP application before implementing DCA
- RQ – DCA produces more fermentative metabolites compared to DCA-CF
- The higher the RQ value, the higher the production of fermentative metabolites

Crop Load Effects the Incidence of Water Core in 'Fuji' Apples – Daniel Neuwald (Germany)

- The incidence and severity of water core increased when the trees had a suboptimal crop load

5. Professional Symposium Tour

Visits were made to a vegetable packer, Bracia Bracik, a fruit packing operation, Rajpol Trade, and the Skierniewice Research Institute of Horticulture. The latter Postharvest facility has well-equipped laboratories, and their CA research facilities range from small single fruit respiration monitoring jars, to canisters and International Controlled Atmosphere (ICA) cabinets.

Single fruit respiration monitoring jars

Rajpol Trade Packing Operation

This is an impressive, modern, well-automated facility that processes the following production volumes from 140 growers on 1 300 hectares (tons):

Apples	35 000
Pears	1 200
Plums	1 500
Sweet cherry	500
Sour cherry	500
Red current	100
Gooseberry	50

The sorting and packing area is 18 000 m^2 in extent. Dynamic Controlled Atmosphere storage capacity is 14 000 tons, and ULO storage 12 000 tons. They supply retailers in Europe and the broader region, and have the necessary integrated production and audit systems in place.

Automatic palletisation at Rajpol Trade packhouse

6. Take-home Message and Recommendations

It was perhaps not such a co-incidence, but the night before the conference, we bumped into Dr Randolf Beaudry, a key note speaker, on the way to the hotel restaurant and had dinner together. Not long afterwards, Dr Chris Watkins arrived with his wife. This illustrates the point for researchers to stay in the premier hotel where all the dignitaries stay, as network opportunities abound in hotel dining facilities, foyers and lifts.

One of the objectives of doing a presentation is to raise one's profile. It was helpful that Anél had the 2nd presentation after the dignitaries, and also had a poster, to put herself on the map.

It was apparent that the research being conducted by the Postharvest Technology division of the ARC is on par with that of the rest of the world. It was also obvious that there are still many unanswered questions in the postharvest field. It was further noticeable that when one asks specific questions of experts, for instance, at a meeting arranged with Dr Angelo Zanella, they fall back on the biochemical pathways and processes to inform their answers. This is why it is important that our industry allocates a certain portion of its funding towards fundamental research to delve into the basic workings of fruit biochemistry.

Dr Daniel Neuwald of Ravensburg, Germany has developed a postharvest App (similar to the Arrie App) for pome fruit, and is being tested by them and Dr Ines Hanrahan of Washington Tree Fruit Research Commission. It is recommended that Hortgro Science / Experico exchange the stone and pome Apps for testing in their respective industries.

A summarised version of the report will be published in the SA Fruit Journal, while the detailed report will be circulated to the CA Storage and Postharvest Group.

It is recommended that Drs Watkins and Beaudry be considered for a Hortgro Science postharvest symposium day, due to their wealth of experience on the topics of DPA, 1-MCP, DCA and quality issues such as internal browning.

Arrange a meeting with Dr Bart Nicolai with technical people on his visit to the Quality in Supply Chains symposium in Stellenbosch in early September.

Experico to conduct a trial on delayed CA (6 – 8 weeks) on pears after 1-MCP treatment.

A congress gala dinner discussion with James Shillitoe of Fruit Advisory Services Team (FAST) of the UK highlighted the importance of annually monitoring dry matter content of fruit for the purpose of predicting firmness levels, TSS and storage quality. This also came up in the presentation of Dr Roger Harker at the

Hortgro Science symposium. It is recommended that dry matter content be monitored by Hortec as part of the maturity indexing scheme.

A one-day European technical symposium will be held in conjunction with Fruit Logistica, Berlin, on 6 Feb 2018. Amongst others, optimising water use in the supply chain of fresh produce will be one of the topics. It is recommended that Hortgro Science sends a delegate / s to this symposium.

The next CAMA conference will be held 2021, and given the relevant topics covered and access to experts and suppliers of the various technologies, it would be wise for South African CA storage operators to attend.

Appendix 1

Contacts:

Dr Angelo Zanella, Laimburg, Italy.
Dr Chris Watkins, Cornell University, USA.
Dr Randolf Beaudry, Michigan State University, USA.
Dr Bart Nicolai, KU Leuven, Belgium.
Dr Pietro Tonutti, Pisa, Italy.
Dr Ines Hanrahan, WTFRC, USA.
Dr Daniel Neuwald, Ravensburg, Germany.
Marc Spuhler, Ravensburg, Germany.
Dr Dirk Köpcke, LWK, Niedersachsen, Germany.
Dr Rob Veltman, Van Amerongen, Netherlands.
Dr Auri Brackmann, Universidade Federal De Santa Maria, Brazil.
auribrackmann@gmail.com
David Bishop, Storage Control Systems, UK.
Lucie Nouaillac, Absoger, France.
Tito Spaldi, Isolcell, Italy.
James Shillitoe, Fruit Advisory Services Team (FAST), UK.

Appendix 2

Itinerary Richard Hurndall & Anel Botes – CAMA 2017, Warsaw, Poland 16 – 23 June 2017

16/06/17	Depart Cape Town for Amsterdam	23:00	KL 598
17/06/17	Arrive Amsterdam, Netherlands	10:40	
	Depart Amsterdam for Warsaw	14:30	KL 1365
	Arrive Warsaw	16:25	
23/06/17	Depart Warsaw for Amsterdam	06:00	KL 1362
	Arrive Amsterdam	07:55	
	Depart Amsterdam for Cape Town	10:00	KL 597
	Arrive Cape Town	21:20	